Appendices

Appendix A

Test Plan

TCEQ 2010 Flare Study
Flare Test Plan

Test Series No. S1: Varying Steam Assist, 2,342 lb/hr Waste Gas Flow, LHV = 2,149 Btu/scf

Test Point No.	Waste Gas Flow	Waste Gas Composition	Steam/Waste Gas Ratio	Actual Exit Velocity (*) per 40 CFR 60.18 (fps)	Notes
S1.5	1	1	Incipient Smoke Point	1.00	
S1.5 to S1.6	1	1	Increase steam from value in Test Pt. S1.5 to value for Test Pt. S1.6	1.00	**As Needed
S1.6	1	1	< Snuff	1.00	

Test Series No. S2: Varying Steam Assist, 937 lb/hr Waste Gas Flow, LHV = 2,149 Btu/scf

Test Point No.	Waste Gas Flow	Waste Gas Composition	Steam/Waste Gas Ratio	Actual Exit Velocity (*) per 40 CFR 60.18 (fps)	Notes
S2.1	2	1	Incipient Smoke Point	0.40	
S2.1 to S2.2	2	1	Increase steam from value in Test Pt. S2.1 to value for Test Pt. S2.2	0.40	**As Needed
S2.2	2	1	< Snuff	0.40	

(*) Exclusive of center steam

Waste Gas Flow Legend
1 – 0.25% (nominally) of flare design capacity or 2,342 lb/hr for 36 inch steam-assisted flare burner
2 – 0.1% (nominally) of flare design capacity or 937 lb/hr for 36 inch steam-assisted flare burner

Waste Gas Composition & Lower Heating Value (LHV) Legend
1 – 100% Propylene, LHV = 2,149 Btu/scf
2 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to a LHV = 350 Btu/scf
3 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to LHV = 600 Btu/scf

Test Series No. S3: Varying Steam Assist, 937 lb/hr Waste Gas Flow, LHV = 350 Btu/scf

Test Point No.	Waste Gas Flow	Waste Gas Composition	Steam/Waste Gas Ratio	Actual Exit Velocity (*) per 40 CFR 60.18 (fps)	Notes
S3.0	2	2	0	0.57	
S3.1	2	2	Incipient Smoke Point	0.57	**1st cycle only, less for 2nd & 3rd
S3.1 to S3.2	2	2	Increase steam from Incipient Smoke Point Value to <Snuff	0.57	
S3.2	2	2	< Snuff	0.57	
S3.2 to S3.3	2	2	Change steam from value in Test Pt. S3.2 to value in Test Pt. S3.3	0.57	
S3.3	2	2	2/3 between ISP and snuff ratios	0.57	
S3.3 to S3.4	2	2	Change steam from value in Test Pt. S3.3 to value in Test Pt. S3.4	0.57	
S3.4	2	2	1/3 between ISP and snuff ratios	0.57	

(*) Exclusive of center steam

Waste Gas Flow Legend
1 – 0.25% (nominally) of flare design capacity or 2,342 lb/hr for 36 inch steam-assisted flare burner
2 – 0.1% (nominally) of flare design capacity or 937 lb/hr for 36 inch steam-assisted flare burner

Waste Gas Composition & Lower Heating Value (LHV) Legend
1 – 100% Propylene, LHV = 2,149 Btu/scf
2 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to a LHV = 350 Btu/scf
3 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to LHV = 600 Btu/scf

Test Series No. S4: Varying Steam Assist, 2,342 lb/hr Waste Gas Flow, LHV = 350 Btu/scf

Test Point No.	Waste Gas Flow	Waste Gas Composition	Steam/Waste Gas Ratio	Actual Exit Velocity (*) per 40 CFR 60.18 (fps)	Notes
S4.0	1	2	0	1.42	
S4.1	1	2	Incipient Smoke Point	1.42	**1st cycle only, less for 2nd & 3rd
S4.1 to S4.2	1	2	Increase steam from Incipient Smoke Point Value to <Snuff	1.42	
S4.2	1	2	< Snuff	1.42	
S4.2 to S4.3	1	2	Change steam from value in Test Pt. S4.2 to value in Test Pt. S4.3	1.42	
S4.3	1	2	2/3 between ISP and snuff ratios	1.42	
S4.3 to S4.4	1	2	Change steam from value in Test Pt. S4.3 to value in Test Pt. S4.4	1.42	
S4.4	1	2	1/3 between ISP and snuff ratios	1.42	

(*) Exclusive of center steam

Waste Gas Flow Legend
1 – 0.25% (nominally) of flare design capacity or 2,342 lb/hr for 36 inch steam-assisted flare burner
2 – 0.1% (nominally) of flare design capacity or 937 lb/hr for 36 inch steam-assisted flare burner

Waste Gas Composition & Lower Heating Value (LHV) Legend
1 – 100% Propylene, LHV = 2,149 Btu/scf
2 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to a LHV = 350 Btu/scf
3 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to LHV = 600 Btu/scf

Test Series No. S5: Varying Steam Assist, 937 lb/hr Waste Gas Flow, LHV = 600 Btu/scf

Test Point No.	Waste Gas Flow	Waste Gas Composition	Steam/Waste Gas Ratio	Actual Exit Velocity (*) per 40 CFR 60.18 (fps)	Notes
S5.0	2	3	0	0.55	
S5.1	2	3	Incipient Smoke Point	0.55	**1st cycle only, less for 2nd & 3rd
S5.1 to S5.2	2	3	Increase steam from Incipient Smoke Point to < Snuff	0.55	
S5.2	2	3	< Snuff	0.55	
S5.2 to S5.3	2	3	Change steam from value in Test Pt. S5.2 to value in Test Pt. S5.3	0.55	
S5.3	2	3	1/3 between ISP and snuff ratios	0.55	
S5.3 to S5.4	2	3	Change steam from value in Test Pt. S5.3 to value in Test Pt. S5.4	0.55	
S5.4	2	3	2/3 between ISP and snuff ratios	0.55	

(*) Exclusive of center steam

Waste Gas Flow Legend
1 – 0.25% (nominally) of flare design capacity or 2,342 lb/hr for 36 inch steam-assisted flare burner
2 – 0.1% (nominally) of flare design capacity or 937 lb/hr for 36 inch steam-assisted flare burner

Waste Gas Composition & Lower Heating Value (LHV) Legend
1 – 100% Propylene, LHV = 2,149 Btu/scf
2 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to a LHV = 350 Btu/scf
3 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to LHV = 600 Btu/scf

Test Series No. S6: Varying Steam Assist, 2,342 lb/hr Waste Gas Flow, LHV = 600 Btu/scf

Test Point No.	Waste Gas Flow	Waste Gas Composition	Steam/Waste Gas Ratio	Actual Exit Velocity (*) per 40 CFR 60.18 (fps)	Notes
S6.0	1	3	0	1.36	
S6.1	1	3	Incipient Smoke Point	1.36	**1st cycle only, less for 2nd & 3rd
S6.1 to S6.2	1	3	Increase steam from Incipient Smoke Point to < Snuff	1.36	
S6.2	1	3	< Snuff	1.36	
S6.2 to S6.3	1	3	Change steam from value in Test Pt. S6.2 to value in Test Pt. S6.3	1.36	
S6.3	1	3	1/3 between ISP and snuff ratios	1.36	
S6.3 to S6.4	1	3	Change steam from value in Test Pt. S6.3 to value in Test Pt. S6.4	1.36	
S6.4	1	3	2/3 between ISP and snuff ratios	1.36	

(*) Exclusive of center steam

Waste Gas Flow Legend
1 – 0.25% (nominally) of flare design capacity or 2,342 lb/hr for 36 inch steam-assisted flare burner
2 – 0.1% (nominally) of flare design capacity or 937 lb/hr for 36 inch steam-assisted flare burner

Waste Gas Composition & Lower Heating Value (LHV) Legend
1 – 100% Propylene, LHV = 2,149 Btu/scf
2 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to a LHV = 350 Btu/scf
3 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to LHV = 600 Btu/scf

Extra Test Series: Constant Steam Assist, Varying Waste Gas Flow Rate

Test Series No. S7: Constant Steam Assist, Waste Gas Flow Varies from 2342 to 937 lbs/hr, LHV = 350 Btu/scf

Test Point No.	Waste Gas Flow lbs/hr	Waste Gas Composition	Steam Assist	Actual Exit Velocity (*) per 40 CFR 60.18 (fps)	Notes
S7.1	2342	2	525 lbs/hr upper, 500 lbs/hr center	-	
S7.2	1850	2	525 lbs/hr upper, 500 lbs/hr center	-	
S7.3	1400	2	525 lbs/hr upper, 500 lbs/hr center	-	
S7.4	937	2	525 lbs/hr upper, 500 lbs/hr center	-	

Test Series S7 would be repeated up 2 more times.
(*) Exclusive of center steam

Waste Gas Flow Legend
1 – 0.25% (nominally) of flare design capacity or 2,342 lb/hr for 36 inch steam-assisted flare burner
2 – 0.1% (nominally) of flare design capacity or 937 lb/hr for 36 inch steam-assisted flare burner

Waste Gas Composition & Lower Heating Value (LHV) Legend
1 – 100% Propylene, LHV = 2,149 Btu/scf
2 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to a LHV = 350 Btu/scf
3 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to LHV = 600 Btu/scf
4 – 20/80 ratio Tulsa natural gas to propane diluted with nitrogen to LHV = 600 Btu/scf

Extra Test Series: Constant Steam Assist, Varying Waste Gas Flow Rate

Test Series No. S8: Constant Steam Assist, Waste Gas Flow Varies from 2342 to 937 lbs/hr, LHV = 350 Btu/scf

Test Point No.	Waste Gas Flow lbs/hr	Waste Gas Composition	Steam Assist	Actual Exit Velocity (*) per 40 CFR 60.18 (fps)	Notes
S8.1	2342	2	525 lbs/hr upper, 0 lbs/hr center	-	
S8.2	1850	2	525 lbs/hr upper, 0 lbs/hr center	-	
S8.3	1400	2	525 lbs/hr upper, 0 lbs/hr center	-	
S8.4	937	2	525 lbs/hr upper, 0 lbs/hr center	-	

(*) Exclusive of center steam

Waste Gas Flow Legend
1 – 0.25% (nominally) of flare design capacity or 2,342 lb/hr for 36 inch steam-assisted flare burner
2 – 0.1% (nominally) of flare design capacity or 937 lb/hr for 36 inch steam-assisted flare burner

Waste Gas Composition & Lower Heating Value (LHV) Legend
1 – 100% Propylene, LHV = 2,149 Btu/scf
2 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to a LHV = 350 Btu/scf
3 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to LHV = 600 Btu/scf
4 – 20/80 ratio Tulsa natural gas to propane diluted with nitrogen to LHV = 600 Btu/scf

Extra Test Series: Constant Steam Assist, Varying Waste Gas Flow Rate

Test Series No. S9: Constant Steam Assist, Waste Gas Flow Varies from 2342 to 937 lbs/hr, LHV = 350 Btu/scf

Test Point No.	Waste Gas Flow lbs/hr	Waste Gas Composition	Steam Assist	Actual Exit Velocity (*) per 40 CFR 60.18 (fps)	Notes
S9.1	2342	2	1025 lbs/hr upper, 0 lbs/hr center	-	
S9.2	1850	2	1025 lbs/hr upper, 0 lbs/hr center	-	
S9.3	1400	2	1025 lbs/hr upper, 0 lbs/hr center	-	
S9.4	937	2	1025 lbs/hr upper, 0 lbs/hr center	-	

(*) Exclusive of center steam

Waste Gas Flow Legend
1 – 0.25% (nominally) of flare design capacity or 2,342 lb/hr for 36 inch steam-assisted flare burner
2 – 0.1% (nominally) of flare design capacity or 937 lb/hr for 36 inch steam-assisted flare burner

Waste Gas Composition & Lower Heating Value (LHV) Legend
1 – 100% Propylene, LHV = 2,149 Btu/scf
2 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to a LHV = 350 Btu/scf
3 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to LHV = 600 Btu/scf
4 – 20/80 ratio Tulsa natural gas to propane diluted with nitrogen to LHV = 600 Btu/scf

Extra Test Series: Constant Steam Assist, Varying Waste Gas Flow Rate

Test Series No. S10: Constant Steam Assist, Waste Gas Flow Varies from 2342 to 937 lbs/hr, LHV = 350 Btu/scf

Test Point No.	Waste Gas Flow lbs/hr	Waste Gas Composition	Steam Assist	Actual Exit Velocity (*) per 40 CFR 60.18 (fps)	Notes
S10.1	2342	2	825 lbs/hr upper, 0 lbs/hr center	-	
S10.2	1850	2	825 lbs/hr upper, 0 lbs/hr center	-	
S10.3	1400	2	825 lbs/hr upper, 0 lbs/hr center	-	
S10.4	937	2	825 lbs/hr upper, 0 lbs/hr center	-	

(*) Exclusive of center steam

Waste Gas Flow Legend
1 – 0.25% (nominally) of flare design capacity or 2,342 lb/hr for 36 inch steam-assisted flare burner
2 – 0.1% (nominally) of flare design capacity or 937 lb/hr for 36 inch steam-assisted flare burner

Waste Gas Composition & Lower Heating Value (LHV) Legend
1 – 100% Propylene, LHV = 2,149 Btu/scf
2 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to a LHV = 350 Btu/scf
3 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to LHV = 600 Btu/scf
4 – 20/80 ratio Tulsa natural gas to propane diluted with nitrogen to LHV = 600 Btu/scf

Extra Test Series: Constant Steam Assist, Varying Waste Gas Flow Rate

Test Series No. S11: Constant Steam Assist, Waste Gas Flow Varies from 2342 to 937 lbs/hr, LHV = 350 Btu/scf

Test Point No.	Waste Gas Flow lbs/hr	Waste Gas Composition	Steam Assist	Actual Exit Velocity (*) per 40 CFR 60.18 (fps)	Notes
S11.1	2342	2	525 lbs/hr upper, 300 lbs/hr center	-	
S11.2	1850	2	525 lbs/hr upper, 300 lbs/hr center	-	
S11.3	1400	2	525 lbs/hr upper, 300 lbs/hr center	-	
S11.4	937	2	525 lbs/hr upper, 300 lbs/hr center	-	

(*) Exclusive of center steam

Waste Gas Flow Legend
1 – 0.25% (nominally) of flare design capacity or 2,342 lb/hr for 36 inch steam-assisted flare burner
2 – 0.1% (nominally) of flare design capacity or 937 lb/hr for 36 inch steam-assisted flare burner

Waste Gas Composition & Lower Heating Value (LHV) Legend
1 – 100% Propylene, LHV = 2,149 Btu/scf
2 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to a LHV = 350 Btu/scf
3 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to LHV = 600 Btu/scf
4 – 20/80 ratio Tulsa natural gas to propane diluted with nitrogen to LHV = 600 Btu/scf

Extra Test Series: Constant Steam Assist, Varying Waste Gas Flow Rate

Test Series No. S12: Constant Steam Assist, Waste Gas Flow Varies from 2342 to 937 lbs/hr, LHV = 350 Btu/scf

Test Point No.	Waste Gas Flow lbs/hr	Waste Gas Composition	Steam Assist	Actual Exit Velocity (*) per 40 CFR 60.18 (fps)	Notes
S12.1	2342	5	525 lbs/hr upper, 500 lbs/hr center	-	
S12.2	1850	5	525 lbs/hr upper, 500 lbs/hr center	-	
S12.3	1400	5	525 lbs/hr upper, 500 lbs/hr center	-	
S12.4	937	5	525 lbs/hr upper, 500 lbs/hr center	-	

(*) Exclusive of center steam

Waste Gas Flow Legend
1 – 0.25% (nominally) of flare design capacity or 2,342 lb/hr for 36 inch steam-assisted flare burner
2 – 0.1% (nominally) of flare design capacity or 937 lb/hr for 36 inch steam-assisted flare burner

Waste Gas Composition & Lower Heating Value (LHV) Legend
1 – 100% Propylene, LHV = 2,149 Btu/scf
2 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to a LHV = 350 Btu/scf
3 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to LHV = 600 Btu/scf
4 – 20/80 ratio Tulsa natural gas to propane diluted with nitrogen to LHV = 600 Btu/scf
5 – 20/80 ratio Tulsa natural gas to propane diluted with nitrogen to LHV = 350 Btu/scf

Extra Test Series: Constant Steam Assist, Varying Waste Gas Flow Rate

Test Series No. S13: Constant Steam Assist, Waste Gas Flow Varies from 2342 to 937 lbs/hr, LHV = 350 Btu/scf

Test Point No.	Waste Gas Flow lbs/hr	Waste Gas Composition	Steam Assist	Actual Exit Velocity (*) per 40 CFR 60.18 (fps)	Notes
S13.1	2342	5	525 lbs/hr upper, 300 lbs/hr center	-	
S13.2	1850	5	525 lbs/hr upper, 300 lbs/hr center	-	
S13.3	1400	5	525 lbs/hr upper, 300 lbs/hr center	-	
S13.4	937	5	525 lbs/hr upper, 300 lbs/hr center	-	

(*) Exclusive of center steam

Waste Gas Flow Legend
1 – 0.25% (nominally) of flare design capacity or 2,342 lb/hr for 36 inch steam-assisted flare burner
2 – 0.1% (nominally) of flare design capacity or 937 lb/hr for 36 inch steam-assisted flare burner

Waste Gas Composition & Lower Heating Value (LHV) Legend
1 – 100% Propylene, LHV = 2,149 Btu/scf
2 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to a LHV = 350 Btu/scf
3 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to LHV = 600 Btu/scf
4 – 20/80 ratio Tulsa natural gas to propane diluted with nitrogen to LHV = 600 Btu/scf
5 – 20/80 ratio Tulsa natural gas to propane diluted with nitrogen to LHV = 350 Btu/scf

Extra Test Series: Constant Steam Assist, Varying Waste Gas Flow Rate

Test Series No. S14: Constant Steam Assist, Waste Gas Flow Varies from 2342 to 937 lbs/hr, LHV = 350 Btu/scf

Test Point No.	Waste Gas Flow lbs/hr	Waste Gas Composition	Steam Assist	Actual Exit Velocity (*) per 40 CFR 60.18 (fps)	Notes
S14.1	2342	5	525 lbs/hr upper, 0 lbs/hr center	-	
S14.2	1850	5	525 lbs/hr upper, 0 lbs/hr center	-	
S14.3	1400	5	525 lbs/hr upper, 0 lbs/hr center	-	
S14.4	937	5	525 lbs/hr upper, 0 lbs/hr center	-	

(*) Exclusive of center steam

Waste Gas Flow Legend
1 – 0.25% (nominally) of flare design capacity or 2,342 lb/hr for 36 inch steam-assisted flare burner
2 – 0.1% (nominally) of flare design capacity or 937 lb/hr for 36 inch steam-assisted flare burner

Waste Gas Composition & Lower Heating Value (LHV) Legend
1 – 100% Propylene, LHV = 2,149 Btu/scf
2 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to a LHV = 350 Btu/scf
3 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to LHV = 600 Btu/scf
4 – 20/80 ratio Tulsa natural gas to propane diluted with nitrogen to LHV = 600 Btu/scf
5 – 20/80 ratio Tulsa natural gas to propane diluted with nitrogen to LHV = 350 Btu/scf

Test Series No. A1: Varying Air Assist, 937 lb/hr Waste Gas Flow, LHV = 2,149 Btu/scf

Test Point No.	Waste Gas Flow	Waste Gas Composition	Air/Waste Gas Ratio	Actual Exit Velocity (*) per 40 CFR 60.18 (fps)	Notes
A1.1	1	1	Incipient Smoke Point	0.22	
A1.1 to A1.2	1	1	Increase air from value in Test Pt. A1.1 to value for Test Pt. A1.2	0.22	**As Needed
A1.2	1	1	Maximum fan air flow	0.22	

Test Series No. A2: Varying Air Assist, 359 lb/hr Waste Gas Flow, LHV = 2,149 Btu/scf

Test Point No.	Waste Gas Flow	Waste Gas Composition	Air/Waste Gas Ratio	Actual Exit Velocity (*) per 40 CFR 60.18 (fps)	Notes
A2.1	2	1	Incipient Smoke Point	0.54	
A2.1 to A2.2	2	1	Increase air from value in Test Pt. A2.1 to value for Test Pt. A2.2	0.54	**As Needed
A2.2	2	1	< Snuff	0.54	

(*) Exclusive of air assist

Waste Gas Flow Legend
1 – 0.65% (nominally) of flare design capacity or 937 lb/hr for 24 inch air-assisted flare burner
2 – 0.25% (nominally) of flare design capacity or 359 lb/hr for 24 inch air-assisted flare burner

Waste Gas Composition & Lower Heating Value (LHV) Legend
1 – 100% Propylene, LHV = 2,149 Btu/scf
2 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to a LHV = 350 Btu/scf
3 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to LHV = 600 Btu/scf

Test Series No. A3: Varying Air Assist, 937 lb/hr Waste Gas Flow, LHV = 350 Btu/scf

Test Point No.	Waste Gas Flow	Waste Gas Composition	Air/Waste Gas Ratio	Actual Exit Velocity (*) per 40 CFR 60.18 (fps	Notes
A3.0	1	2	0	0.77	
A3.1	1	2	Incipient Smoke Point air flow rate	0.77	**1st cycle only, less for 2nd & 3rd
A3.1 to A3.2	1	2	Increase air from Incipient Smoke Point air flow rate in Test Pt. A3.1 to maximum fan air flow rate	0.77	
A3.2	1	2	Maximum fan air flow	0.77	
A3.2 to A3.3	1	2	Change air from flow rate in Test Pt. A3.2 to air flow rate in Test Pt. A3.3	0.77	
A3.3	1	2	1/3 between ISP and maximum fan air flow rates	0.77	
A3.3 to A3.4	1	2	Change air from flow rate in Test Pt. A3.3 to air flow rate in Test Pt. A3.4	0.77	
A3.4	1	2	2/3 between ISP and maximum fan air flow rates	0.77	

(*) Exclusive of air assist

Waste Gas Flow Legend
1 – 0.65% (nominally) of flare design capacity or 937 lb/hr for 24 inch air-assisted flare burner
2 – 0.25% (nominally) of flare design capacity or 359 lb/hr for 24 inch air-assisted flare burner

Waste Gas Composition & Lower Heating Value (LHV) Legend
1 – 100% Propylene, LHV = 2,149 Btu/scf
2 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to a LHV = 350 Btu/scf
3 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to LHV = 600 Btu/scf

Test Series No. A4: Varying Air Assist, 937 lb/hr Waste Gas Flow, LHV = 600 Btu/scf

Test Point No.	Waste Gas Flow	Waste Gas Composition	Air/Waste Gas Ratio	Actual Exit Velocity (*) per 40 CFR 60.18 (fps)	Notes
A4.0	1	3	0	0.74	
A4.1	1	3	Incipient Smoke Point air flow rate	0.74	**1st cycle only, less for 2nd & 3rd
A4.1 to A4.2	1	3	Increase air from Incipient Smoke Point air flow rate in Test Pt. A3.1 to maximum fan air flow	0.74	
A4.2	1	3	Maximum fan air flow rate	0.74	
A4.2 to A4.3	1	3	Change air from flow rate in Test Pt. A3.2 to air flow rate in Test Pt. A3.3	0.74	
A4.3	1	3	1/3 between ISP and maximum fan air flow air flow rate values	0.74	
A4.3 to A4.4	1	3	Change air from flow rate in Test Pt. A3.3 to air flow rate in Test Pt. A3.4	0.74	
A4.4	1	3	2/3 between ISP and maximum fan air flow rates	0.74	

(*) Exclusive of air assist

Waste Gas Flow Legend
1 – 0.65% (nominally) of flare design capacity or 937 lb/hr for 24 inch air-assisted flare burner
2 – 0.25% (nominally) of flare design capacity or 359 lb/hr for 24 inch air-assisted flare burner

Waste Gas Composition & Lower Heating Value (LHV) Legend
1 – 100% Propylene, LHV = 2,149 Btu/scf
2 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to a LHV = 350 Btu/scf
3 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to LHV = 600 Btu/scf

Test Series No. A5: Varying Air Assist, 359 lb/hr Waste Gas Flow, LHV = 350 Btu/scf

Test Point No.	Waste Gas Flow	Waste Gas Composition	Air/Waste Gas Ratio	Actual Exit Velocity (*) per 40 CFR 60.18 (fps)	Notes
A5.0	2	2	0	0.31	
A5.1	2	2	Incipient Smoke Point air flow rate	0.31	**1st cycle only, less for 2nd & 3rd
A5.1 to A5.2	2	2	Increase air from Incipient Smoke Point air flow rate in Test Pt. A5.1 to <Snuff	0.31	
A5.2	2	2	< Snuff	0.31	
A5.2 to A5.3	2	2	Change air from flow rate in Test Pt. A5.2 to air flow rate in Test Pt. A5.3	0.31	
A5.3	2	2	1/3 between ISP and snuff air flow rates	0.31	
A5.3 to A5.4	2	2	Change air from flow rate in Test Pt. A5.3 to air flow rate in Test Pt. A5.4	0.31	
A5.4	2	2	2/3 between ISP and snuff air flow rates	0.31	

(*) Exclusive of air assist

Waste Gas Flow Legend
1 – 0.65% (nominally) of flare design capacity or 937 lb/hr for 24 inch air-assisted flare burner
2 – 0.25% (nominally) of flare design capacity or 359 lb/hr for 24 inch air-assisted flare burner

Waste Gas Composition & Lower Heating Value (LHV) Legend
1 – 100% Propylene, LHV = 2,149 Btu/scf
2 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to a LHV = 350 Btu/scf
3 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to LHV = 600 Btu/scf

Test Series No. A6: Varying Air Assist, 359 lb/hr Waste Gas Flow, LHV = 600 Btu/scf

Test Point No.	Waste Gas Flow	Waste Gas Composition	Air/Waste Gas Ratio	Actual Exit Velocity per 40 CFR (*) 60.18 (fps	Notes
A6.0	2	3	0	0.30	
A6.1	2	3	Incipient Smoke Point air flow rate	0.30	**1st cycle only, less for 2nd & 3rd
A6.1 to A6.2	2	3	Increase air from Incipient Smoke Point air flow rate in Test Pt. 6.1 to <Snuff	0.30	
A6.2	2	3	< Snuff	0.30	
A6.2 to A6.3	2	3	Change air from flow rate in Test Pt. A6.2 to air flow rate in Test Pt. A6.3	0.30	
A6.3	2	3	1/3 between ISP and snuff air flow rate values	0.30	
A6.3 to A6.4	2	3	Change air from flow rate in Test Pt. A6.3 to air flow rate in Test Pt. A6.4	0.30	
A6.4	2	3	2/3 between ISP and snuff air flow rates	0.30	

(*) Exclusive of air assist

Waste Gas Flow Legend
1 – 0.65% (nominally) of flare design capacity or 937 lb/hr for 24 inch air-assisted flare burner
2 – 0.25% (nominally) of flare design capacity or 359 lb/hr for 24 inch air-assisted flare burner

Waste Gas Composition & Lower Heating Value (LHV) Legend
1 – 100% Propylene, LHV = 2,149 Btu/scf
2 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to a LHV = 350 Btu/scf
3 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to LHV = 600 Btu/scf

Extra Test Series: Propane/TNG

Test Series No. A7: Varying Air Assist, 359 lb/hr Waste Gas Flow, LHV = 350 Btu/scf

Test Point No.	Waste Gas Flow	Waste Gas Composition	Air/Waste Gas Ratio	Actual Exit Velocity per 40 CFR (*) 60.18 (fps	Notes
A7.0	2	5	0	0.30	
A7.1	2	5	Incipient Smoke Point air flow rate	0.30	**1st cycle only, less for 2nd & 3rd
A7.1 to A7.2	2	5	Increase air from Incipient Smoke Point air flow rate in Test Pt. 7.1 to <Snuff	0.30	
A7.2	2	5	< Snuff	0.30	
A7.2 to A7.3	2	5	Change air from flow rate in Test Pt. A7.2 to air flow rate in Test Pt. A7.3	0.30	
A7.3	2	5	1/3 between ISP and snuff air flow rate values	0.30	
A7.3 to A7.4	2	5	Change air from flow rate in Test Pt. A7.3 to air flow rate in Test Pt. A7.4	0.30	
A7.4	2	5	2/3 between ISP and snuff air flow rates	0.30	

(*) Exclusive of air assist

Waste Gas Flow Legend
1 – 0.65% (nominally) of flare design capacity or 937 lb/hr for 24 inch air-assisted flare burner
2 – 0.25% (nominally) of flare design capacity or 359 lb/hr for 24 inch air-assisted flare burner

Waste Gas Composition & Lower Heating Value (LHV) Legend
1 – 100% Propylene, LHV = 2,149 Btu/scf
2 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to a LHV = 350 Btu/scf
3 – 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to LHV = 600 Btu/scf
4 – 20/80 ratio Tulsa natural gas to propane diluted with nitrogen to LHV = 600 Btu/scf
5 – 20/80 ratio Tulsa natural gas to propane diluted with nitrogen to LHV = 350 Btu/scf

Appendix B

Flare Test Facility Description

Flare Test Facility and Instrumentation

Once the test plan was developed, UT Austin worked with ARI and Zink to design the test facility and instrumentation needed to make measurements of all the operational parameters and emissions in the flare plume. The test facility and instrumentation are described in this appendix. Additonal information on all test facility measurements and instrumentation is included in Appendix C – Data Quality Objectives. Information about and the actual calibration of instruments is included in Appendix K – Quality Assurance Documentation for Test System and Instrumentation Used During Field Tests.

The flare test facility was composed of two major systems: the flare test system (Figure B-1) and the flare plume sampling system (Figure B-2). The flare test system consisted of the flare burners (air- and steam-assisted), the vent gas supply system, the air- or steam-assist system and the flare control room. The flare plume sampling system consisted of the sample collector, the eductor, global positioning system, crane, meteorology system, and the sampling probes and lines.

Figure B-1. Overall view of Flare Test System

Figure B-2. Flare Plume Sampling System During Morning Start-up Routine

Flare Test System

Operating parameters for the flare burners (Figure B-3) were controlled by Zink personnel and monitored using their standard process and control instrumentation (Figures B-4 and B-5) for steam delivery and vent gas supply with additional instrumentation and sampling ports added for this study where necessary. Please refer to Zink drawings (Fuel Metering PandID and Steam Metering PandID) at the end of this appendix and in Appendix K – the John Zink Final Report for piping, instrumentation and calibration details. Zink recorded all flare operating data in a data acquisition system in the flare control room (Figures B-8 and B-10). To verify the actual composition of the vent gas being used during each test, a stack testing company, TRC, was employed to provide semi-continuous measurements (two measurements per test run, 5 minutes apart) of the vent gas composition prior to entering the flare burner. TRC also made semi-continuous measurements of propylene, methane and ethane in the flare plume as a backup to ARI's primary determination of DRE.

The exits of the steam- and air-assisted flare burners were 13 and 33 feet above ground level, respectively (Figure B-3). Please refer to Zink drawings LHTS-24 and QS-36 of the air flare and steam flares, respectively, for design details. The steam flare had a nominal diameter of 36 inches and a design capacity (propylene) of 937,000 lb/hr.

Figure B-3. Flare Burners – Air-assisted on left and steam-assisted on right

It has center and upper steam assist (Figures B-4 and B-5). John Zink recommends 300 lb/hr as the minimum continuous flow rate of center steam and 525 lb/hr minimum flow rate of upper steam for this flare. The steam flare has 3 pilots (Figure B-6) each rated at 75,000 Btu/hr. Steam- and air-assist flow rates were measured by Zink and controlled at the flare control room.

Figure B-4. Steam lines for the steam-assisted flare burner.

Figure B-5. Steam-assisted flare burner with upper steam assist line on left and center steam assist line on right. Steam control station is to the right of the steam lines.

Figure B- 6. Typical pilot (left) and upper steam ring with nozzles.

The air flare had a nominal diameter of 24 inches and a design capacity (propylene) of 144,000 lb/hr. A fan (Figure B-7) with a variable frequency drive motor provided air assist to the base of air flare. The air flare had vent gas separators (Figure B-8) that provided parallel flow paths for the air and vent gas through the flare burner. This flare also had three pilots also rated at 75,000 Btu/hr each.

Vent gas supply (Figure B-9) flow rates of nitrogen, propylene or propane, and Tulsa Natural Gas (TNG) were individually controlled and measured before being blended at the vent gas supply station and sent via underground piping to the flare. The temperature of the vent gas was measured immediately before it entered the base of each flare.

All of the flare operations were controlled in the Zink flare tests control room (Figure B-9). Only Zink, UT Austin, TCEQ, ARI, TRC and LSI personnel were allowed in the control room during the flare tests. The UT Austin team would prescribe the test conditions to be run and Zink personnel would operate the flare as prescribed using direct controls in the control room and/or via radio communications with Zink personnel at their stations. Zink provided a data acquisition system in the control room where all their control and measurement data were recorded.

All ARI measurements of the plume sample were sent to the control (Figure B-11) where they could be displayed in real time (Figure B-12) along with the Zink operating data and the LSI and UT video images. UT Austin recorded an image of the flame exiting the flare tip for all tests using a Sony digital high definition (720p) camera with a film speed of 60 frames per second.

Figure B-7. Air supply for air-assisted flare burner

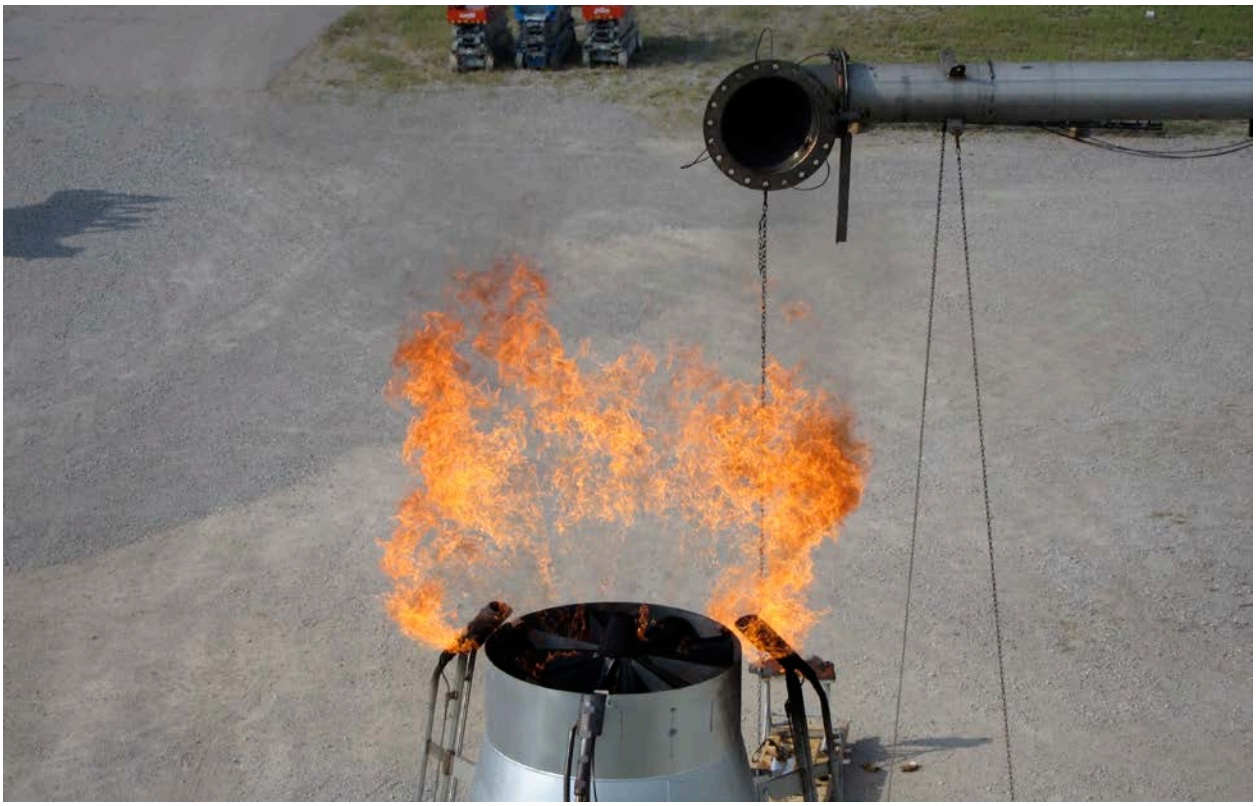

Figure B-8. Air Flare tip with vent gas separators.

Figure B-9. Control room (with glass windows) and vent gas supply system (center background)

Figure B-10. Piping for flow control, mixing and measurement of the vent gas supply

Figure B-11. Control room for the Flare Test System

Figure B-12. Monitor in Control Room displaying Zink measurement of flare operating parameters (top left), LSI's FLIR and IR video (right half) and ARI's flare emissions measurements (bottom left)

Flare Plume Sampling System (Figure B-13)

The sample collector (Figure B-14) was moved into position so that it was located approximately at the midpoint of the flare plume at a position far enough downwind from the flare tip to ensure that combustion reactions had ceased and with the face of the inlet oriented perpendicular to the travel of the plume. (A detail drawing of the sample collector is included in Appendix B – JZ Specialized Sample Hood). The method used as the gauge to know that the collector inlet was past the combustion zone was to position the inlet to the sample collector so that the plume temperature at the inlet was 250°F or less, as measured by three thermocouples in the inlet to the sample collector. The position of the sample collector at the midpoint of the plume was facilitated using the visual, FLIR and IR video camera images (Figure B-15) and the temperature of the flare plume as it entered the sample collector.

The eductor (Figure B-14) of the sample collector would continuously draw approximately 1950 cfm of flare plume through the collector. A mixing and flow conditioning section at the entrance to the sample collector would prepare the flow prior to reaching ARI's and TRC's sampling probes. Samples (approximately 1 liter per minute for vent gas sample line and 8 liters per minute for plume sample line) would be continuously drawn through the sample lines to the analyzers and instruments in each company's mobile laboratory trailers.

The position of the sample collector was tracked through the use of the global positioning system (Figure B-16) on the sample collector and manually by using a graduated chain attached to the sample collector inlet. After any change in height, Zink personnel would report this height to the control room where it would be logged. They would also report the radial distance from the inlet to the sample collector to the center of the flare burner.

TRC used gas chromatography to analyze both flare stack and plume gases (methane, ethane and propylene) semi-continuously (two measurements per run, 5 minutes apart). Flare plume constituents (CO, CO_2, O_2, speciated VOCs, HCHO, NOx, particulate matter and THC) were measured continuously (1 Hz) by ARI using their mobile laboratory, which has two dual quantum cascade laser instruments and several LiCOR non-dispersive infrared sensor instruments. Destruction removal and combustion efficiencies (DRE and CE) were calculated based on the measurements of TRC (vent gas) and the ARI (flare plume) measurements using the carbon content of the constituents in the flare plume and the composition of the vent gas. Please refer to Appendix I for a detailed explanation of the method used to determine the DRE and CE using the extractive sampling system.

Meteorology measurements were needed for multiple purposes, including determining the speed and direction of the cross wind at the exit of the flare burners. These measurements (Figure B-17) were made by ARI.

Figure B-13. Flare Plume Sampling System making measurements of flare plume while held in position by crane and ground crew.

Figure B-14. Sample Collector at Near Ground Level – Collector inlet is at foreground and eductor is at far end. In photo, Zink personnel make adjustments to heated transfer line supports. Shackles and cable at center allow crane to lift and position Sample Collector.

Figure B-15. Sony Handycam – for visible light (left), thermal infrared – for heat (center), and GasFind infrared – for hydrocarbons (right) cameras

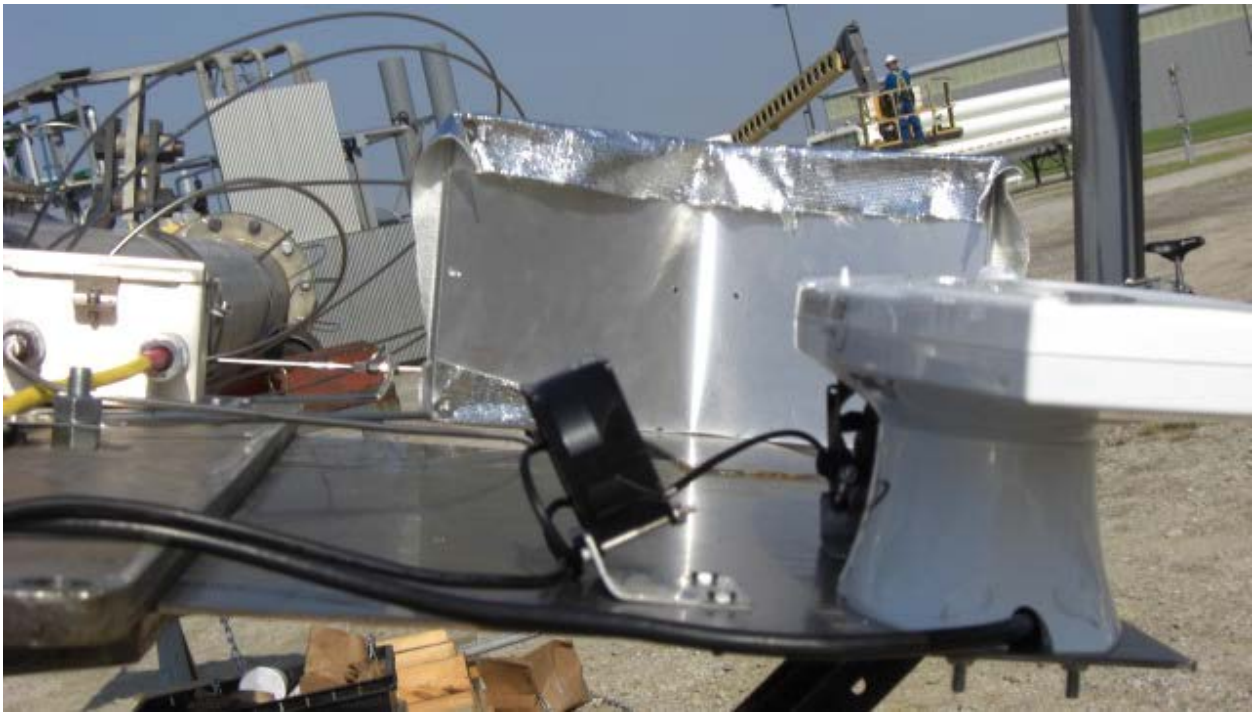

Figure B-16. Global Positioning System mounted on Sample Collector

Figure B-17. Meteorology System

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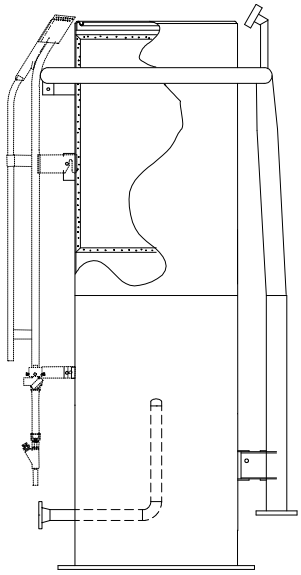
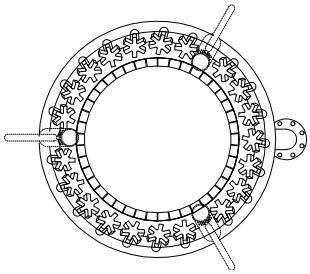
EEF-QS-36C
STEAM ASSISTED FLARE TIP

DESIGN INFORMATION	
OVERALL LENGTH	10’ – 1”
WEIGHT	840 #
EXIT AREA	5.957 ft^2
# OF PILOT POSITIONS	3
PILOT GAS MANIFOLD	YES

MATERIALS OF CONSTRUCTION	
SECTION	**MATERIAL**
UPPER 5’ RISER	310 SS, 3/16” PLATE
LOWER RISER	A36 CS, 1/4” PLATE
FLAME RETENTION RING	310 SS
INLET FLANGE	A105 CS
STEAM INLET FLANGES	A105 CS
STEAM INJECTION SPIDERS	CK-20 SS
UPPER STEAM MANIFOLD	321 / 310 SS
CENTER STEAM NOZZLE	304 SS
REFRACTORY	None

NOZZLE INFORMATION			
DESCRIPTION	**SIZE**	**QTY.**	**TYPE**
FLARE GAS	36”	1	PLATE FLANGE
UPPER STEAM	6”	1	150 # RF FLANGE
CENTER STEAM	2”	1	150 # RF FLANGE
PILOT GAS MANIFOLD	1”	1	PLAIN END





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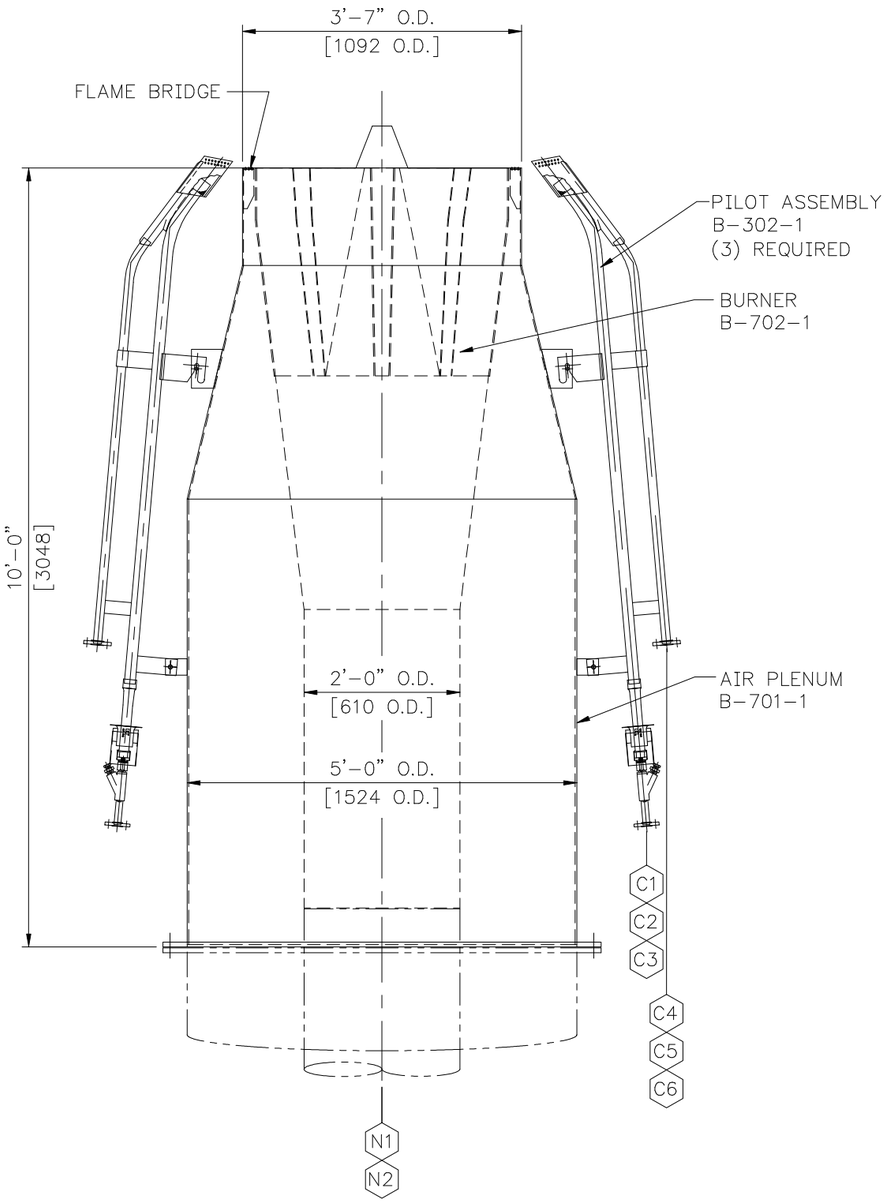
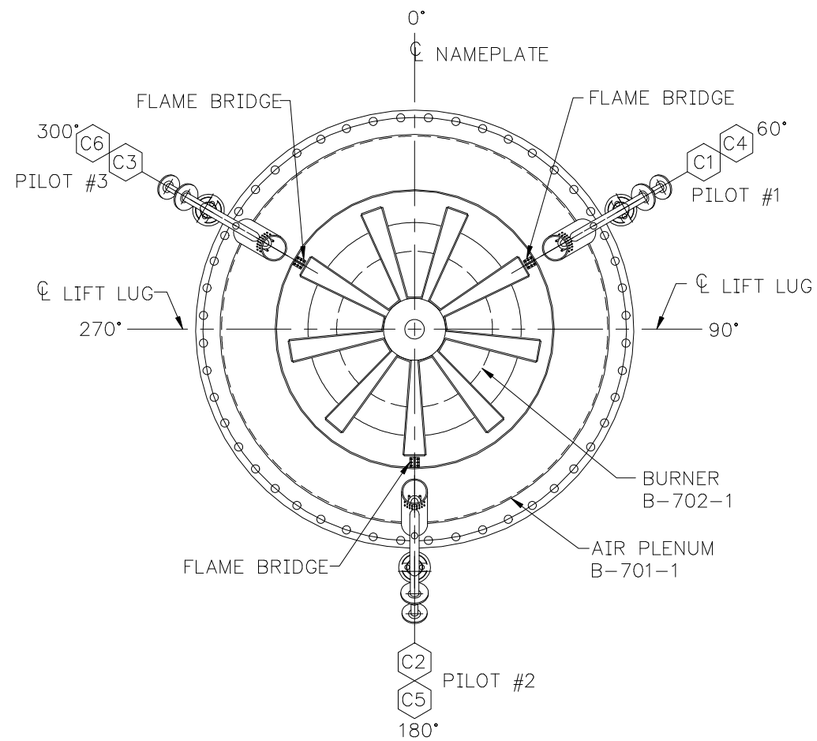


ELEVATION

(NOT TRUE ORIENTATION)



PLAN VIEW

(TRUE ORIENTATION)

PARTS LIST

MARK	QTY	DESCRIPTION
B-701-1	1	AIR PLENUM
B-702-1	1	BURNER SECTION W/(9) ARMS
B-302-1	3	EEP-503 PILOT ASSEMBLY

NOZZLE LEGEND

N1	1	60" PLENUM INLET
N2	1	24" BURNER INLET
C1,C2,C3	1 EA.	3/4" PILOT GAS CONNECTION
C4,C5,C6	1 EA.	1" PILOT IGNITION GAS CONNECTION

GENERAL NOTES

1. DIMENSIONS SHOWN IN [ ] ARE MILLIMETERS.
2. PILOT MIXER ORIFICE DRILLED FOR NATURAL GAS 75 SCFH [2.1 Nm3/HR] AT 15 PSIG [0.7 Kg/cm3].
3. PREFIX ALL TAG NO'S WITH S.O.
4. FLANGE BOLT HOLES TO STRADDLE RADIAL CENTERLINES.

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AIR FLARE TIP LHTS-24/60
W/(3) PILOTS

CERTIFIED
DATE:

DRAWING NUMBER
TCEQ LHTS-24

REV. 0

SCALE NONE

1 OF 1

JOHN ZINK®
®JOHN ZINK COMPANY LLC

LHTS STYLE FLARE TIP DATA SHEET

CUSTOMER:	JOHN ZINK COMPANY	**DATE**:	July 11, 2011
END USER:	JOHN ZINK COMPANY	**PROPOSAL NO.:**	N/A
PLANT LOCATION:		**REFERENCE NO.**:	N/A
MODEL:	EEF-LH-24/60	**ENGINEER**:	Z. KODESH

OVERALL LENGTH: 10'-0"	DESIGN CONDITION: N/A	TYPE OF PILOT: EEP-502
FIRING POSITION: VERTICAL	PILOT FUEL: NATURAL GAS	NO. OF PILOTS: 3
EXIT AREA: 1.68 ft^2		THERMOCOUPLE REQD: 1/Pilot
		TYPE: K (CHROMEL-ALUMEL)

WELDING PROCEDURES: AWS

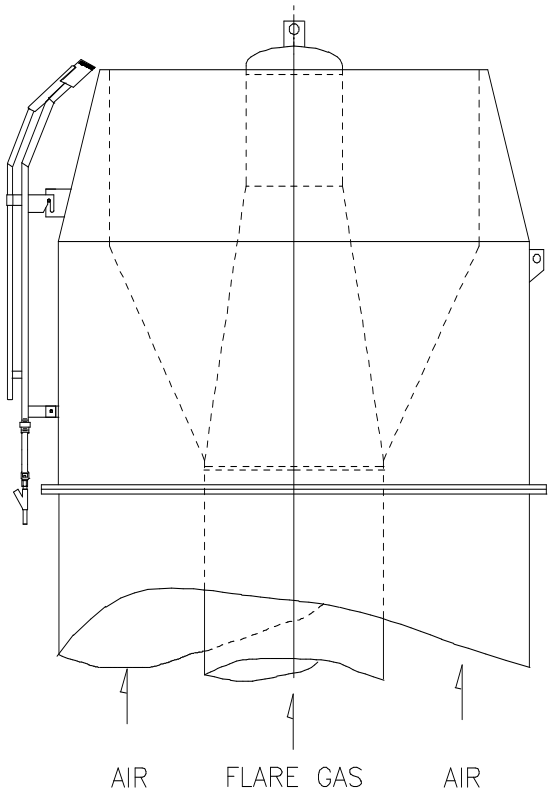
FINISH: HIGH TEMPERATURE ALUMINUM ON CARBON STEEL

MATERIAL OF CONSTRUCTION

SECTION	MATERIAL
AIR PLENUM	CARBON STEEL
FLANGE	CARBON STEEL
PILOT(S)	309 S.S./304 S.S.

NOZZLES	SIZE	NO.	TYPE
INLET	24"	1	PLAIN END
PILOT	3/4"	3	PLAIN END MALE
IGNITOR	1"	3	PLAIN END MALE
AIR PLENUM	60"	1	PLATE FLANGE

COMMENTS:



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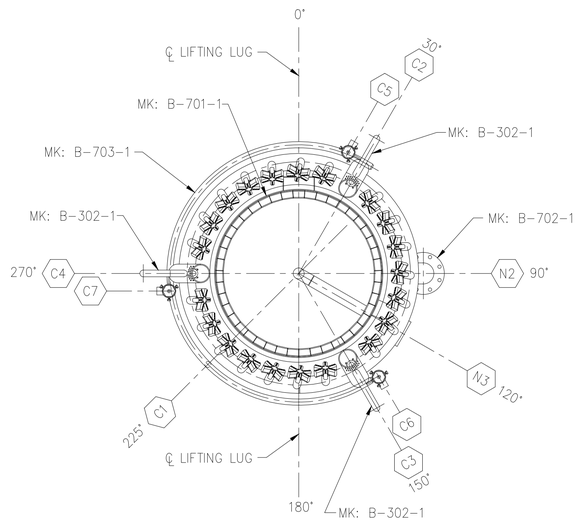
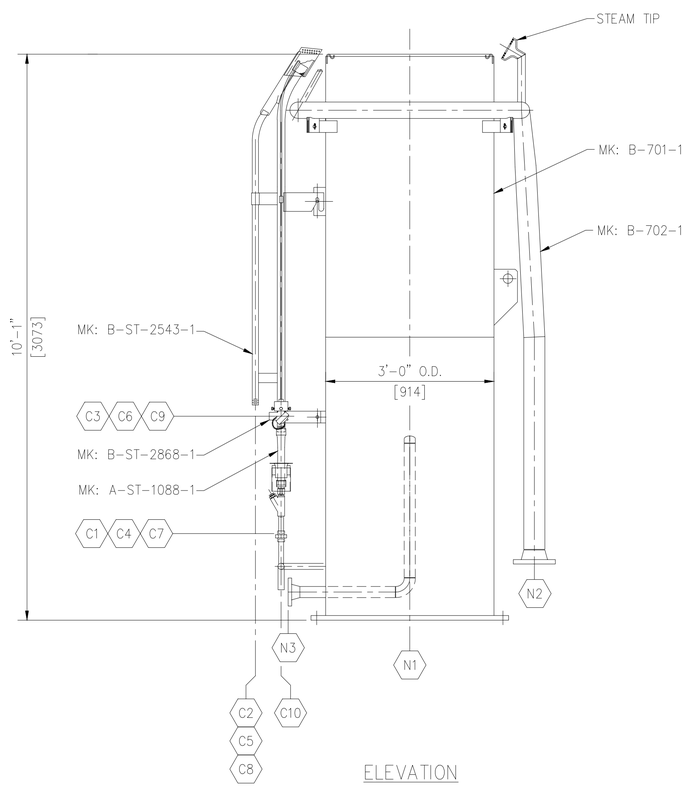


PLAN VIEW

(TRUE ORIENTATION)



ELEVATION

(NOT TRUE ORIENTATION)

PARTS LIST

MARK NO.	QTY	DESCRIPTION	PART NO.
B-ST-2073-1	1	EEF-QSC-36" FLARE TIP ASSEMBLY CONSISTING OF:	1061928
	1	B-ST-2074-1: EEF-QSC-36" FLARE TIP BODY	1061914
	1	B-ST-2075-1: UPPER STEAM MANIFOLD	1061955
	1	ST10578-1: PILOT GAS MANIFOLD	1061971
B-ST-2865	3	EEP-503 PILOT ASSEMBLY CONSISTING OF:	1098623
	3	B-ST-2543-1: EEP-503 PILOT BODY	1092920
	3	A-ST-1088-1: PILOT MIXER ASSEMBLY	0008127
	3	B-ST-2868-1: THERMOCOUPLE & MOUNTING BRACKETS	0034308

NOZZLE LEGEND

CONNECTION	QTY	DESCRIPTION
N1	1	36" TIP INLET CONNECTION:
N2	1	UPPER STEAM MANIFOLD CONNECTION: 4" 150# RFWN
N3	1	CENTER STEAM CONNECTION: 2" 150# RFWN
C1, C4, C7	3	3/4" PILOT GAS CONNECTION
C2, C5, C8	3	1" PILOT IGNITION GAS CONNECTION
C3, C6, C9	3	3/4" THERMOCOUPLE CONNECTION
C10	1	1" PILOT GAS MANIFOLD INLET CONNECTION

GENERAL NOTES

1. DIMENSIONS SHOWN IN [ ] ARE MILLIMETERS.
2. PILOT MIXER ORIFICE DRILLED FOR NATURAL GAS 75 SCFH [2.1 Nm3/HR] AT 15 PSIG [0.7 Kg/cm3]
3. PREFIX ALL TAG NO'S WITH S.O.
4. FLANGE BOLT HOLES TO STRADDLE RADIAL CENTERLINES.

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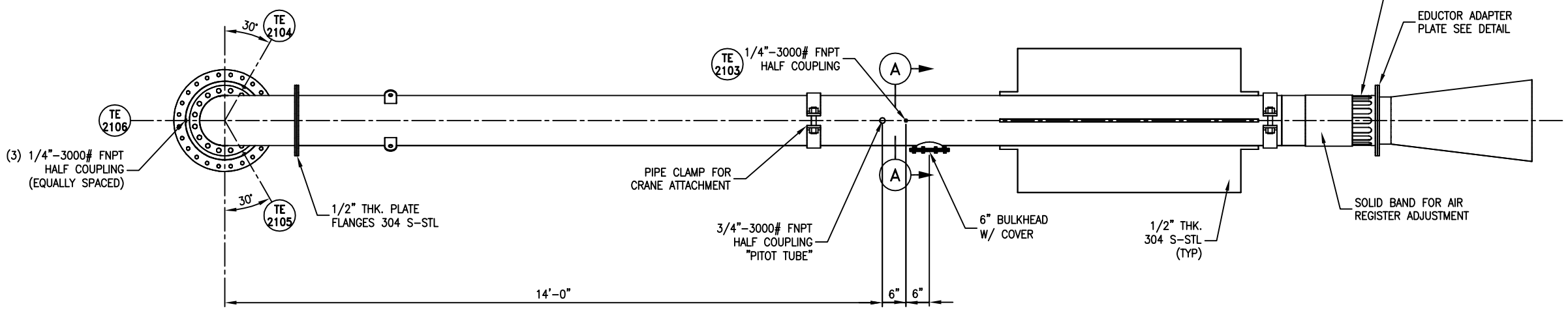
EEF-QSC-36" FLARE TIP ASSEMBLY
WITH (3) EEP-503 PILOTS

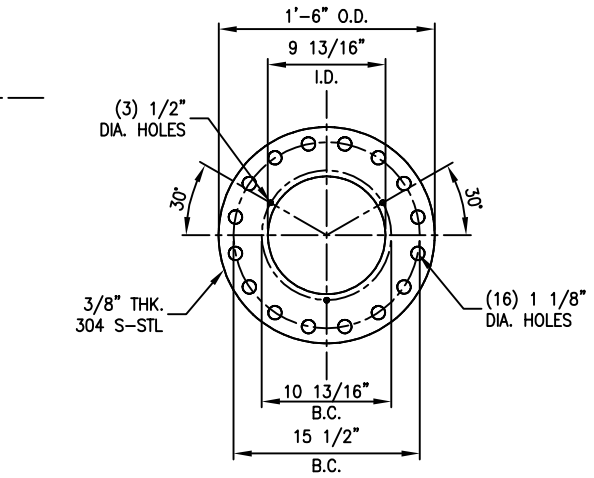
CERTIFIED
DATE:

DRAWING NUMBER: TCEQ QS-36
REV. 0
SCALE NONE
1 OF 1

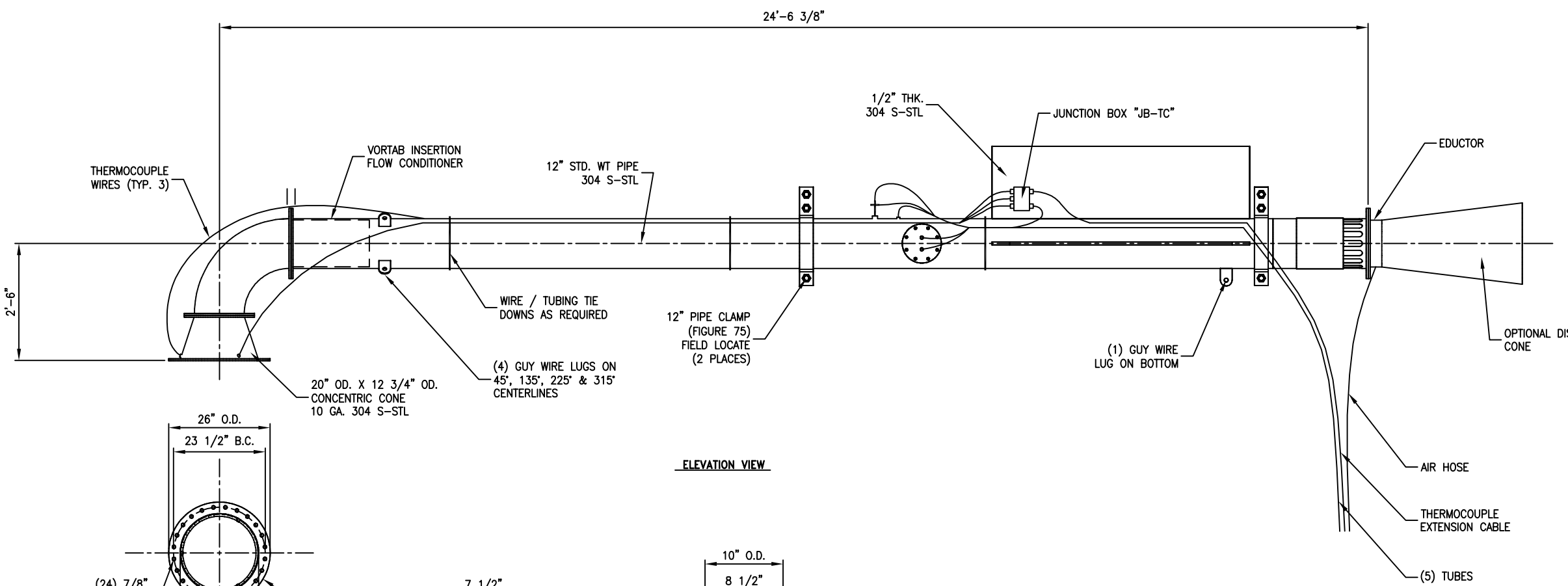
R:\Active\P-Flare\9105010\DRAFTING\DRAWINGS



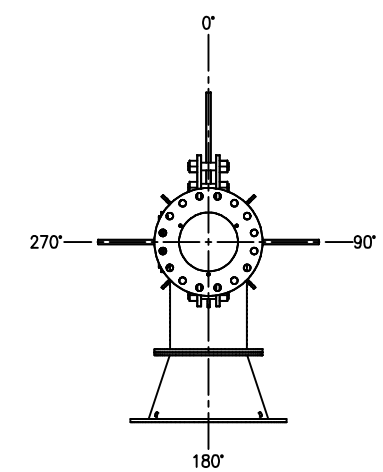
PLAN VIEW



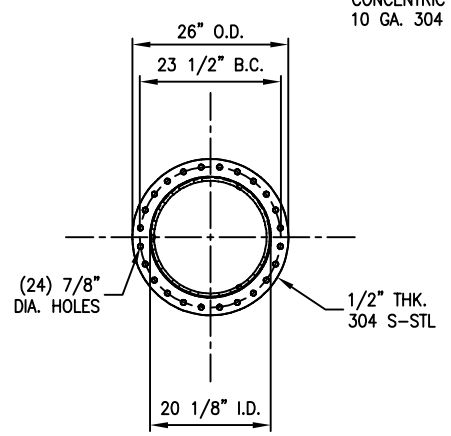
EDUCTOR ADAPTER PLATE DETAILS



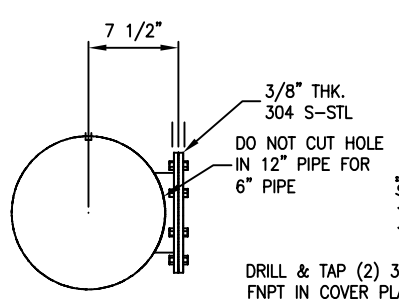
ELEVATION VIEW



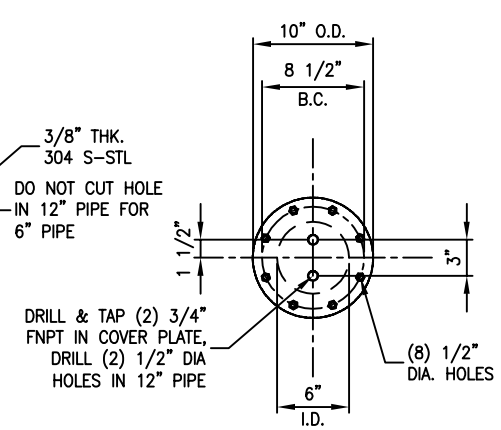
END VIEW



FLANGE DETAIL



SECTION "A-A"



END VIEW

6" BULKHEAD DETAILS

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JOBSITE:
S.O. NO: 9105175
P.O. NO:
DR: C. DWYER DATE: JUNE 11,10
CK: DATE:
APP: DATE:

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GENERAL ARRANGEMENT
SPECIALIZED SAMPLE HOOD

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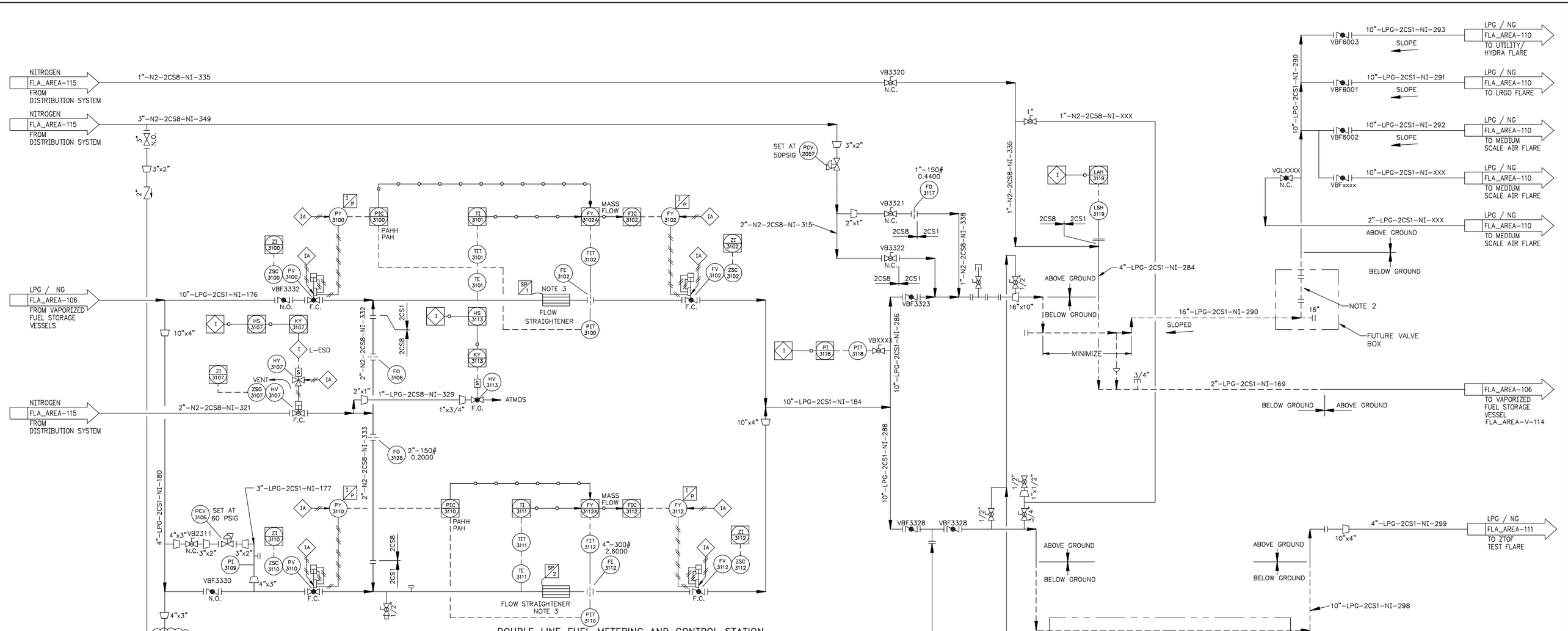
DRAWING NUMBER B-F-9105175-201
REV. 0
SCALE NONE
1 OF 4



NOTES:

1. FIELD VERIFY TIE-IN LOCATION, ELEVATION AND TIE-IN REQUIREMENTS.
2. SPOOL PIECE FOR FUTURE 10" BUTTERFLY VALVE.
3. FOR FLOW ORIFICE AND FLOW STRAIGHTENER LOCATIONS AND CRITICAL DIMENSIONS, SEE DWG NO D-TC-FLA_AREA-627, SHEET 2

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USER: JOHN ZINK COMPANY LLC

NO.	REVISION DESCRIPTION	BY	CK.	APP.	DATE
6	REVISED	BN	ZK	ZK	6-8-10
5	REVISED PIPING	BN	ZK	ZK	3/25/10
4	REVISED PER TEST CENTER MODIFICATION	DHC			2/11/09
3	GENERAL REVISIONS (JOHN ZINK)	KH			8/23/02
2	ADDED FLOW STRAIGHTENERS & RELOCATED PRESSURE TRANSMITTERS	JHK	HS	HS	5/13/02
1	ISSUED FOR DESIGN "SAVED UNDER PROJECT 01-153"	CTT	HS	HS	11/30/01
0	PHASE I - ISSUED FOR DESIGN	CTT	KAG	HS	5/25/01

JOB NO: 01-832
ACAD FILE: D-TC-FLA_AREA-107
PLOT DATE: 5/13/2002 07:17:40

UNIFIELD ENGINEERING™

JOHN ZINK®
JOHN ZINK COMPANY LLC
R&D TEST FACILITY, CALL 1-918-234-5800 FAX (918) 234-5895

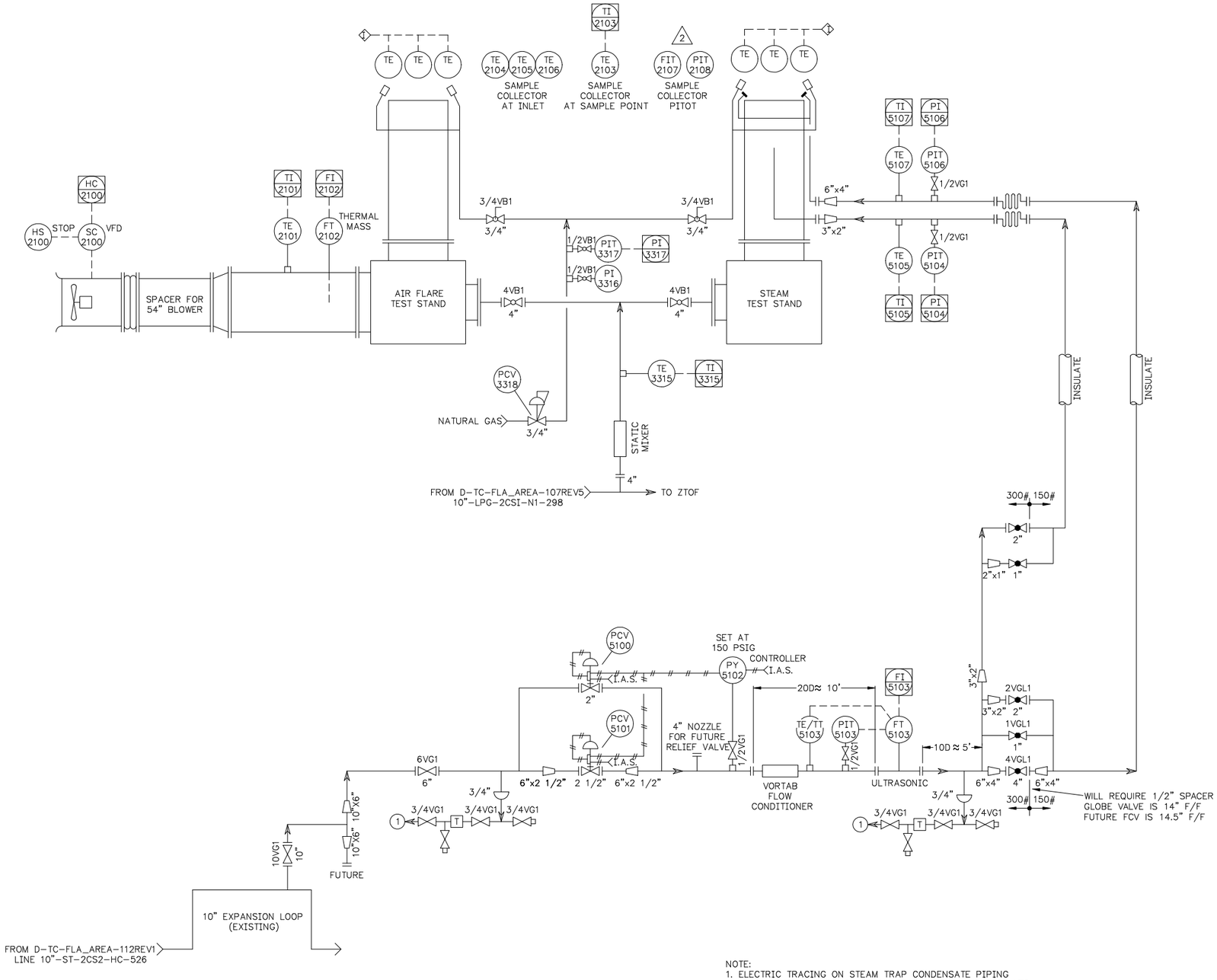
JOBSITE: TULSA, OK
R&D TEST FACILITY
S.O. NO. -
P.O. NO. -
DR. JHZ DATE: 10/15/99
CK. KAG DATE: 12/14/00
APP. HS DATE: 12/14/00

FLARE TEST FACILITY UPGRADE
FUEL METERING AND CONTROL STATIONS
PIPING AND INSTRUMENTATION DIAGRAM

CERTIFIED
DATE:

DRAWING NUMBER D-TC-FLA_AREA-107
REV. 6
SCALE NONE
SHEET 1 of 1

BASE NUMBER	APPROVAL



NOTE:
1. ELECTRIC TRACING ON STEAM TRAP CONDENSATE PIPING SHALL EXTEND THROUGH STEAM TRAP PIPING AND DRIP LEG TO CONNECTION POINT ON MAIN STEAM HEADER.

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NO.	REVISION DESCRIPTION	BY	CK.	APP.	DATE
2	REVISED PER ENGINEERING	BN		ZK	8-9-10
1	REVISED PER ENGINEERING	BN		ZK	6-8-10

FOR: JOHN ZINK COMPANY LLC
USER: JOHN ZINK COMPANY LLC
JOBSITE: TULSA, OK
R & D TEST FACILITY
S.O. NO. 9105010
P.O. NO.
DR. Beth DATE: 3-25-10
CK. DATE:
APP. ZK DATE:
CERTIFIED DATE:

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JOHN ZINK COMPANY LLC
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FLARE TEST FACILITY UPGRADE
FUEL METERING AND CONTROL STATIONS
PIPING AND INSTRUMENT DIAGRAM

DRAWING NUMBER D-TC-FLA_AREA-120 REV 2
SCALE NONE

BASE NUMBER	APPROVAL

Appendix C

Measurement Data Quality Objectives

Measurement Data Quality Objectives

Measurement Location	Parameter/Instrument	Species Measured/Units	Detection Limit	Precision	Accuracy	Company
Flare Flue Gas	Pulsed Quantum Cascade Tunable Infrared Laser Differential Absorption Spectrometer (QC-TILDAS)	CO (Carbon Monoxide)/ ppt	600 ppt (1-second)	300 ppt (1-s rms)	4%	Aerodyne
Flare Flue Gas	QC-TILDAS	NO_2 (Nitrogen Dioxide)/ ppt	700 ppt (1 second)	350 ppt (1-s rms)	5%	Aerodyne
Flare Flue Gas	QC-TILDAS	HCHO (Formaldehyde),CH_3CHO (acetaldehyde) HC_2H(Acetylene)/ ppt	700 ppt (1 second)	350 ppt (1-s rms)	6%	Aerodyne
Flare Flue Gas	QC-TILDAS	HCOOH (Formic Acid)/ ppb	1 ppb (1 second)	500 ppt (1-s rms)	8%	Aerodyne
Flare Flue Gas	QC-TILDAS	CH_4(Methane),C_2H_4 (Ethylene),C_3H_6 (Propylene)/ ppb	7 ppb (1 second)	3.5 ppb (1-s rms)	4%	Aerodyne
Flare Flue Gas	ThermoElectron 42i	NO (Niitrogen Oxide)/ ppb	0.4 ppb (1 second)	0.2 ppb (1-s rms)	5%	Aerodyne
Flare Flue Gas	LiCor	CO_2 (Carbon Dioxide)/ ppb	0.7 ppm (1 second)	350 ppb (1-s rms)	5%	Aerodyne
Flare Flue Gas	2B Tech 205	O_3 (Ozone)/ ppb	1 ppb (2 second)	0.5 ppb (2-s rms)	2%	Aerodyne
Flare Flue Gas	Auto GC	EPA TO-14 Analytes	3 ppb	0.5 ppb	1%	Aerodyne
Flare Flue Gas	PTR-MS	Oxygenated/Aromatic and selected olefinic VOC/ ppb	0.2 - 6 ppb (1 second)	0.1 - 3 ppb (1-s rms)	20%	Aerodyne
Flare Flue Gas	Aerosol Mass Spectrometer	Size-resolved chemical composition and mass loadings of PM1/ ng/m_3	100 ng/m3, 30 - 800 nm (10 s)	N/A	12%	Aerodyne
Flare Flue Gas	Multi-Angle Absorption Photometer (MAAP)	Black Carbon/ $\mu g/m^3$	5 µg/m3 (1.5 s)	5 µg/m3 (1.5 s)	15%	Aerodyne
Flare Flue Gas	Scanning Mobility Particle Sizer (SMPS)	PM Size Distribution nm	15 - 600 nm (1 min)	N/A	mode uncertainty depends on distribution	Aerodyne
Flare Flue Gas	Condensate Particle Counter (CPC)	Particle Number (D_p>7nm)/ nm	7 nm - 2.5 µm	N/A	2% reading	Aerodyne

Measurement Data Quality Objectives

Measurement Location	Parameter/Instrument	Species Measured/Units	Detection Limit	Precision	Accuracy	Company
Flare Flue Gas	Dustrak	Particle Mass (80 nm < D_p < 2.5 µm)/ ng/m^3	50 ng/m3 (60 s)	Zero Stability 2 ng/m3	15%	Aerodyne
Flare Test Facility	Meteorology	Wind Speed/ mph	0.2 m/s	0.1 m/s	5%	Aerodyne
Flare Test Facility	Meteorology	Wind Direction/ ° azimuth	1º	0.5 º	5%	Aerodyne
Flare Test Facility	Meteorology	Ambient Temperature/ °F	NA	0.2 degree (1 sec)	5%	Aerodyne
Flare Test Facility	Meteorology	Relative Humidity/ %	NA	1% RH	5%	Aerodyne
Flare Test Facility	Meteorology	Barametric Pressure/ mmHg	NA	0.5 Torr	3%	Aerodyne
Flare Flue Gas	TECO 55C	TNMHC	3 ppb	± 15%	± 20 %, monitor	Aerodyne
Flare Stack	Gas Chromatograph (GC)	concentrations of methane in flare gas/ ppmV	0.01 % (100 ppmv)	5%	±200 ppmv	TRC
Flare Flue Gas	Gas Chromatograph (GC)	concentrations of methane in flare plume/ ppmV	0.01 % (100 ppmv)	5%	±200 ppmv	TRC
Flare Stack	Gas Chromatograph (GC)	concentrations of ethane in flare gas/ ppmV	0.01 % (100 ppmv)	5%	±200 ppmv	TRC
Flare Flue Gas	Gas Chromatograph (GC)	concentrations of ethane in flare plume/ ppmV	0.01 % (100 ppmv)	5%	±200 ppmv	TRC
Flare Stack	Gas Chromatograph (GC)	concentrations of propylene in flare gas/ ppm	0.01 % (100 ppmv)	5%	±200 ppmv	TRC
Flare Flue Gas	Gas Chromatograph (GC)	concentrations of propylene in flare plume/ ppm	0.01 % (100 ppmv)	5%	±200 ppmv	TRC
Flare Flue Gas	Calculation	mass emission rates/ lb/hr	N/A	5%	5%	TRC
Flare Test Facility	Meteorology	Wind Speed/ mph	2.2 mph	0.5 mph	± 0.6 mph	John Zink Co. LLC
Flare Test Facility	Meteorology	Wind Direction/ ° Azimuth	1°	0.5°	± 3°	John Zink Co. LLC

Measurement Data Quality Objectives

Measurement Location	Parameter/Instrument	Species Measured/Units	Detection Limit	Precision	Accuracy	Company
Flare Test Facility	Meteorology	Ambient Temperature/ ° F	N/A	N/A	± 0.54°F	John Zink Co. LLC
Flare Test Facility	Meteorology	Relative Humidity/ %	1%	1% per year	± 2%	John Zink Co. LLC
Flare Test Facility	Meteorology	Barametric Pressure/ psia	± 0.005 psi	± 0.001 psi	± 0.008 psia	John Zink Co. LLC
Flare System	Orifice Plate	Propylene Flow/ lb/hr	N/A	N/A	± 27 Lb/hr	John Zink Co. LLC
Flare System	Orifice Plate	Natural Gas Flow/ lb/hr	N/A	N/A	± 1 Lb/hr	John Zink Co. LLC
Flare System	Orifice Plate	N_2 (Nitrogen) Flow/ lb/hr	N/A	N/A	± 19 Lb/hr	John Zink Co. LLC
Flare System	Pressure Transmitter	Pilot Gas Pressure/ Psig	N/A	N/A	± 0.158 Psig	John Zink Co. LLC
Flare System	Ultrasonic Flow Meter	Total Steam Flow/ lb/hr	0.1 Ft/sec	± 0.2% of reading	± 0.2% of reading *	John Zink Co. LLC
Flare System	Thermocouple	Center Steam Temperature/ °F	N/A	± 0.18 °F	± 2.7 °F	John Zink Co. LLC
Flare System	Pressure Transmitter	Center Steam Pressure/ Psig	N/A		± 0.158 Psig	John Zink Co. LLC
Flare System	Thermocouple	Upper Ring Steam Temperature/ °F	N/A	± 0.18 °F	± 2.7 °F	John Zink Co. LLC
Flare System	Pressure Transmitter	Upper ring pressure/ Psia	N/A	N/A	± 0.158 Psig	John Zink Co. LLC
Flare System	Thermal Mass Flow Meter	Air Flow/ lb/hr	N/A	± 184 Lb/hr	± (1.3% of reading + 459) Lb/hr	John Zink Co. LLC
Flare System	Thermocouple	Mixed Fuel Temperature/ °F	N/A	± 0.18 °F	± 2.7 °F	John Zink Co. LLC
Flare System	Thermocouple	Flare Flue Gas Temperature/ °F	N/A	± 0.18 °F	± 2.7 °F	John Zink Co. LLC
Flare Flue Gas	I-FTIR	Butane	20 ppm*m	7 ppm*m	7 ppm*m	Telops
Flare Flue Gas	I-FTIR	Ethylene	0.5 ppm*m	0.2 ppm*m	0.2 ppm*m	Telops
Flare Flue Gas	I-FTIR	Propylene	2 ppm*m	0.7 ppm*m	0.7 ppm*m	Telops
Flare Flue Gas	I-FTIR	Formaldehyde	20 ppm*m	7 ppm*m	7 ppm*m	Telops
Flare Flue Gas	I-FTIR	Formic Acid	0.4 ppm*m	0.1 ppm*m	0.1 ppm*m	Telops
Flare Flue Gas	I-FTIR	CO_2 (Carbon Dioxide)	4000 ppm*m	1000 ppm*m	1000 ppm*m	Telops
Flare Flue Gas	I-FTIR	H_20	3000 ppm*m	1000 ppm*m	1000 ppm*m	Telops
Flare Flue Gas	I-FTIR	O_3 (Ozone)	2 ppm*m	0.7 ppm*m	0.7 ppm*m	Telops

Measurement Data Quality Objectives

Measurement Location	Parameter/Instrument	Species Measured/Units	Detection Limit	Precision	Accuracy	Company
Flare Flue Gas	I-FTIR	SO_2 (Sulfur Dioxide)	20 ppm*m	7 ppm*m	7 ppm*m	Telops
Flare Flue Gas	A-FTIR	CO_2(Carbon Dioxide)	1 ppm	~5%	±15%	IMACC
Flare Flue Gas	A-FTIR	Acetylene	1 ppm	~5%	±15%	IMACC
Flare Flue Gas	A-FTIR	CO (Carbon Monoxide)	0.1 ppm	~5%	±15%	IMACC
Flare Flue Gas	A-FTIR	Plume Temperature	100° C	± 10° C	± 50°C	IMACC
Flare Flue Gas	A-FTIR	Hydrocarbon Continuum	1 ppm	~5%	±15%	IMACC
Flare Flue Gas	A-FTIR	Isobutane	0.2 ppm	~5%	±15%	IMACC
Flare Flue Gas	A-FTIR	Methane	1 ppm	~5%	±15%	IMACC
Flare Flue Gas	A-FTIR	Ethane	1 ppm	~5%	±15%	IMACC
Flare Flue Gas	A-FTIR	Propane	1 ppm	~5%	±15%	IMACC
Flare Flue Gas	A-FTIR	Butane	0.5 ppm	~5%	±15%	IMACC
Flare Flue Gas	A-FTIR	H_2O (Water)	ambient	~5%	±15%	IMACC
Flare Flue Gas	A-FTIR	Propylene	0.4 ppm	~5%	±15%	IMACC
Flare Flue Gas	P-FTIR	Acetylene	5 ppm	Not Available	Not Available	IMACC
Flare Flue Gas	P-FTIR	Plume Temperature	100° C	± 10° C	± 50°C	IMACC
Flare Flue Gas	P-FTIR	CO (Carbon Monoxide)	0.5 ppm	Not Available	Not Available	IMACC
Flare Flue Gas	P-FTIR	CO_2 (Carbon Dioxide	0.5 ppm	Not Available	Not Available	IMACC
Flare Flue Gas	P-FTIR	Ethane	2 ppm	Not Available	Not Available	IMACC
Flare Flue Gas	P-FTIR	Hydrocarbon Continuum	2 ppm	Not Available	Not Available	IMACC
Flare Flue Gas	P-FTIR	Isobutane	0.45 ppm	Not Available	Not Available	IMACC
Flare Flue Gas	P-FTIR	Methane	2 ppm	Not Available	Not Available	IMACC
Flare Flue Gas	P-FTIR	Ethane	2 ppm	Not Available	Not Available	IMACC
Flare Flue Gas	P-FTIR	Propane	2 ppm	Not Available	Not Available	IMACC
Flare Flue Gas	P-FTIR	H_2O (Water)	ambient	Not Available	Not Available	IMACC
Flare Flue Gas	P-FTIR	Propylene	0.9 ppm	Not Available	Not Available	IMACC

Appendix D

Summary of Data from All Steam Flare Test Series and Runs

Definition of Column Titles for Table D-1

Column Name	Definition
Test Point	Test series test point name from Test Plan
Run Number	Run number of test point
Date	Date of test in month/date/year format
Time	
Start	Local time for start of test
End	Local time for end of test
Elapsed	Elapsed time from start of test to end of test
Actual Vent Gas (VG) Flow Rates	
Propylene (lb/hr)	Flow rate of propylene per Appendix G
TNG (lb/hr)	Flow rate of Tulsa Natural Gas per Appendix G
Nitrogen (lb/hr)	Flow rate of nitrogen as measured by Zink
Total (lb/hr)	Sum of propylene, TNG and nitrogen flows above
Actual Vent Gas	
LHV (Btu/scf)	Calculated lower heating value of vent gas based on Actual Vent Gas (VG) Flow Rate composition
Mol Wt (lb/lb-mole)	Calculated molecular weight of vent gas based on Actual Vent Gas (VG) Flow Rate composition
Exit Velocity* (fps)	Vent Gas Exit Velocity (includes center steam assist) per 40 cfr 60.18 (f) (4)
Combustion Zone HV (Btu/scf)	Combustion Zone Gas Net Heat Value as calculated by Equation 5.1 in the report
Actual Steam Flow Rates	
Center (lb/hr)	Time averaged center steam flow during test point run as calculated from Zink steam flow measurements
Upper (lb/hr)	Time averaged upper steam flow during test point run as calculated from Zink steam flow measurements
Total (lb/hr)	Sum of center and upper steam flows above
Assist Ratio – Steam/VG Flow Rate	Ratio of Actual Total Steam flow to Actual Vent Gas flow rates
Wind	
Speed (mph)	Time averaged wind speed during test point run as calculated from ARI continuous wind speed measurements
Direction (Degrees)	Time averaged wind direction during test point run as calculated from ARI continuous wind direction measurements
Ambient Temperature (Degrees F)	Time averaged ambient temperature during test point run as calculated from ARI continuous ambient temperature measurements

Baro Pressure (psia)	Time averaged barometric pressure during test point run as calculated from ARI continuous ambient temperature measurements
Momentum Flux Ratio	Ratio of the momentum of the flare exit gas to the momentum of the wind
DRE (Propene) and/or CE	
Telops	
Avg CE (%)	Average combustion efficiency for test point run as reported by Telops
σ	Standard deviation for Telops CE for test point run
IMACC – AFTIR	
Avg CE (%)	Average combustion efficiency for test point run as reported by IMACC AFTIR
σ	Standard deviation for IMACC AFTIR CE for test point run
IMACC – PFTIR (%)	
Avg CE (%)	Average combustion efficiency for test point run as reported by IMACC PFTIR
σ	Standard deviation for IMACC AFTIR CE for test point run
ARI	
σ (low)	Standard deviation, less than mean, for ARI CE for test point run
CE (%)	Combustion efficiency (CE) for test point run as reported by ARI
σ (high)	Standard deviation, greater than mean, for ARI CE for test point run
σ (low)	Standard deviation, less than mean, for ARI CE for test point run
DRE (%)	Destruction and removal efficiency (DRE) for test point run as reported by ARI
σ (high)	Standard deviation, greater than mean, for ARI DRE for test point run

Table D-1. Summary of Data from All Steam Flare Test Series and Runs

Test Point	Run Number	Date	Times Start	Times End	Times Elapsed	Actual Vent Gas (VG) Flow Rates Propylene	TNG	Nitrogen	Total	Actual Vent Gas LHV	Mol Wt	Exit Velocity	Combustion Zone HV	Actual Steam Flow Rates Center	Upper	Total	Assist Ratio Steam / VG Flow Rate	Wind Speed	Direction	Ambient Temp	Baro Pressure	Momentum Flux Ratio	DRE (Propylene) and/or CE: Telops Avg CE (%)	Telops □	IMACC - AFTIR Avg CE (%)	IMACC - AFTIR □	IMACC - PFTIR Avg CE (%	IMACC - PFTIR □	ARI □ (low)	ARI CE (%)	ARI □ (high)	ARI □ (low)	ARI DRE (%)	ARI □ (high)
		m/dd/yy				lb/hr	lb/hr	lb/hr	lb/hr	Btu/scf	lb/lb-mole	fps	Btu/scf	lb/hr	lb/hr	lb/hr		MPH	Degrees	Degrees F	psia													
S1.5	1	9/20/2010	10:45	10:54	0:09	2337	0.0	0	2,337	2,145	42.00	1.52	405	526	3,794	4,320	1.85	8.0	176	79.6	14.44	0.025	93.3	2	100.0	0.0	99.9	0.0	0.03	99.9	0.03	0.18	99.9	0.06
S1.6	1	9/20/2010	11:00	11:11	0:11	2341	0.0	0	2,341	2,149	42.07	1.52	344	521	4,765	5,286	2.26	6.9	171	81.2	14.44	0.033	NMR	-	100.0	0.0	99.9	0.0	0.10	99.7	0.07	0.21	99.9	0.12
S1.7	1	9/20/2010	11:17	11:35	0:18	2341	0.0	0	2,341	2,148	42.06	1.51	293	514	5,850	6,364	2.72	8.1	176	84.2	14.43	0.024	NMR	-	99.9	0.2	99.8	0.2	0.52	99.3	0.05	0.21	99.7	0.20
S1.8	1	9/20/2010	11:42	11:52	0:10	2338	0.0	0	2,338	2,146	42.02	1.50	252	506	7,044	7,550	3.23	8.6	167	86.7	14.43	0.022	90.7	3	95.7	3.6	98.5	0.3	1.31	95.9	0.55	0.30	97.7	0.53
S1.9	1	9/20/2010	11:56	12:06	0:10	2337	0.0	0	2,337	2,144	41.98	1.50	228	505	7,939	8,444	3.61	8.8	158	87.8	14.43	0.020	NMR	-	76.6	6.3	94.7	0.7	3.88	84.9	1.19	1.46	88.7	1.76
S2.1	1	9/16/2010	14:43	14:51	0:08	937	0.1	0	937	2,124	41.58	0.94	341	541	1,602	2,142	2.29	10.8	28	90.4	14.42	0.005	NMR	-	n/a	n/a	99.1	0.5	0.05	99.2	0.49	0.30	99.5	0.13
S2.1	2	9/16/2010	15:34	15:41	0:06	937	0.0	0	937	2,113	41.38	0.94	329	538	1,694	2,232	2.38	7.2	29	90.3	14.42	0.010	NMR	-	n/a	n/a	99.5	0.1	0.35	97.2	0.31	0.34	98.3	0.22
S2.1	3	9/16/2010	16:18	16:26	0:08	937	0.0	0	937	2,111	41.33	0.95	346	543	1,554	2,097	2.24	6.8	58	83.1	14.42	0.012	NMR	-	n/a	n/a	99.5	0.1	0.11	99.6	0.02	0.21	99.8	0.14
S2.1	Averages					937	0.0	0	937	2,116	41.43	0.95	339	540	1,617	2,157	2.30	8.3	39	88.0	14.42	0.009	NMR	-	n/a	n/a	99.4	0.2	0.17	98.7	0.27	0.29	99.2	0.16
S2.1	% Std Dev																						NMR		n/a		0.2			1.3			0.8	
S2.2	1	9/16/2010	15:02	15:12	0:09	937	0.0	0	937	2,103	41.18	0.95	100	542	7,770	8,311	8.87	10.8	25	89.6	14.43	0.005	77	46	14.4	7.0	23.7	12.7	2.82	22.7	9.15	11.01	26.4	1.80
S2.2	2	9/16/2010	16:04	16:12	0:07	937	0.1	0	937	2,125	41.60	0.95	108	545	7,081	7,626	8.14	9.5	60	85.2	14.43	0.006	65	35	43.1	11.7	56.4	1.9	3.64	24.0	3.25	5.75	28.1	3.64
S2.2	3	9/16/2010	16:46	16:51	0:05	937	0.1	0	937	2,133	41.76	0.95	104	544	7,413	7,957	8.49	9.6	26	84.1	14.42	0.006	70	40	29.2	10.9	57.3	2.6	4.71	23.0	5.69	6.97	26.4	3.52
S2.2	Averages					937	0.1	0	937	2,120	41.51	0.95	104	544	7,421	7,965	8.50	10.0	37	86.3	14.42	0.006	71	40	28.9	9.9	45.8	5.8	3.72	23.2	6.03	7.91	27.0	2.99
S2.2	% Std Dev																						8.5		49.7		41.8			3.0			3.6	
S2.3	1	9/16/2010	15:15	15:26	0:11	937	0.1	0	937	2,049	40.11	0.96	172	545	4,097	4,642	4.95	9.6	39	89.7	14.42	0.006	98.6	0	33.6	14.2	74.4	5.2	7.06	52.5	5.76	5.81	56.5	3.79
S2.3	2	9/16/2010	15:46	16:00	0:13	937	0.0	0	937	2,112	41.36	0.95	144	546	5,095	5,641	6.02	8.0	42	88.7	14.42	0.009	89.7	4	38.1	20.2	92.1	3.9	2.23	29.0	2.93	3.42	32.2	1.37
S2.3	3	9/16/2010	16:29	16:41	0:11	937	0.0	0	937	2,122	41.56	0.94	152	539	4,761	5,301	5.66	7.6	32	84.8	14.42	0.009	87.0	4	23.6	15.1	83.9	9.6	6.07	40.5	12.12	12.32	44.2	3.57
S2.3	Averages					937	0.0	0	937	2,094	41.01	0.95	156	543	4,651	5,195	5.54	8.4	38	87.7	14.42	0.008	91.8	2.7	31.7	16.5	83.5	6.2	5.12	40.7	6.94	7.18	44.3	2.91
	% Std Dev																						6.6		23.4		10.6			28.8			27.4	
S3.1	1	9/17/2010	10:08	10:28	0:20	194	18.9	717	930	349	29.70	1.1	134	540	430	970	1.04	2.6	178	75.0	14.45	0.090	68.6	12	26.7	16.4	23.5	20.8	8.38	34.3	9.46	10.36	38.1	5.22
S3.2	2	9/17/2010	11:42	11:54	0:12	193	19.5	710	922	350	29.68	0.6	180	52	518	570	0.62	7.5	168	85.0	14.44	0.004	87.9	9	71.2	6.7	88.0	2.1	2.03	88.6	0.51	0.84	90.4	1.11
S3.5	1	9/17/2010	10:31	10:41	0:10	191	18.6	711	920	346	29.68	0.7	227	109	217	326	0.35	7.2	151	77.7	14.45	0.004	NMR	-	96.6	0.5	97.1	1.8	2.65	95.1	1.47	1.41	95.7	1.33
S3.5	2	9/17/2010	11:22	11:39	0:17	197	19.6	715	932	355	29.72	0.6	219	76	307	383	0.41	7.5	167	82.4	14.45	0.004	91.3	10	95.7	2.4	96.3	0.8	1.04	96.5	0.38	0.56	97.2	0.58
S3.5	Averages					194	19.1	713	926	350	29.70	0.7	223	92	262	354	0.38	7.3	159	80.0	14.45	0.004	91	10	96.1	1.5	96.7	1.3	1.84	95.8	0.92	0.98	96.5	0.95
S3.6	1	9/17/2010	10:42	10:49	0:07	189	18.4	705	913	346	29.68	0.6	357	0	0	0	0.00	7.4	160	79.0	14.45	0.003	NMR	-	97.3	0.7	99.1	0.1	0.09	99.8	0.03	0.19	99.9	0.07
S3.7	1	9/17/2010	11:03	11:14	0:11	191	18.9	716	926	346	29.67	0.6	255	0	228	228	0.25	7.1	133	80.4	14.45	0.003	NMR	-	97.8	0.9	98.5	0.3	0.23	99.3	0.12	0.27	99.5	0.19
S4.1	1	9/17/2010	14:05	14:17	0:12	489	45.5	1,802	2,336	348	29.72	2.0	207	567	439	1,005	0.43	7.0	124	91.3	14.42	0.043	91.7	4	91.6	3.0	94.0	1.3	0.57	97.5	0.29	0.41	98.1	0.36
S4.1	2	9/17/2010	15:00	15:08	0:08	484	45.2	1,801	2,330	346	29.71	2.0	198	564	524	1,089	0.47	4.9	163	97.7	14.41	0.089	NMR	-	89.6	6.7	94.5	1.3	1.74	94.8	1.05	0.93	96.0	0.80
S4.1	3	9/17/2010	15:54	16:01	0:07	491	45.0	1,800	2,335	350	29.72	2.0	200	560	536	1,096	0.47	5.6	146	98.3	14.41	0.066	NMR	-	89.3	4.9	94.6	0.9	0.85	95.2	0.50	0.61	96.3	0.47
S4.1	Averages					488	45.2	1,801	2,334	348	29.72	1.97	202	564	500	1,063	0.46	5.8	144	95.8	14.41	0.066	91.7	4.0	90.2	4.9	94.4	1.2	1.06	95.8	0.61	0.65	96.8	0.54
S4.1	% Std Dev																						NMR		1.4		0.3			1.5			1.2	
S4.2	1	9/17/2010	14:20	14:30	0:10	490	45.2	1,804	2,338	349	29.72	2.0	229	565	207	773	0.33	4.6	152	94.0	14.42	0.100	NMR	-	94.7	0.7	97.7	0.5	0.48	98.3	0.30	0.40	98.7	0.32
S4.2	2	9/17/2010	15:13	15:22	0:09	483	45.6	1,801	2,330	345	29.69	2.0	227	562	209	771	0.33	4.1	170	98.2	14.41	0.126	NMR	-	94.1	3.9	97.3	0.6	0.89	97.8	0.43	0.52	98.3	0.50
S4.2	3	9/17/2010	16:04	16:15	0:11	490	44.9	1,801	2,335	349	29.72	2.0	241	555	111	666	0.29	4.8	189	98.0	14.40	0.092	89.8	3	98.0	1.0	98.1	0.6	0.28	98.9	0.14	0.29	99.2	0.22
S4.2	Averages					487	45.2	1,802	2,335	348	29.71	1.97	232	561	176	736	0.32	4.5	171	96.7	14.41	0.106	89.8	3.0	95.6	1.9	97.7	0.6	0.55	98.3	0.29	0.40	98.7	0.35
S4.2	% Std Dev																						NMR		2.2		0.4			0.5			0.5	
S4.3	1	9/17/2010	14:40	14:54	0:14	485	45.0	1,802	2,332	346	29.71	2.0	129	567	1,879	2,447	1.05	5.2	180	97.4	14.41	0.077	NMR	-	19.8	10.3	34.9	18.3	4.23	22.0	3.67	4.70	27.4	2.94
S4.3	2	9/17/2010	15:32	15:46	0:14	479	45.8	1,800	2,324	343	29.68	2.0	95	564	3,228	3,792	1.63	5.4	189	98.4	14.41	0.073	84.7	8	15.4	5.1	0.0	0.0	1.53	16.5	3.17	4.49	21.7	1.29
S4.3	3	9/17/2010	16:28	16:39	0:11	500	46.6	1,802	2,349	355	29.75	2.0	114	628	2,447	3,075	1.31	6.6	163	97.7	14.40	0.051	NMR	-	17.4	6.3	0.0	0.0	4.19	16.3	5.08	7.17	22.2	3.22
S4.3	Averages					488	45.8	1,801	2,335	348	29.71	2.00	113	586	2,518	3,105	1.33	5.7	177	97.8	14.41	0.067	84.7	8.0	17.5	7.2	11.6	6.1	3.32	18.3	3.97	5.45	23.7	2.48
	% Std Dev																						NMR		12.8		173.2			17.5			13.2	
S4.4	1	9/17/2010	16:49	17:03	0:14	516	47.5	1,808	2,372	363	29.79	1.4	299	0	327	327	0.14	5.9	159	93.6	14.40	0.032	NMR	-	97.9	1.7	97.2	1.7	0.29	97.8	0.09	0.22	98.3	0.25
S4.5	1	9/21/2010	14:01	14:11	0:10	510	49.3	1,806	2,365	360	29.76	1.9	212	517	524	1,041	0.44	16.0	180	93.7	14.36	0.008	NMR	-	92.9	4.3	92.6	1.3	1.08	90.5	0.75	0.79	92.2	0.57
S4.6	1	9/21/2010	14:21	14:31	0:10	514	49.4	1,813	2,376	362	29.77	1.8	281	324	112	436	0.18	17.0	178	89.8	14.36	0.006	NMR	-	99.7	0.3	96.1	1.3	0.92	97.8	0.26	0.38	98.3	0.45
S4.7	1	9/21/2010	14:39	14:48	0:09	511	49.4	1,810	2,370	361	29.76	1.9	193	513	772	1,285	0.54	17.7	178	91.3	14.35	0.006	NMR	-	87.3	5.3	86.5	3.1	0.66	88.7	0.91	0.98	90.6	0.44
S4.8	1	9/21/2010	14:51	15:01	0:10	509	48.7	1,809	2,367	360	29.76	1.9	178	487	1,021	1,508	0.64	12.8	180	91.8	14.35	0.012	33	66	70.7	7.0	78.4	0.0	0.95	83.8	1.06	1.15	86.4	0.58
S4.9	1	9/21/2010	15:04	15:12	0:08	510	49.8	1,811	2,371	360	29.75	1.9	164	498	1,261	1,759	0.74	18.0	176	91.6	14.35	0.006	25	34	60.2	10.6	70.0	3.9	0.58	76.2	1.02	1.17	79.7	0.41
S4.10	1	9/21/2010	15:17	15:26	0:09	511	51.1	1,814	2,376	361	29.74	1.9	154	489	1,498	1,987	0.84	16.2	178	89.2	14.35	0.007	90	15	48.2	11.4	65.3	3.6	1.81	66.5	1.27	1.46	70.8	1.15
S4.11	1	9/21/2010	15:43	15:57	0:14	515	49.8	1,816	2,381	362	29.76	1.9	134	513	1,988	2,501	1.05	12.7	178	84.3	14.35	0.012	NMR	-	24.3	7.3	48.6	10.6	0.02	22.1	1.51	2.07	26.9	0.20
S5.1	1	9/21/2010	8:38	8:48	0:10	320	33.7	586	940	594	30.81	1.0	253	488	280	768	0.82	8.0	194	62.4	14.39	0.008	NMR	-	97.4	1.0	99.2	0.5	0.77	98.0	0.36	0.45	98.3	0.43
S5.1	2	9/21/2010	10:16	10:27	0:11	314	32.3	578	924	592	30.83	1.0	251	479	281	759	0.82	10.3	178	78.2	14.39	0.005	NMR	-	97.4	2.1	93.3	2.7	0.96	94.9	0.65	0.68	95.9	0.53
S5.1	3	9/21/2010	11:24	11:32	0:08	309	31.6	574	915	588	30.81	1.0	248	473	287	760	0.83	10.7	178	83.3	14.38	0.006	NMR	-	98.0	1.6	94.8	2.2	1.41	93.8	0.71	0.73	94.9	0.72
S5.1	Averages					314	32.5	579	926	591	30.82	1.02	251	480	283	763	0.82	9.7	183	74.6	14.39	0.006	NMR	-	97.6	1.6	95.8	1.8	1.05	95.6	0.57	0.62	96.4	0.56

Table D-1. Summary of Data from All Steam Flare Test Series and Runs

Test Point	Run Number	Date m/dd/yy	Times Start	Times End	Times Elapsed	Actual Vent Gas (VG) Flow Rates Propylene lb/hr	Propylene TNG lb/hr	Propylene Nitrogen lb/hr	Propylene Total lb/hr	Actual Vent Gas LHV Btu/scf	Actual Vent Gas Mol Wt lb/lb-mole	Actual Vent Gas Exit Velocity fps	Combustion Zone HV Btu/scf	Actual Steam Flow Rates Center lb/hr	Actual Steam Flow Rates Upper lb/hr	Actual Steam Flow Rates Total lb/hr	Assist Ratio Steam / VG Flow Rate	Wind Speed MPH	Wind Direction Degrees	Ambient Temp Degrees F	Baro Pressure psia	Momentum Flux Ratio	DRE (Propylene) and/or CE Telops Avg CE (%)	Telops □	IMACC - AFTIR Avg CE (%)	IMACC - AFTIR □	IMACC - PFTIR Avg CE (%	IMACC - PFTIR □	ARI □ (low)	ARI CE (%)	ARI □ (high)	ARI □ (low)	ARI DRE (%)	ARI □ (high)
% Std Dev																							NMR		0.3		3.2			2.2			1.8	
S5.2	1	9/21/2010	8:53	9:03	0:10	320	33.8	585	938	595	30.81	1.0	130	454	1,580	2,035	2.17	10.2	191	64.8	14.39	0.005	73	24	25.2	6.2	48.1	5.7	6.07	32.3	4.09	4.71	38.2	3.59
S5.3	1	9/21/2010	9:08	9:16	0:08	318	32.6	583	934	594	30.84	1.0	180	480	813	1,293	1.38	12.0	182	67.9	14.39	0.004	NMR	-	74.5	9.5	87.4	1.3	1.05	87.7	1.28	1.27	90.0	0.62
S5.3	2	9/21/2010	10:48	10:57	0:09	312	31.7	578	922	590	30.82	1.0	181	482	783	1,264	1.37	9.3	178	80.8	14.38	0.006	NMR	-	77.5	4.5	88.1	2.3	2.19	86.8	1.66	1.54	89.2	1.12
S5.3	3	9/21/2010	11:58	12:06	0:08	307	31.6	572	911	588	30.79	1.0	171	465	885	1,349	1.48	10.6	180	86.1	14.38	0.005	91	26	81.6	7.7	80.1	3.0	2.22	84.9	1.16	1.15	87.7	1.13
S5.3	Averages					313	32.0	578	922	590	30.82	1.01	177	475	827	1,302	1.41	10.6	180	78.2	14.38	0.005	91.0	26.0	77.9	7.2	85.2	2.2	1.82	86.5	1.36	1.32	89.0	0.95
% Std Dev																							NMR		4.6		5.2			1.6			1.3	
S5.4	1	9/21/2010	9:57	10:07	0:10	318	32.2	579	929	595	30.86	1.0	147	484	1,221	1,705	1.83	10.9	180	75.8	14.39	0.004	NMR	-	50.9	13.4	60.1	4.7	3.00	63.7	3.08	3.15	68.6	1.72
S5.4	2	9/21/2010	11:07	11:17	0:10	311	31.3	576	918	589	30.82	1.0	142	475	1,277	1,752	1.91	9.8	178	81.9	14.39	0.005	NMR	-	43.3	7.8	64.6	2.3	5.59	60.8	3.91	3.82	66.0	2.91
S5.4	3	9/21/2010	12:14	12:25	0:11	304	31.2	567	901	586	30.79	1.0	141	474	1,249	1,723	1.91	14.3	174	87.5	14.37	0.002	94	3	42.7	9.0	75.9	6.0	1.69	59.4	1.55	2.53	65.4	1.50
S5.4	Averages					311	31.6	574	916	590	30.82	1.01	143	478	1,249	1,727	1.88	11.7	177	81.7	14.38	0.004	94	3	45.6	10.1	66.8	4.3	3.43	61.3	2.85	3.17	66.6	2.04
% Std Dev																							NMR		10.1		12.2			3.6			2.5	
S5.5	1	9/21/2010	9:23	9:32	0:09	318	32.3	582	932	594	30.85	1.0	197	485	648	1,133	1.22	9.4	193	71.3	14.39	0.006	NMR	-	87.8	6.8	90.2	1.4	1.17	92.3	1.04	0.98	93.8	0.61
S5.6	1	9/21/2010	9:38	9:51	0:13	317	32.2	581	930	593	30.84	1.0	214	484	510	994	1.07	9.6	193	73.4	14.39	0.006	NMR	-	91.0	4.9	94.2	2.4	2.68	94.2	0.68	0.67	95.4	1.16
S5.6	2	9/21/2010	10:33	10:42	0:09	312	31.8	577	921	590	30.82	1.0	218	491	463	954	1.04	9.6	180	80.4	14.38	0.006	NMR	-	93.8	3.6	93.1	1.9	0.96	92.8	0.38	0.54	94.0	0.56
S5.6	3	9/21/2010	11:39	11:47	0:08	308	31.9	571	912	590	30.80	1.0	216	492	463	955	1.05	10.3	180	84.4	14.38	0.005	98	2	95.7	3.2	91.4	3.3	1.43	92.7	0.83	0.85	94.1	0.76
S5.6	Averages					312	32.0	577	921	591	30.82	1.02	216	489	479	968	1.05	9.8	184	79.4	14.38	0.005	98	2	93.5	3.9	92.9	2.5	1.69	93.2	0.63	0.68	94.5	0.83
% Std Dev																							NMR		2.5		1.5			0.9			0.8	
S6.1	1	9/20/2010	8:56	9:08	0:12	826	79.1	1,456	2,361	609	30.96	1.9	291	518	1,003	1,521	0.64	8.8	180	66.1	14.44	0.023	NMR	-	99.1	2.0	98.7	0.9	0.21	99.3	0.05	0.25	99.5	0.18
S6.1	2	9/20/2010	14:29	14:39	0:10	834	74.1	1,472	2,380	607	31.02	1.9	288	522	1,032	1,554	0.65	7.5	173	94.4	14.39	0.036	98	6	99.9	0.1	99.0	0.3	0.05	99.2	0.00	0.21	99.5	0.13
S6.1	3	9/20/2010	16:11	16:22	0:11	871	79.0	1,473	2,423	625	31.09	1.9	301	510	1,019	1,529	0.63	7.5	174	89.5	14.38	0.036	NMR	-	100.0	0.1	99.2	0.2	0.12	98.9	0.04	0.24	99.3	0.16
S6.1	Averages					844	77.4	1,467	2,388	613	31.02	1.90	293	517	1,018	1,535	0.64	7.9	176	83.4	14.40	0.032	98	6	99.7	0.7	98.9	0.5	0.13	99.1	0.03	0.23	99.4	0.16
% Std Dev																							NMR		0.5		0.3			0.2			0.1	
S6.2	1	9/20/2010	9:26	9:41	0:15	785	79.4	1,452	2,316	590	30.82	1.9	147	503	3,616	4,119	1.78	6.2	172	69.5	14.44	0.047	NMR	-	11.0	3.2	64.4	10.9	3.00	29.6	3.37	3.84	33.6	1.92
S6.2	2	9/20/2010	15:51	16:06	0:15	855	78.9	1,473	2,408	617	31.04	1.9	158	507	3,617	4,125	1.71	8.1	170	91.4	14.38	0.031	90	0	11.8	5.4	63.3	28.4	4.86	36.5	4.05	4.47	40.7	2.96
S6.2	3	9/20/2010	17:10	17:22	0:12	878	80.7	1,480	2,439	627	31.09	1.9	158	488	3,743	4,231	1.73	12.2	178	82.5	14.37	0.013	NMR	-	13.1	3.5	65.0	22.3	2.09	31.2	2.23	3.40	36.1	0.67
S6.2	Averages					840	79.7	1,469	2,388	611	30.99	1.88	154	499	3,659	4,158	1.74	8.8	173	81.1	14.39	0.030	90.0	0.0	12.0	4.0	64.3	20.6	3.31	32.4	3.22	3.90	36.8	1.85
% Std Dev																							NMR		8.6		1.3			11.1			9.7	
S6.3	1	9/20/2010	14:15	14:25	0:10	808	72.9	1,472	2,353	594	30.94	1.9	212	517	1,982	2,499	1.06	6.3	170	95.4	14.40	0.050	NMR	-	93.2	4.2	96.0	0.8	0.15	96.3	0.00	0.40	97.5	0.23
S6.3	2	9/20/2010	14:58	15:09	0:11	845	77.5	1,473	2,395	612	31.02	1.9	226	517	1,886	2,403	1.00	7.8	156	92.9	14.39	0.033	NMR	-	94.1	3.6	96.9	1.2	0.27	96.5	0.09	0.25	97.5	0.25
S6.3	3	9/20/2010	16:37	16:47	0:10	861	79.7	1,477	2,417	619	31.04	1.9	233	506	1,849	2,355	0.97	8.5	180	87.6	14.37	0.028	96.7	3	94.5	3.7	96.4	1.0	0.22	96.3	0.05	0.33	97.4	0.23
S6.3	Averages					838	76.7	1,474	2,388	608	31.00	1.90	224	513	1,906	2,419	1.01	7.5	169	92.0	14.38	0.037	96.7	3	93.9	3.8	96.4	1.0	0.22	96.3	0.04	0.33	97.5	0.24
% Std Dev																							NMR		0.7		0.5			0.1			0.1	
S6.4	1	9/20/2010	9:52	10:02	0:10	816	78.8	1,453	2,347	604	30.94	1.9	176	496	2,888	3,383	1.44	4.7	176	72.6	14.44	0.082	NMR	-	34.9	9.2	77.1	4.9	4.50	71.2	3.32	3.25	75.6	2.51
S6.4	2	9/20/2010	15:33	15:45	0:12	863	78.4	1,473	2,414	621	31.07	1.9	191	509	2,673	3,182	1.32	8.4	178	92.3	14.38	0.029	NMR	-	65.6	7.6	86.9	3.2	4.25	85.1	2.56	2.41	88.6	2.05
S6.4	3	9/20/2010	16:54	17:05	0:11	859	79.6	1,479	2,418	618	31.04	1.9	188	505	2,744	3,248	1.34	8.9	178	84.0	14.37	0.025	98.7	1	58.0	3.7	85.4	3.4	2.43	82.1	2.17	1.87	86.4	1.16
S6.4	Averages					846	78.9	1,468	2,393	614	31.02	1.89	185	503	2,768	3,271	1.37	7.3	177	83.0	14.39	0.045	98.7	1	52.8	6.8	83.1	3.8	3.73	79.5	2.68	2.51	83.6	1.90
% Std Dev																							NMR		30.3		6.3			9.2			8.3	
S6.5	1	9/20/2010	14:42	14:51	0:09	832	74.8	1,473	2,379	606	31.00	1.9	249	524	1,477	2,001	0.84	7.8	150	94.3	14.39	0.033	NMR	-	99.0	0.9	98.7	0.5	0.25	98.4	0.15	0.29	98.9	0.19
S6.6	1	9/20/2010	15:18	15:28	0:10	845	77.5	1,471	2,394	613	31.02	1.9	199	510	2,423	2,933	1.23	7.7	159	93.1	14.38	0.034	NMR	-	74.1	5.5	90.3	1.1	2.23	86.4	0.26	0.85	89.9	1.11
S7.1	1	9/28/2010	9:25	9:33	0:08	499	52.6	1,810	2,362	356	29.70	1.9	208	513	540	1,053	0.45	6.1	334	53.3	14.38	0.048	98	3	NM	-	--	--	1.53	93.2	0.84	0.98	94.1	0.90
S7.1	2	9/28/2010	10:44	10:51	0:07	499	47.9	1,806	2,353	354	29.73	1.9	207	515	541	1,056	0.45	10.1	33	64.4	14.39	0.018	NMR	-	NM	-	93.9	1.4	4.67	89.6	1.17	1.45	90.5	2.46
S7.1	Averages					499	50.3	1808	2357	355	29.72	1.9	207	514	540	1054	0.45	8.1	184	58.9	14.38	0.033	98	3	NM	-	93.9	1.4	3.10	91.4	1.00	1.21	92.3	1.68
S7.2	1	9/28/2010	9:39	9:47	0:08	392	39.5	1,443	1,874	350	29.69	1.6	185	514	545	1,059	0.57	6.2	333	56.0	14.38	0.035	98	4	NM	-	89.3	3.1	1.90	84.3	1.47	1.76	85.7	1.18
S7.2	2	9/28/2010	11:11	11:18	0:07	398	39.9	1,425	1,863	359	29.73	1.6	188	508	553	1,062	0.57	9.7	18	70.0	14.39	0.014	NMR	-	NM	-	88.7	2.3	2.30	91.8	0.55	0.86	92.9	1.28
S7.2	3	9/28/2010	11:33	11:40	0:07	379	39.0	1,420	1,838	346	29.65	1.6	181	515	541	1,057	0.57	10.1	320	74.5	14.39	0.013	NMR	-	NM	-	82.2	12.0	2.80	86.4	2.60	2.43	87.7	1.50
S7.2	Averages					390	39.5	1,429	1,858	352	29.69	1.64	185	513	547	1,059	0.57	8.6	224	66.8	14.39	0.021	98	4	NM	-	86.7	5.8	2.33	87.5	1.54	1.68	88.8	1.32
% Std Dev																							NMR		NM		4.5			4.4			4.2	
S7.3	1	9/28/2010	9:53	10:01	0:08	286	29.8	1,083	1,399	343	29.63	1.4	158	518	527	1,046	0.75	7.4	332	57.3	14.38	0.016	80	50	NM	-	77.6	5.2	4.64	76.2	4.63	4.34	78.1	2.42
S7.3	2	9/28/2010	11:22	11:29	0:07	297	29.9	1,084	1,410	353	29.70	1.4	162	516	538	1,054	0.75	7.9	329	71.9	14.39	0.015	NMR	-	NM	-	73.9	4.3	7.78	71.9	4.70	4.56	73.8	4.22
S7.3	Averages					291	29.9	1083	1405	348	29.66	1.4	160	517	533	1050	0.75	7.6	330	64.6	14.39	0.016	80	50	NM	-	75.7	4.7	6.21	74.1	4.67	4.45	75.9	3.32
S7.4	1	9/28/2010	10:09	10:25	0:16	182	19.7	728	930	329	29.54	1.1	120	532	521	1,053	1.13	7.6	28	59.1	14.38	0.010	98	1	NM	-	38.6	14.5	6.44	27.2	6.19	6.68	29.5	3.85
S7.5	1	9/28/2010	10:30	10:37	0:07	234	25.4	921	1,180	334	29.57	1.2	139	524	543	1,067	0.90	9.2	332	62.3	14.39	0.009	NMR	-	NM	-	66.5	8.5	7.75	60.0	4.33	4.20	62.3	4.12
S7.6	1	9/28/2010	10:59	11:06	0:07	639	65.1	2,324	3,028	354	29.70	2.3	229	501	536	1,038	0.34	10.8	326	68.2	14.39	0.024	NMR	-	NM	-	95.5	0.7	1.92	95.3	0.66	0.86	96.0	1.05
S8.1	1	9/28/2010	13:02	13:10	0:08	510	50.6	1,838	2,399	356	29.72	1.5	264	0	534	534	0.22	12.6	330	79.5	14.37	0.007	87	7	NM	-	95.1	1.8	0.67	97.6	0.35	0.44	98.0	0.39
S8.2	1	9/28/2010	13:13	13:20	0:07	389	38.1	1,435	1,862	349	29.70	1.1	242	0	529	529	0.28	12.7	322	80.2	14.37	0.004	80	86	NM	-	93.3	2.8	0.48	97.4	0.07	0.31	98.0	0.33
S8.3	1	9/28/2010	13:26	13:33	0:07	293	29.3	1,089	1,411	348	29.68	0.9	219	0	541	541	0.38	12.4	328	78.4	14.37	0.003	50	83	NM	-	86.5	12.7	0.47	96.0	0.27	0.44	96.8	0.34

Table D-1. Summary of Data from All Steam Flare Test Series and Runs

Test Point	Run Number	Date	Times Start	Times End	Times Elapsed	Actual Vent Gas (VG) Flow Rates Propylene	TNG	Nitrogen	Total	Actual Vent Gas LHV	Mol Wt	Exit Velocity*	Combustion Zone HV	Actual Steam Flow Rates Center	Upper	Total	Assist Ratio Steam / VG Flow Rate	Wind Speed	Direction	Ambient Temp	Baro Pressure	Momentum Flux Ratio	DRE (Propylene) and/or CE Telops Avg CE (%)	Telops □	IMACC - AFTIR Avg CE (%)	IMACC - AFTIR □	IMACC - PFTIR Avg CE (%	IMACC - PFTIR □	ARI □ (low)	ARI CE (%)	ARI □ (high)	ARI □ (low)	ARI DRE (%)	ARI □ (high)
		m/dd/yy				lb/hr	lb/hr	lb/hr	lb/hr	Btu/scf	lb/lb-mole	fps	Btu/scf	lb/hr	lb/hr	lb/hr		MPH	Degrees	Degrees F	psia													
S8.4	1	9/28/2010	13:40	13:46	0:06	199	19.7	730	949	351	29.70	0.6	187	0	547	547	0.58	11.7	322	78.4	14.36	0.001	NMR	-	NM	-	90.6	1.8	0.35	93.9	0.05	0.35	95.3	0.30
S8.5	1	9/28/2010	14:00	14:07	0:07	165	15.8	562	743	373	29.82	0.4	175	0	549	549	0.74	11.8	308	77.6	14.36	0.001	NMR	-	NM	-	86.5	5.0	0.54	93.2	0.49	0.59	94.7	0.36
S9.1	1	9/28/2010	14:25	14:32	0:07	490	49.2	1,824	2,364	347	29.67	1.4	207	0	1,007	1,007	0.43	12.2	321	80.3	14.35	0.007	82	15	NM	-	92.2	2.6	0.76	93.3	0.47	0.64	94.4	0.50
S9.2	1	9/28/2010	14:37	14:44	0:07	398	41.7	1,438	1,877	356	29.69	1.1	193	0	1,007	1,007	0.54	10.7	324	79.6	14.35	0.006	80	78	NM	-	89.5	2.7	0.96	92.6	0.54	0.72	93.8	0.62
S9.3	1	9/28/2010	14:54	15:01	0:07	306	29.9	1,089	1,425	359	29.75	0.9	173	0	976	976	0.68	11.4	327	80.1	14.35	0.003	NMR	-	NM	-	84.9	2.4	2.06	87.3	1.51	1.45	89.4	1.06
S9.4	1	9/28/2010	15:13	15:20	0:07	207	19.9	717	944	368	29.80	0.6	138	0	1,007	1,007	1.07	10.8	332	79.6	14.34	0.002	84	13	NM	-	76.6	2.8	3.47	76.4	2.69	2.54	79.8	1.86
S9.5	1	9/28/2010	14:14	14:20	0:06	163	15.4	560	739	369	29.81	0.4	122	0	974	974	1.32	12.9	328	79.8	14.36	0.001	NMR	-	NM	-	70.8	9.2	2.87	71.8	3.19	3.12	76.0	1.62
S10.1	1	9/28/2010	16:02	16:11	0:09	494	49.3	1,804	2,348	353	29.70	1.4	226	0	834	834	0.36	10.9	328	76.2	14.34	0.009	NMR	-	NM	-	94.7	0.6	0.97	95.0	0.51	0.61	95.8	0.56
S10.2	1	9/28/2010	15:51	15:59	0:08	396	39.4	1,441	1,877	354	29.71	1.1	208	0	837	837	0.45	11.7	327	77.3	14.34	0.005	NMR	-	NM	-	94.9	1.7	1.06	93.7	0.67	0.77	94.7	0.62
S10.3	1	9/28/2010	15:39	15:47	0:08	305	29.9	1,087	1,422	359	29.74	0.9	186	0	845	845	0.59	9.4	313	77.0	14.34	0.004	80	63	NM	-	92.9	1.2	1.44	91.9	0.96	1.03	93.4	0.86
S10.4	1	9/28/2010	15:26	15:35	0:09	206	19.8	716	942	367	29.79	0.6	154	0	835	835	0.89	8.4	323	78.3	14.34	0.002	95	4	NM	-	84.7	2.6	2.21	84.7	1.41	1.43	87.6	1.19
S11.1	1	9/28/2010	16:17	16:25	0:08	498	50.5	1,806	2,354	355	29.71	1.7	228	286	542	827	0.35	10.5	329	75.8	14.34	0.014	NMR	-	NM	-	95.4	1.3	1.32	95.4	0.64	0.72	96.0	0.74
S11.2	1	9/28/2010	16:32	16:40	0:08	396	40.2	1,430	1,866	356	29.71	1.4	209	273	558	831	0.45	9.8	328	74.5	14.34	0.011	75	74	NM	-	93.9	2.6	1.17	93.3	0.75	0.91	94.3	0.73
S11.3	1	9/28/2010	16:46	16:53	0:07	297	29.9	1,085	1,412	353	29.70	1.1	183	211	624	835	0.59	10.2	328	73.5	14.34	0.006	80	270	NM	-	91.7	0.8	1.97	88.3	0.12	0.54	89.9	1.13
S11.4	1	9/28/2010	17:02	17:10	0:08	202	20.3	724	946	358	29.72	0.8	153	204	618	823	0.87	11.7	25	70.9	14.34	0.002	67	33	NM	-	82.7	6.8	2.22	82.1	2.80	2.59	84.4	1.08

Test Point	Run Number	Date	Times Start	Times End	Times Elapsed	Actual Vent Gas (VG) Flow Rates Propylene	TNG	Nitrogen	Total	Actual Vent Gas LHV	Mol Wt	Exit Velocity*	Combustion Zone HV	Actual Steam Flow Rates Center	Upper	Total	Assist Ratio Steam/ VG Flow Rate	Wind Speed	Direction	Ambient Temp	Baro Pressure	Momentum Flux Ratio	DRE (Propane) and/or CE Telops Avg CE (%)	Telops □	IMACC - AFTIR Avg CE (%)	IMACC - AFTIR □	IMACC - PFTIR Avg CE (%	IMACC - PFTIR □	ARI □ (low)	ARI CE (%)	ARI □ (high)	ARI □ (low)	ARI DRE (%)	ARI □ (high)
		m/dd/yy				lb/hr	lb/hr	lb/hr	lb/hr	Btu/scf	lb/lb-mole	fps	Btu/scf	lb/hr	lb/hr	lb/hr		MPH	Degrees	Degrees F	psia													
S12.1	1	9/29/2010	8:33	8:47	0:14	501	53.9	1,808	2,363	364	29.94	1.9	212	504	545	1,049	0.44	2.9	17	50.6	14.38	0.209	NMR	-	NM	-	98.4	0.4	0.03	97.4	0.01	0.19	97.7	0.11
S12.1	2	9/29/2010	9:33	9:41	0:08	500	61.0	1,807	2,368	366	29.90	1.9	214	493	548	1,041	0.44	1.7	17	65.8	14.37	0.601	84	54	NM	-	98.6	0.5	0.06	96.9	0.01	0.18	97.4	0.11
S12.1	Averages					501	57.5	1,807	2,366	365	29.92	1.9	213	499	547	1,045	0.44	2.3	17	58.2	14.38	0.405	84	54	NM	-	98.5	0.5	0.0	97.2	0.0	0.2	97.5	0.1
S12.2	1	9/29/2010	8:51	9:00	0:09	382	44.9	1,420	1,847	357	29.87	1.6	187	500	553	1,054	0.57	1.1	17	55.7	14.38	1.080	NMR	-	NM	-	96.5	2.1	0.09	91.0	0.06	0.20	91.9	0.11
S12.2	2	9/29/2010	9:46	9:52	0:06	392	47.1	1,426	1,865	364	29.89	1.6	191	486	566	1,052	0.56	0.9	17	68.2	14.37	1.504	87	7	NM	-	96.7	0.6	0.07	92.4	0.10	0.18	93.4	0.11
S12.2	Averages					387	46.0	1,423	1,856	360	29.88	1.6	189	493	560	1,053	0.57	1.0	17	61.9	14.38	1.292	87	7	NM	-	96.6	1.4	0.1	91.7	0.1	0.2	92.7	0.1
S12.3	1	9/29/2010	9:04	9:13	0:09	278	33.7	1,083	1,394	344	29.78	1.3	158	498	540	1,038	0.74	1.1	17	59.2	14.38	0.729	NMR	-	NM	-	89.9	1.4	0.33	77.3	0.24	0.22	79.1	0.13
S12.3	2	9/29/2010	9:57	10:05	0:08	292	36.6	1,078	1,406	360	29.86	1.3	164	483	577	1,060	0.75	5.4	334	69.7	14.37	0.030	0	91	NM	-	86.8	3.0	0.23	75.5	0.12	0.22	77.3	0.14
S12.3	Averages					285	35.2	1,080	1,400	352	29.82	1.3	161	491	558	1,049	0.75	3.2	175	64.4	14.38	0.379	0	91	NM	-	88.3	2.2	0.3	76.4	0.2	0.2	78.2	0.1
S12.4	1	9/29/2010	9:21	9:28	0:07	191	22.9	726	940	350	29.83	1.1	128	500	548	1,047	1.11	0.7	17	63.0	14.37	1.158	75	68	NM	-	48.4	18.9	0.16	38.0	0.11	0.23	40.6	0.13
S13.1	1	9/29/2010	11:54	12:00	0:06	521	58.6	1,814	2,394	375	29.99	1.7	239	300	546	846	0.35	5.2	180	85.5	14.36	0.059	75	223	NM	-	98.4	0.3	0.10	98.0	0.03	0.18	98.3	0.11
S13.2	1	9/29/2010	11:33	11:44	0:11	396	46.6	1,431	1,874	365	29.92	1.4	214	307	525	832	0.44	3.2	192	83.3	14.37	0.103	87	9	NM	-	97.8	0.5	0.21	94.6	0.03	0.19	95.3	0.12
S13.3	1	9/29/2010	10:08	10:18	0:10	292	34.7	1,077	1,404	359	29.87	1.1	184	298	555	853	0.61	0.5	325	71.1	14.37	2.428	90	8	NM	-	93.9	1.6	0.10	87.8	0.05	0.19	89.0	0.11
S13.4	1	9/29/2010	10:26	11:00	0:34	176	22.4	721	919	331	29.69	0.9	137	310	539	849	0.92	1.3	284	73.4	14.37	0.232	NMR	-	NM	-	59.4	17.1	0.16	42.5	0.07	0.23	44.2	0.14
S13.4	2	9/29/2010	11:01	11:11	0:10	179	22.2	720	922	336	29.72	0.9	138	321	534	855	0.93	4.3	240	78.8	14.37	0.021	81	9	NM	-	68.4	7.3	0.03	46.9	0.00	0.21	48.3	0.12
S13.4	3	9/29/2010	12:38	12:44	0:06	191	22.1	734	947	368	29.82	0.9	164	310	446	756	0.80	1.8	34	88.4	14.36	0.119	NMR	-	NM	-	86.3	1.4	0.46	60.2	0.26	0.24	61.7	0.15
S13.4	Averages					182	22.2	725	929	345	29.74	0.87	147	314	506	820	0.88	2.5	186	80.2	14.37	0.124	81	9	NM	-	71.3	8.6	0.2	49.9	0.1	0.2	51.4	0.1
	% Std Dev																						NMR		NM		19.2			18.5			17.8	
S13.5	1	9/29/2010	11:18	11:27	0:09	250	29.4	928	1,207	357	29.86	1.0	172	313	517	830	0.69	3.4	37	81.7	14.37	0.047	NMR	-	NM	-	90.9	1.2	0.23	83.1	0.15	0.22	84.7	0.13
S14.1	1	9/29/2010	12:05	12:13	0:08	499	57.5	1,814	2,370	385	29.91	1.4	283	0	540	540	0.23	4.7	250	87.3	14.36	0.051	0	216	NM	-	99.1	0.2	0.09	98.9	0.01	0.18	99.1	0.11
S14.4	1	9/29/2010	12:21	12:30	0:09	193	22.6	726	942	377	29.87	0.6	201	0	533	533	0.57	7.2	17	88.8	14.36	0.003	80	47	NM	-	94.0	1.2	0.13	95.3	0.09	0.18	96.1	0.11

NM = No measurements made. Instrument was not used on this test run.
NMR = No measurement reported.
* Includes Center Steam

Table D-2. Summary of Data from Steam Flare Tests for CE >= 80%

Test Point	Run Number	Combustion Efficiency (CE)						
		Telops		IMACC - AFTIR		IMACC - PFTIR		ARI
		Telops - ARI	Avg CE (%)	IMACCA - ARI	Avg CE (%)	IMACCP - ARI	Avg CE (%)	CE (%)
S1.5	1	-6.59	93.3	0.1	100.0	0.0	99.9	99.9
S3.6	1	NMR	NMR	-2.5	97.3	-0.7	99.1	99.8
S1.6	1	NMR	NMR	0.3	100.0	0.2	99.9	99.7
S2.1	3	NMR	NMR	n/a	n/a	-0.1	99.5	99.6
S3.7	1	NMR	NMR	-1.5	97.8	-0.9	98.5	99.3
S1.7	1	NMR	NMR	0.7	99.9	0.5	99.8	99.3
S6.1	1	NMR	NMR	-0.1	99.1	-0.6	98.7	99.3
S6.1	2	-1.25	98	0.6	99.9	-0.3	99.0	99.2
S2.1	1	NMR	NMR	n/a	n/a	0.0	99.1	99.2
S6.1	3	NMR	NMR	1.0	100.0	0.3	99.2	98.9
S14.1	1	-98.89	0	NM	NM	0.2	99.1	98.9
S4.2	3	-9.07	89.8	-0.9	98.0	-0.8	98.1	98.9
S6.5	1	NMR	NMR	0.5	99.0	0.3	98.7	98.4
S4.2	1	NMR	NMR	-3.6	94.7	-0.7	97.7	98.3
S13.1	1	-23.04	75	NM	NM	0.3	98.4	98.0
S5.1	1	NMR	NMR	-0.6	97.4	1.3	99.2	98.0
S4.2	2	NMR	NMR	-3.8	94.1	-0.5	97.3	97.8
S4.4	1	NMR	NMR	0.1	97.9	-0.6	97.2	97.8
S8.1	1	-10.59	87	NM	NM	-2.5	95.1	97.6
S4.1	1	-5.77	91.7	-5.9	91.6	-3.5	94.0	97.5
S12.1	1	NMR	NMR	NM	NM	1.0	98.4	97.4
S8.2	1	-17.44	80	NM	NM	-4.2	93.3	97.4
S2.1	2	NMR	NMR	n/a	n/a	2.2	99.5	97.2
S12.1	2	-12.87	84	NM	NM	1.7	98.6	96.9
S3.5	2	-5.25	91.3	-0.9	95.7	-0.2	96.3	96.5
S6.3	2	NMR	NMR	-2.4	94.1	0.5	96.9	96.5
S6.3	3	0.41	96.7	-1.8	94.5	0.1	96.4	96.3
S6.3	1	NMR	NMR	-3.1	93.2	-0.3	96.0	96.3
S8.3	1	-45.97	50	NM	NM	-9.5	86.5	96.0
S1.8	1	-5.16	90.7	-0.1	95.7	2.6	98.5	95.9
S11.1	1	NMR	NMR	NM	NM	0.1	95.4	95.4
S7.6	1	NMR	NMR	NM	NM	0.2	95.5	95.3
S14.4	1	-15.29	80	NM	NM	-1.2	94.0	95.3
S4.1	3	NMR	NMR	-5.9	89.3	-0.6	94.6	95.2
S3.5	1	NMR	NMR	1.5	96.6	2.0	97.1	95.1
S10.1	1	NMR	NMR	NM	NM	-0.3	94.7	95.0
	Sum of Differences			Sum of Differences		Sum of Differences		
		-256.78		-28.2		-14.1		
	Mean Difference			Mean Difference		Mean Difference		
		20.2		1.7		1.1		
	Standard Deviation			Standard Deviation		Standard Deviation		
		32.2		2.5		2.1		
		N = 14		N = 22		N = 36		N = 36

Table D-2. Summary of Data from Steam Flare Tests for CE >= 80%

Test Point	Run Number	Combustion Efficiency (CE)						
		Telops		IMACC - AFTIR		IMACC - PFTIR		ARI
		Telops - ARI	Avg CE (%)	IMACCA - ARI	Avg CE (%)	IMACCP - ARI	Avg CE (%)	CE (%)
S5.1	2	NMR	NMR	2.5	97.4	-1.7	93.3	94.9
S4.1	2	NMR	NMR	-5.3	89.6	-0.4	94.5	94.8
S13.2	1	-7.63	87	NM	NM	3.2	97.8	94.6
S5.6	1	NMR	NMR	-3.2	91.0	0.0	94.2	94.2
S8.4	1	NMR	NMR	NM	NM	-3.4	90.6	93.9
S5.1	3	NMR	NMR	4.1	98.0	1.0	94.8	93.8
S10.2	1	NMR	NMR	NM	NM	1.3	94.9	93.7
S11.2	1	-18.28	75	NM	NM	0.7	93.9	93.3
S9.1	1	-11.25	82	NM	NM	-1.1	92.2	93.3
S8.5	1	NMR	NMR	NM	NM	-6.7	86.5	93.2
S7.1	1	4.82	98	Nm	n/a	n/a	--	93.2
S5.6	2	NMR	NMR	1.0	93.8	0.2	93.1	92.8
S5.6	3	5.26	98	2.9	95.7	-1.3	91.4	92.7
S9.2	1	-12.61	80	NM	NM	-3.1	89.5	92.6
S12.2	2	-5.42	87	NM	NM	4.3	96.7	92.4
S5.5	1	NMR	NMR	-4.5	87.8	-2.1	90.2	92.3
S10.3	1	-11.88	80	NM	NM	1.0	92.9	91.9
S7.2	2	NMR	NMR	NM	NM	-3.1	88.7	91.8
S12.2	1	NMR	NMR	NM	NM	5.5	96.5	91.0
S4.5	1	NMR	NMR	2.4	92.9	2.1	92.6	90.5
	Sum of Differences			Sum of Differences		Sum of Differences		
		-56.99		0.0		-3.4		
	Mean Difference			Mean Difference		Mean Difference		
		9.6		3.2		2.2		
	Standard Deviation			Standard Deviation		Standard Deviation		
		11.3		3.7		2.9		
		N = 8		N = 8		N = 19		N = 20

S7.1	2	NMR	NMR	NM	NM	4.2	93.9	89.6
S4.7	1	NMR	NMR	-1.4	87.3	-2.2	86.5	88.7
S3.2	2	-0.71	87.9	-17.4	71.2	-0.6	88.0	88.6
S11.3	1	-8.31	80	NM	NM	3.4	91.7	88.3
S13.3	1	2.24	90	NM	NM	6.2	93.9	87.8
S5.3	1	NMR	NMR	-13.1	74.5	-0.2	87.4	87.7
S9.3	1	NMR	NMR	NM	NM	-2.3	84.9	87.3
S5.3	2	NMR	NMR	-9.3	77.5	1.3	88.1	86.8
S7.2	3	NMR	NMR	NM	NM	-4.3	82.2	86.4
S6.6	1	NMR	NMR	-12.2	74.1	3.9	90.3	86.4
S6.4	2	NMR	NMR	-19.4	65.6	1.8	86.9	85.1
	Sum of Differences			Sum of Differences		Sum of Differences		
		-6.79		-72.9		11.3		
	Mean Difference			Mean Difference		Mean Difference		
		3.8		12.2		2.8		
	Standard Deviation			Standard Deviation		Standard Deviation		
		6.1		14.8		3.4		
		N = 3		N = 6		N = 11		N = 11

Table D-2. Summary of Data from Steam Flare Tests for CE >= 80%

Test Point	Run Number	Combustion Efficiency (CE)						
		Telops		IMACC - AFTIR		IMACC - PFTIR		ARI
		Telops - ARI	Avg CE (%)	IMACCA - ARI	Avg CE (%)	IMACCP - ARI	Avg CE (%)	CE (%)
S5.3	3	6.09	91	-3.3	81.6	-4.8	80.1	84.9
S1.9	1	NMR	NMR	-8.3	76.6	9.8	94.7	84.9
S10.4	1	10.27	95	NM	NM	0.0	84.7	84.7
S7.2	1	13.72	98	NM	NM	5.0	89.3	84.3
S4.8	1	-50.81	33	-13.2	70.7	-5.4	78.4	83.8
S13.5	1	NMR	NMR	NM	NM	7.9	90.9	83.1
S6.4	3	16.56	98.7	-24.2	58.0	3.2	85.4	82.1
S11.4	1	-15.14	67	NM	NM	0.6	82.7	82.1
	Sum of Differences			Sum of Differences		Sum of Differences		
		-19.31		-48.9		16.2		
	Mean Difference			Mean Difference		Mean Difference		
		18.8		12.2		4.6		
	Standard Deviation			Standard Deviation		Standard Deviation		
		26.1		16.7		5.9		
		N = 6		N = 4		N = 8		N = 8

Appendix E

Summary of Data from All Air Flare Test Series and Runs

Definition of Column Titles for Table E-1

Column Name	Definition
Test Point	Test series test point name from Test Plan
Run Number	Run number of test point
Date	Date of test in month/date/year format
Time	
Start	Local time for start of test
End	Local time for end of test
Elapsed	Elapsed time from start of test to end of test
Actual Vent Gas (VG) Flow Rates	
Propylene (lb/hr)	Flow rate of propylene per Appendix G
TNG (lb/hr)	Flow rate of Tulsa Natural Gas per Appendix G
Nitrogen (lb/hr)	Flow rate of nitrogen as measured by Zink
Total (lb/hr)	Sum of propylene, TNG and nitrogen flows above
Actual Vent Gas	
LHV (Btu/scf)	Calculated lower heating value of vent gas based on Actual Vent Gas (VG) Flow Rate composition
Mol Wt (lb/lb-mole)	Calculated molecular weight of vent gas based on Actual Vent Gas (VG) Flow Rate composition
Exit Velocity* (fps)	Vent Gas Exit Velocity per 40 cfr 60.18 (f) (4)
Air Assist Flow Rate	
SCFM	Time averaged air assist flow rate (SCFM) during test point run as calculated from Zink airflow measurements
lb/hr	Time averaged air assist flow rate (SCFM) during test point run as calculated from Zink airflow measurements converted to mass flow rates (lb/hr)
Excess Air – SR	Stoichiometric Ratio: Ratio of the Actual Air Assist (lb) to the amount of air (lb) required for stoichiometric combustion of the fuel (lb) in the Actual Vent Gas
Wind	
Speed (mph)	Time averaged wind speed during test point run as calculated from ARI continuous wind speed measurements
Direction (Degrees)	Time averaged wind direction during test point run as calculated from ARI continuous wind direction measurements
Ambient Temperature (Degrees F)	Time averaged ambient temperature during test point run as calculated from ARI continuous ambient temperature measurements
Baro Pressure (psia)	Time averaged barometric pressure during test point run as calculated from ARI continuous ambient temperature measurements

Momentum Flux Ratio	Ratio of the momentum of the flare exit gas to the momentum of the wind
DRE (Propene) and/or CE	
Telops	
Avg CE (%)	Average combustion efficiency for test point run as reported by Telops
σ	Standard deviation for Telops CE for test point run
IMACC – PFTIR (%)	
Avg CE (%)	Average combustion efficiency for test point run as reported by IMACC PFTIR
σ	Standard deviation for IMACC AFTIR CE for test point run
ARI	
σ (low)	Standard deviation, less than mean, for ARI CE for test point run
CE (%)	Combustion efficiency (CE) for test point run as reported by ARI
σ (high)	Standard deviation, greater than mean, for ARI CE for test point run
σ (low)	Standard deviation, less than mean, for ARI CE for test point run
DRE (%)	Destruction and removal efficiency (DRE) for test point run as reported by ARI
σ (high)	Standard deviation, greater than mean, for ARI DRE for test point run

Table E-1. Summary of Data from All Air Flare Test Series and Runs

Test Point	Run Number	Date	Times			Actual Vent Gas (VG) Flow Rates					Actual Vent Gas			Air Assist Flow Rate			Wind		Ambient Temp	Baro Pressure	Momentum Flux	Measured DRE (Propylene) and/or CE								
			Start	End	Elapsed	Propylene	TNG	Nitrogen	Total	Temperature	LHV	Mol Wt	Exit Velocity			Excess Air	Speed	Direction				Telops		IMACC - PFTIR		ARI				
		m/dd/yy				lb/hr	lb/hr	lb/hr	lb/hr	°F	Btu/scf	lb/lb-mole	fps	SCFM	lb/hr	SR	MPH	Degrees	Degrees F	psia	Ratio	Avg CE (%)	σ	Avg CE (%)	σ	σ (low)	CE (%)	σ (high)	σ (low)	DRE (%)
A1.1	1	9/22/2010	9:51	9:58	0:07	919	0	0	919	87	2,108	41.27	1.4	33,075	149,173	11.0	12.7	178	75.6	14.42	16.75	NMR	–	92.7	1.4	0.56	96.9	0.64	0.51	98.0
A2.1	1	9/22/2010	10:07	10:14	0:07	352	0	0	352	91	2,108	41.28	0.5	18,433	83,136	15.9	12.2	178	79.7	14.42	5.76	NMR	–	93.7	1.7	0.62	96.8	0.45	0.44	97.8
A2.1	2	9/22/2010	10:50	11:05	0:15	355	0	0	355	95	2,125	41.61	0.5	18,584	83,818	15.9	12.8	174	81.5	14.42	5.30	NMR	–	92.0	1.0	0.45	95.9	0.37	0.41	97.1
A2.1	3	9/22/2010	11:32	11:41	0:09	355	0	0	355	96	2,126	41.63	0.5	18,622	83,990	16.0	14.1	180	81.9	14.42	4.43	NMR	–	93.6	1.8	1.20	95.1	0.93	0.72	96.6
A2.1	Averages					354	0	0	354	94	2,120	41.51	0.5	18,546	83,648	16.0	13.0	177	81.0	14.42	5.11	NMR	-	93.1	1.5	0.76	95.9	0.58	0.52	97.2
	% Std Dev																					NMR		1.0			0.9			0.6
A2.3	1	9/22/2010	10:17	10:25	0:08	352	0	0	352	90	2,108	41.28	0.5	19,687	88,791	17.0	10.1	180	79.9	14.42	9.57	NMR	–	91.4	1.5	0.66	94.4	0.45	0.46	96.1
A2.4	1	9/22/2010	10:29	10:37	0:08	353	0	0	353	91	2,113	41.36	0.5	32,992	148,799	28.5	10.0	185	79.4	14.42	27.13	NMR	–	81.6	6.8	1.53	88.3	1.24	0.99	92.2
A2.4	2	9/22/2010	11:21	11:31	0:10	354	0	0	354	91	2,120	41.51	0.5	32,938	148,556	28.3	9.9	185	79.4	14.42	27.78	NMR	–	80.3	4.0	1.44	88.2	1.11	0.99	92.0
A2.4	3	9/22/2010	11:55	12:01	0:06	354	0	0	354	95	2,120	41.51	0.5	32,869	148,245	28.3	10.4	180	83.9	14.42	25.30	NMR	–	84.5	1.0	0.60	91.3	0.42	0.48	94.7
A2.4	Averages					354	0	0	354	92	2,118	41.46	1	32,933	148,533	28.4	10.1	183.6	80.9	14.4	26.70	NMR	-	82.1	3.9	1.19	89.3	0.92	0.82	93.0
	% Std Dev																					NMR		2.7			2.0			1.7
A2.5	1	9/22/2010	10:42	10:47	0:05	355	0	0	355	93	2,124	41.58	0.5	26,513	119,580	22.8	13.3	174	80.8	14.42	10.06	NMR	–	88.3	2.7	0.27	92.4	0.25	0.37	95.1
A2.5	2	9/22/2010	11:09	11:20	0:11	353	0	0	353	91	2,115	41.40	0.5	26,487	119,462	22.8	10.2	183	81.2	14.42	16.97	NMR	–	87.3	4.0	0.81	91.7	0.79	0.69	94.3
A2.5	3	9/22/2010	11:42	11:53	0:11	355	0.1	0	355	98	2,124	41.59	0.5	26,399	119,067	22.7	13.1	178	84.8	14.42	10.45	NMR	–	86.9	2.5	0.82	93.7	0.60	0.51	95.9
A2.5	Averages					354	0	0	354	94	2,121	41.52	0.5	26,467	119,370	22.8	12.2	178	82.2	14.42	11.96	NMR	-	87.5	3.1	0.63	92.6	0.55	0.52	95.1
	% Std Dev																					NMR		0.8			1.1			0.8
A3.1	1	9/22/2010	14:14	14:23	0:09	183	18.4	701	903	100	339	29.64	1.9	4,077	18,386	6.1	13.4	176	89.3	14.40	0.25	NMR	-	97.4	1.7	1.65	97.3	0.53	0.59	98.0
A3.1	2	9/22/2010	16:10	16:18	0:08	181	18.8	703	903	91	339	29.62	1.9	4,298	19,387	6.5	10.3	178	82.3	14.38	0.46	NMR	-	98.0	1.0	0.11	99.2	0.13	0.26	99.6
A3.1	3	9/22/2010	16:38	16:47	0:09	181	18.6	702	902	94	339	29.63	1.9	4,732	21,342	7.2	10.4	168	84.8	14.38	0.56	NMR	-	96.6	1.8	0.52	98.5	0.32	0.37	99.0
A3.1	Averages					182	18.6	702	903	95	339	29.63	1.9	4,369	19,705	6.6	11.4	174	85.5	14.39	0.40	NMR	-	97.4	1.5	0.76	98.3	0.33	0.41	98.8
A3.1	% Std Dev																					NMR		0.7			1.0			0.8
A3.2	1	9/22/2010	14:56	15:05	0:09	181	17.9	699	898	101	329	29.58	1.9	29,303	132,164	44.6	12.3	176	93.1	14.39	15.01	NMR	-	54.0	14.4	0.86	58.7	1.15	1.34	64.8
A3.2	2	9/22/2010	15:55	16:08	0:13	181	18.8	702	902	94	337	29.61	1.9	29,360	132,420	44.5	12.8	178	86.6	14.39	13.63	NMR	-	38.4	8.7	2.66	61.0	1.60	1.69	67.1
A3.2	3	9/22/2010	17:11	17:18	0:07	181	18.6	702	902	93	336	29.61	1.9	29,324	132,256	44.4	10.5	167	87.5	14.38	20.24	NMR	-	51.7	3.9	3.48	57.7	1.82	1.97	63.8
A3.2	Averages					181	18	701	901	96	334	29.60	1.9	29,329	132,280	44.5	11.9	173	89.1	14.39	15.94	NMR	-	48.0	9.0	2.33	59.1	1.52	1.67	65.2
A3.2	% Std Dev																					NMR		17.5			2.9			2.6
A3.3	1	9/22/2010	15:06	15:17	0:11	181	18.4	701	900	97	334	29.60	1.9	13,330	60,121	20.2	11.1	169	90.1	14.39	3.81	NMR	-	74.3	3.5	2.34	85.2	0.94	0.93	88.1
A3.4	1	9/22/2010	15:19	15:29	0:10	181	18.3	701	900	97	337	29.62	1.9	21,276	95,958	32.3	11.8	176	87.9	14.39	8.45	NMR	-	58.7	4.0	2.40	72.3	2.02	1.87	76.9
A3.4	2	9/22/2010	16:29	16:36	0:07	181	18.5	704	903	93	337	29.63	1.9	21,312	96,121	32.3	10.4	170	82.0	14.38	10.82	NMR	-	57.8	4.3	2.31	72.0	1.87	1.84	76.6
A3.4	3	9/22/2010	17:00	17:08	0:08	181	18.5	702	902	93	338	29.62	1.9	21,288	96,011	32.3	12.7	178	87.2	14.38	7.33	NMR	-	60.5	4.5	2.07	71.6	2.17	1.99	76.4
A3.4	Averages					181	18.4	702	902	94	338	29.63	1.9	21,292	96,030	32.3	11.6	175	85.7	14.38	8.69	NMR	-	59.0	4.2	2.26	72.0	2.02	1.90	76.6
A3.4	% Std Dev																					NMR		2.4			0.5			0.4
A3.5	1	9/22/2010	15:31	15:43	0:12	181	18.4	701	901	95	336	29.61	1.9	7,927	35,754	12.0	10.6	167	86.2	14.39	1.47	NMR	-	89.2	3.0	2.55	95.4	1.01	0.88	96.5
A3.6	1	9/22/2010	15:45	15:52	0:07	181	18.6	701	901	96	339	29.63	1.9	10,832	48,856	16.4	12.1	161	85.9	14.39	2.10	NMR	-	81.5	2.9	1.86	89.5	0.86	0.88	91.7
A3.6	2	9/22/2010	16:19	16:27	0:08	181	18.8	704	904	90	338	29.62	1.9	10,530	47,494	15.9	11.9	170	80.4	14.38	2.01	NMR	-	79.4	3.6	3.59	89.1	1.78	1.39	91.6
A3.6	3	9/22/2010	16:49	16:57	0:08	181	18.2	702	901	94	337	29.63	1.9	10,183	45,927	15.5	13.1	178	86.7	14.38	1.57	NMR	-	82.1	2.8	1.82	85.9	1.36	1.21	89.0
A3.6	Averages					181	18.5	702	902	93	338	29.62	1.9	10,515	47,426	15.9	12.4	169	84.4	14.38	1.88	NMR	-	81.0	3.1	2.42	88.2	1.33	1.16	90.8
A3.6	% Std Dev																					NMR		1.8			2.3			1.7
A4.1	1	9/23/2010	9:04	9:17	0:13	315	31.6	591	937	81	584	30.82	1.9	11,482	51,785	10.0	9.1	172	68.6	14.40	3.84	NMR	-	94.9	1.1	0.41	97.4	0.26	0.36	98.1

Table E-1. Summary of Data from All Air Flare Test Series and Runs

Test Point	Run Number	Date	Times			Actual Vent Gas (VG) Flow Rates					Actual Vent Gas			Air Assist Flow Rate			Wind		Ambient Temp	Baro Pressure	Momentum Flux	Measured DRE (Propylene) and/or CE								
			Start	End	Elapsed	Propylene	TNG	Nitrogen	Total	Temperature	LHV	Mol Wt	Exit Velocity			Excess Air	Speed	Direction				Telops		IMACC - PFTIR		ARI				
		m/dd/yy				lb/hr	lb/hr	lb/hr	lb/hr	°F	Btu/scf	lb/lb-mole	fps	SCFM	lb/hr	SR	MPH	Degrees	Degrees F	psia	Ratio	Avg CE (%)	σ	Avg CE (%)	σ	σ (low)	CE (%)	σ (high)	σ (low)	DRE (%)
A4.1	2	9/23/2010	9:50	10:00	0:10	299	32.2	591	922	82	564	30.69	1.9	11,134	50,216	10.2	12.4	178	71.1	14.40	1.97	NMR	-	95.9	0.9	0.64	96.4	0.35	0.44	97.3
A4.1	3	9/23/2010	10:33	10:41	0:08	298	30.3	594	923	89	560	30.68	1.9	10,854	48,956	10.0	10.0	178	76.3	14.40	2.94	97	3	95.6	0.9	0.48	97.6	0.29	0.35	98.3
A4.1	Averages					304	31.4	592	927	84	569	30.73	1.9	11,157	50,319	10.1	10.5	176	72.0	14.40	2.77	97	3	95.5	1.0	0.51	97.1	0.30	0.39	97.9
A4.1	% Std Dev																					NMR		0.5			0.7			0.5
A4.2	1	9/23/2010	8:40	8:55	0:15	299	30.3	591	920	79	563	30.69	1.9	33,207	149,772	30.6	9.2	178	66.4	14.40	31.36	94	5	71.4	4.8	3.78	78.8	1.45	1.26	83.4
A4.3	1	9/23/2010	9:18	9:28	0:10	300	30.6	592	922	82	564	30.69	1.9	14,988	67,600	13.7	9.2	175	69.8	14.40	6.41	NMR	-	90.9	0.9	1.02	94.8	0.61	0.57	96.1
A4.3	2	9/23/2010	10:01	10:09	0:08	299	30.3	591	920	82	563	30.70	1.9	14,738	66,472	13.6	10.7	180	71.1	14.40	4.63	NMR	-	89.1	1.9	1.57	91.7	0.95	0.85	93.6
A4.3	3	9/23/2010	10:43	10:50	0:07	298	30.5	593	921	89	561	30.68	1.9	14,302	64,507	13.2	15.2	178	77.8	14.40	2.24	99	1	91.9	1.3	1.43	94.3	1.00	0.79	95.8
A4.3	Averages					299	30.5	592	921	84	563	30.69	1.9	14,676	66,193	13.5	11.7	177	72.9	14.40	3.88	99	1	90.6	1.4	1.34	93.6	0.85	0.74	95.2
A4.3	% Std Dev																					NMR		1.5			1.8			1.4
A4.4	1	9/23/2010	9:29	9:38	0:09	301	30.6	594	926	83	564	30.69	1.9	18,237	82,253	16.7	9.8	178	71.1	14.40	8.52	NMR	-	86.5	2.0	2.06	88.5	0.18	0.37	91.0
A4.4	2	9/23/2010	10:11	10:19	0:08	297	30.4	591	919	86	561	30.68	1.9	18,055	81,432	16.7	9.6	180	72.3	14.40	8.65	NMR	-	86.8	2.4	2.17	88.0	0.28	0.33	90.6
A4.4	3	9/23/2010	10:52	11:01	0:09	297	30.7	595	923	88	559	30.66	1.9	18,042	81,375	16.7	14.3	178	77.4	14.40	4.01	NMR	-	86.3	1.8	2.33	89.0	1.52	1.28	91.6
A4.4	Averages					299	30.6	594	923	86	561	30.68	1.9	18,111	81,686	16.7	11.2	178	73.63	14.40	6.44	NMR		86.5	2.0	2.19	88.5	0.66	0.66	91.0
A4.4	% Std Dev																					NMR		0.3			0.6			0.5
A4.5	1	9/23/2010	9:41	9:49	0:08	299	30.1	592	922	83	563	30.70	1.9	24,859	112,119	22.9	9.5	178	71.7	14.40	16.84	NMR	-	76.9	4.8	2.25	84.4	2.24	1.76	87.7
A4.5	2	9/23/2010	10:20	10:30	0:10	300	30.3	594	924	87	562	30.69	1.9	24,824	111,960	22.8	10.4	180	75.0	14.40	14.25	NMR	-	77.9	2.5	2.09	84.0	1.90	1.57	87.3
A4.5	3	9/23/2010	11:05	11:16	0:11	299	30.9	595	925	88	561	30.68	1.9	24,743	111,596	22.7	14.5	180	77.1	14.40	7.29	75	16	78.1	2.7	2.66	85.2	1.41	1.20	88.5
A4.5	Averages					299	30.4	594	924	86	562	30.69	1.9	24,809	111,892	22.8	11.4	179	74.6	14.40	11.64	75	16	77.6	3.3	2.33	84.6	1.85	1.51	87.9
A4.5	% Std Dev																					NMR		0.9			0.8			0.7
A4.6	1	9/23/2010	11:17	11:27	0:10	297	30.3	594	921	91	559	30.67	1.9	6,692	30,184	6.2	16.3	180	79.4	14.40	0.43	NMR	-	98.7	1.1	0.25	98.9	0.25	0.36	99.4
A5.1	1	9/27/2010	10:12	10:21	0:09	73	7.6	275	356	81	344	29.64	0.8	1,940	8,750	7.3	2.7	342	56.4	14.47	1.18	NMR	-	99.4	0.6	1.60	94.4	0.59	0.80	94.8
A5.1	2	9/27/2010	11:15	11:24	0:09	75	7.4	273	355	91	351	29.70	0.8	1,759	7,933	6.5	3.8	333	68.5	14.47	0.53	NMR	-	98.8	1.1	1.52	96.6	0.13	0.28	97.0
A5.1	3	9/27/2010	11:47	11:56	0:09	71	7.6	272	351	93	341	29.60	0.8	1,848	8,333	7.1	7.2	333	71.0	14.46	0.17	NMR	-	99.3	0.8	0.89	96.9	2.08	1.43	97.4
A5.1	Averages					73	7.6	274	354	88	345	29.65	0.8	1,849	8,339	7.0	4.6	336	65.3	14.47	0.40	NMR	-	99.2	0.8	1.33	96.0	0.94	0.84	96.4
A5.1	% Std Dev																					NMR		0.3			1.4			1.5
A5.2	1	9/27/2010	10:30	10:37	0:07	72	7.7	274	354	84	343	29.62	0.8	16,660	75,140	63.1	2.1	359	59.5	14.47	139.33	NMR	-	34.3	20.8	1.79	63.3	0.86	1.04	68.7
A5.3	1	9/27/2010	10:39	10:49	0:10	72	7.5	274	354	85	342	29.63	0.8	8,243	37,175	31.4	2.8	346	61.6	14.47	20.60	NMR	-	60.5	8.4	2.08	78.2	0.75	0.97	81.2
A5.3	2	9/27/2010	11:35	11:44	0:09	72	7.5	273	352	93	344	29.65	0.8	9,155	41,289	34.8	5.3	339	70.0	14.46	7.32	NMR	-	72.1	10.9	1.50	85.0	1.44	1.46	87.5
A5.3	3	9/27/2010	12:13	12:22	0:09	71	7.5	271	350	96	342	29.62	0.8	7,289	32,876	28.0	2.5	302	75.0	14.46	20.90	NMR	-	68.6	10.1	3.51	79.1	1.22	1.12	82.3
A5.3	Averages					72	7.5	273	352	91	343	29.63	0.8	8,229	37,113	31.4	3.5	329	68.9	14.46	13.20	NMR	-	67.1	9.8	2.36	80.8	1.14	1.19	83.7
A5.3	% Std Dev																					NMR		8.9			4.6			4.0
A5.4	1	9/27/2010	10:52	11:00	0:08	72	7.5	274	354	87	340	29.62	0.8	6,758	30,479	25.8	4.4	324	64.1	14.47	5.46	NMR	-	78.2	6.3	2.10	80.9	3.16	2.86	83.6
A5.5	1	9/27/2010	11:01	11:10	0:09	72	7.6	274	353	89	340	29.62	0.8	5,137	23,169	19.6	4.0	65	66.1	14.47	4.02	NMR	-	86.2	7.1	2.85	90.7	1.42	1.23	92.2
A5.5	2	9/27/2010	11:25	11:34	0:09	71	7.4	273	352	91	341	29.62	0.8	5,122	23,101	19.7	2.7	340	68.8	14.47	8.98	NMR	-	91.4	2.3	2.19	92.7	0.94	0.89	94.0
A5.5	3	9/27/2010	12:01	12:12	0:11	72	7.5	272	351	95	342	29.63	0.8	5,338	24,074	20.4	5.6	49	72.7	14.46	2.25	NMR	-	93.6	1.4	1.95	94.6	0.44	0.66	95.5
A5.5	Averages					72	7.5	273	352	92	341	29.62	0.8	5,199	23,448	19.9	4.1	151	69.2	14.47	3.96	NMR	-	90.4	3.6	2.33	92.7	0.93	0.92	93.9
A5.5	% Std Dev																					NMR		4.2			2.1			1.7
A6.1	1	9/23/2010	13:58	14:09	0:11	118	11.9	221	351	100	584	30.80	0.7	2,528	11,404	5.9	15.9	180	85.9	14.37	0.07	NMR	-	99.0	0.7	1.01	99.4	0.21	0.31	99.7
A6.1	2	9/23/2010	15:24	15:34	0:10	118	12.3	221	352	98	586	30.79	0.7	2,470	11,141	5.7	16.0	180	86.0	14.36	0.06	NMR	-	98.3	2.2	1.97	99.4	0.20	0.36	99.6
A6.1	3	9/23/2010	16:01	16:07	0:06	118	12.3	222	352	94	584	30.77	0.7	2,795	12,606	6.5	13.8	178	80.4	14.35	0.11	NMR	-	97.9	2.5	1.49	99.1	0.46	0.51	99.4
A6.1	Averages					118	12.2	221	351	97	585	30.78	0.7	2,598	11,717	6.0	15.2	179	84.1	14.36	0.08	NMR		98.4	1.8	1.49	99.3	0.29	0.39	99.6
A6.1	% Std Dev																					NMR		0.6			0.2			0.2

Table E-1. Summary of Data from All Air Flare Test Series and Runs

Test Point	Run Number	Date	Times			Actual Vent Gas (VG) Flow Rates					Actual Vent Gas			Air Assist Flow Rate		Excess Air	Wind		Ambient Temp	Baro Pressure	Momentum Flux Ratio	Measured DRE (Propylene) and/or CE								
			Start	End	Elapsed	Propylene	TNG	Nitrogen	Total	Temperature	LHV	Mol Wt	Exit Velocity				Speed	Direction				Telops		IMACC - PFTIR		ARI				
		m/dd/yy				lb/hr	lb/hr	lb/hr	lb/hr	°F	Btu/scf	lb/lb-mole	fps	SCFM	lb/hr	SR	MPH	Degrees	Degrees F	psia	Ratio	Avg CE (%)	σ	Avg CE (%)	σ	σ (low)	CE (%)	σ (high)	σ (low)	DRE (%)
A6.2	1	9/23/2010	14:10	14:18	0:08	118	12.1	221	352	98	586	30.79	0.7	5,561	25,083	12.9	15.1	176	83.8	14.37	0.35	96	3	92.7	2.9	0.16	91.8	0.64	0.68	94.7
A6.3	1	9/23/2010	14:19	14:32	0:13	118	12.1	221	351	97	584	30.79	0.7	3,959	17,856	9.2	15.2	178	82.6	14.37	0.17	NMR	-	93.4	3.2	3.15	97.1	0.86	0.45	98.0
A6.3	2	9/23/2010	15:37	15:46	0:09	118	12.2	221	351	97	585	30.78	0.7	3,771	17,009	8.8	15.6	180	84.2	14.35	0.15	NMR	-	91.8	3.5	0.04	94.7	1.27	0.69	96.5
A6.3	3	9/23/2010	16:08	16:16	0:08	119	12.4	221	353	95	588	30.81	0.7	4,004	18,057	9.2	15.1	177	81.2	14.35	0.18	97	3	93.5	3.0	0.28	95.1	0.37	0.22	96.7
A6.3	Averages					118	12.2	221	352	96	586	30.79	0.7	3,911	17,641	9.1	15.3	178	82.7	14.36	0.17	97	3	92.9	3.2	1.16	95.6	0.83	0.45	97.1
A6.3	% Std Dev																					NMR		1.0			1.4			0.8
A6.4	1	9/23/2010	14:34	14:47	0:13	118	12.1	221	351	99	585	30.79	0.7	8,998	40,584	20.9	14.1	180	83.9	14.36	1.05	NMR	-	91.4	3.1	1.17	86.2	3.36	1.17	90.4
A6.4	2	9/23/2010	15:48	16:00	0:12	118	12.4	222	352	95	586	30.78	0.7	8,965	40,436	20.8	15.4	176	81.8	14.35	0.86	NMR	-	90.2	3.2	1.22	90.6	0.43	0.59	94.1
A6.4	3	9/23/2010	16:17	16:23	0:06	119	12.4	221	352	97	587	30.79	0.7	9,009	40,631	20.8	12.3	180	82.9	14.35	1.37	NMR	-	94.4	4.0	1.44	90.8	0.03	0.50	94.3
A6.4	Averages					118	12.3	221	352	97	586	30.79	0.7	8,991	40,550	20.8	14.0	179	82.9	14.36	1.07	NMR	-	92.0	3.4	1.28	89.2	1.27	0.75	92.9
A6.4	% Std Dev																					NMR		2.3			2.9			2.4
A6.5	1	9/23/2010	14:48	14:59	0:11	118	12.1	221	351	99	584	30.79	0.7	12,548	56,594	29.2	15.5	185	84.9	14.36	1.70	NMR	-	87.0	7.6	0.01	81.5	1.81	0.54	87.9
A6.6	1	9/23/2010	15:06	15:23	0:17	119	12.4	221	352	101	588	30.79	0.7	32,436	146,295	75.0	15.0	176	87.1	14.36	12.23	96	2	72.1	8.2	0.62	73.9	0.69	1.13	82.5

Test Point	Run Number	Date	Times			Actual Vent Gas (VG) Flow Rates					Actual Vent Gas			Air Assist Flow Rate		Excess Air	Wind		Ambient Temp	Baro Pressure	Momentum Flux Ratio	Measured DRE (Propane) and/or CE								
			Start	End	Elapsed	Propane	TNG	Nitrogen	Total	Temperature	LHV	Mol Wt	Exit Velocity				Speed	Direction				Telops		IMACC - PFTIR		ARI				
		m/dd/yy				lb/hr	lb/hr	lb/hr	lb/hr	°F	Btu/scf	lb/lb-mole	fps	SCFM	lbs/hr	SR	MPH	Degrees	Degrees F	psia	Ratio	Avg CE (%)	σ	Avg CE (%)	σ	σ (low)	CE (%)	σ (high)	σ (low)	DRE (%)
A7.1	1	9/27/2010	14:00	14:16	0:16	81	8.3	280	370	101	376	30.04	0.8	2,020	9,109	6.7	3.6	326	83.0	14.44	0.84	NMR	-	99.3	0.7	0.03	98.6	0.26	0.23	98.9
A7.1	2	9/27/2010	15:00	15:09	0:09	76	8.1	281	365	91	356	29.91	0.8	1,579	7,123	5.5	3.8	37	72.3	14.42	0.45	NMR	-	99.1	0.6	0.14	99.8	0.02	0.18	99.8
A7.1	Averages					79	8.2	281	367	96	366	29.98	0.8	1,799	8,116	6.1	3.7	181	77.6	14.43	0.63	NMR	-	99.2	0.7	0.09	99.2	0.14	0.20	99.4
A7.2	1	9/27/2010	14:17	14:25	0:08	76	8.0	280	364	99	357	29.93	0.8	5,010	22,597	17.6	5.0	314	80.4	14.43	2.58	NMR	-	98.6	0.3	0.15	93.0	0.16	0.20	94.0
A7.2	2	9/27/2010	15:10	15:19	0:09	76	7.5	281	364	94	356	29.94	0.8	4,339	19,569	15.3	5.1	41	75.8	14.42	1.83	NMR	-	95.9	3.2	0.09	91.7	0.31	0.18	92.9
A7.2	Averages	Averages				76	7.7	280	364	96	357	29.93	0.8	4,674	21,083	16.4	5.0	178	78.1	14.43	2.18	NMR		97.3	1.8	0.12	92.4	0.23	0.19	93.4
A7.3	1	9/27/2010	14:27	14:35	0:08	75	8.5	281	364	95	355	29.89	0.8	9,050	40,819	31.8	5.1	25	76.3	14.43	7.77	NMR	-	96.4	1.0	0.06	81.5	0.01	0.19	83.7
A7.3	2	9/27/2010	15:22	15:31	0:09	76	8.0	281	365	94	356	29.92	0.8	8,047	36,293	28.2	3.3	59	77.3	14.42	14.96	NMR	-	94.0	1.9	0.11	77.4	0.01	0.20	80.0
A7.3	Averages					76	8.2	281	365	94	356	29.91	0.8	8,549	38,556	30.0	4.2	42	76.8	14.43	10.31	NMR	-	95.2	1.5	0.08	79.5	0.01	0.20	81.9
A7.4	1	9/27/2010	14:36	14:44	0:08	75	9.4	281	365	93	356	29.90	0.8	14,930	67,337	52.1	4.4	24	73.4	14.43	27.89	NMR	-	90.7	1.4	0.22	61.4	0.01	0.21	65.8
A7.5	1	9/27/2010	14:50	14:58	0:08	76	8.0	282	366	89	356	29.91	0.8	6,334	28,569	22.2	5.8	28	70.4	14.43	2.90	NMR	-	94.6	2.5	0.19	87.2	0.14	0.21	88.9

NMR = No measurement reported.

Table E-2. Summary of Data from Air Flare Test for CE >= 80%

Test Point	Run Number	Measured CE (%)				
		Telops		IMACC - PFTIR		ARI
		Avg CE (%)	Telops - ARI	Avg CE (%)	IMACCP - ARI	CE (%)
A7.1	2	NMR	NMR	99.1	-0.7	99.8
A6.1	1	NMR	NMR	99.0	-0.5	99.4
A6.1	2	NMR	NMR	98.3	-1.0	99.4
A3.1	2	NMR	NMR	98.0	-1.2	99.2
A6.1	3	NMR	NMR	97.9	-1.2	99.1
A4.6	1	NMR	NMR	98.7	-0.2	98.9
A7.1	1	NMR	NMR	99.3	0.7	98.6
A3.1	3	NMR	NMR	96.6	-1.8	98.5
A4.1	3	97	-0.6	95.6	-2.0	97.6
A4.1	1	NMR	NMR	94.9	-2.5	97.4
A3.1	1	NMR	NMR	97.4	0.2	97.3
A6.3	1	NMR	NMR	93.4	-3.7	97.1
A1.1	1	NMR	NMR	92.7	-4.2	96.9
A5.1	3	NMR	NMR	99.3	2.3	96.9
A2.1	1	NMR	NMR	93.7	-3.2	96.8
A5.1	2	NMR	NMR	98.8	2.2	96.6
A4.1	2	NMR	NMR	95.9	-0.5	96.4
A2.1	2	NMR	NMR	92.0	-3.9	95.9
A3.5	1	NMR	NMR	89.2	-6.2	95.4
A6.3	3	97	1.9	93.5	-1.6	95.1
A2.1	3	NMR	NMR	93.6	-1.5	95.1
			Sum of Differences		Sum of Differences	
			1.3		-30.3	
			Mean Difference		Mean Difference	
			1.2		1.9	
			Standard Deviation		Standard Deviation	
			2.0		2.5	
			N = 2		N = 21	N = 21

Table E-2. Summary of Data from Air Flare Test for CE >= 80%

Test Point	Run Number	Measured CE (%)				
		Telops		IMACC - PFTIR		ARI
		Avg CE (%)	Telops - ARI	Avg CE (%)	IMACCP - ARI	CE (%)
A4.3	1	NMR	NMR	90.9	-3.9	94.8
A6.3	2	NMR	NMR	91.8	-2.8	94.7
A5.5	3	NMR	NMR	93.6	-1.0	94.6
A5.1	1	NMR	NMR	99.4	5.0	94.4
A2.3	1	NMR	NMR	91.4	-3.0	94.4
A4.3	3	99	4.7	91.9	-2.4	94.3
A2.5	3	NMR	NMR	86.9	-6.7	93.7
A7.2	1	NMR	NMR	98.6	5.6	93.0
A5.5	2	NMR	NMR	91.4	-1.4	92.7
A2.5	1	NMR	NMR	88.3	-4.1	92.4
A6.2	1	96	4.2	92.7	0.9	91.8
A7.2	2	NMR	NMR	95.9	4.2	91.7
A4.3	2	NMR	NMR	89.1	-2.6	91.7
A2.5	2	NMR	NMR	87.3	-4.4	91.7
A2.4	3	NMR	NMR	84.5	-6.8	91.3
A6.4	3	NMR	NMR	94.4	3.6	90.8
A5.5	1	NMR	NMR	86.2	-4.5	90.7
A6.4	2	NMR	NMR	90.2	-0.4	90.6
			Sum of Differences		Sum of Differences	
			8.9		-24.7	
			Mean Difference		Mean Difference	
			4.4		3.5	
			Standard Deviation		Standard Deviation	
			6.3		4.1	
			N = 2		N =18	N = 18

Table E-2. Summary of Data from Air Flare Test for CE >= 80%

Test Point	Run Number	Measured CE (%)				
		Telops		IMACC - PFTIR		ARI
		Avg CE (%)	Telops - ARI	Avg CE (%)	IMACCP - ARI	CE (%)
A3.6	1	NMR	NMR	81.5	-8.1	89.5
A3.6	2	NMR	NMR	79.4	-9.8	89.1
A4.4	3	NMR	NMR	86.3	-2.8	89.0
A4.4	1	NMR	NMR	86.5	-2.0	88.5
A2.4	1	NMR	NMR	81.6	-6.7	88.3
A2.4	2	NMR	NMR	80.3	-7.9	88.2
A4.4	2	NMR	NMR	86.8	-1.2	88.0
A7.5	1	NMR	NMR	94.6	7.4	87.2
A6.4	1	NMR	NMR	91.4	5.2	86.2
A3.6	3	NMR	NMR	82.1	-3.8	85.9
			Sum of Differences		Sum of Differences	
			NMR		-29.7	
			Mean Difference		Mean Difference	
			NMR		5.5	
			Standard Deviation		Standard Deviation	
			NMR		6.5	
			N = 0		N = 10	N = 10
A4.5	3	75	-10.2	78.1	-7.1	85.2
A3.3	1	NMR	NMR	74.3	-10.9	85.2
A5.3	2	NMR	NMR	72.1	-12.9	85.0
A4.5	1	NMR	NMR	76.9	-7.5	84.4
A4.5	2	NMR	NMR	77.9	-6.1	84.0
A7.3	1	NMR	NMR	96.4	14.9	81.5
A6.5	1	NMR	NMR	87.0	5.5	81.5
A5.4	1	NMR	NMR	78.2	-2.7	80.9
			Sum of Differences		Sum of Differences	
			-10.2		-26.9	
			Mean Difference		Mean Difference	
			10.2		8.5	
			Standard Deviation		Standard Deviation	
			10.2		9.9	
			N = 1		N = 8	N = 8

Appendix F

Emissions Measured During Propylene Flare Tests for DRE (Propylene) > 60%

Table F-1. Emissions Measured During Propylene Steam Flare Tests for DRE (Propylen) > 60 %

Test Point	Run Number	Actual Vent Gas (VG) Flow Rates							Total Other VOCs	Other VOCs (lb/hr)										TVOC	THC	ARI
		Propylene lbs/hr	TNG lbs/hr	Nitrogen lbs/hr	Total lbs/hr	Propylene lb/hr	Methane lb/hr	Ethane lb/hr	lb/hr	Acetylene	Ethylene	Butene isomers	Formaldehyde	Acetaldehyde	Propanal	Acrolein	Methanol	Acetone	Propylene-Oxide	lb/hr	lb/hr	DRE (%)
S1.5	1	2337	0.0	0	2337	1.37	0.18	0.01	0.26	0.031	0.053	0.000	0.081	0.051	0.001	0.040	0.002	0.002	0.002	1.64	1.83	99.9
S3.6	1	189	18.4	705	913	0.13	0.02	0.00	0.03	0.003	0.005	0.000	0.008	0.005	0.000	0.004	0.000	0.000	0.000	0.16	0.17	99.9
S1.6	1	2341	0.0	0	2341	2.96	0.39	0.03	0.57	0.067	0.115	0.001	0.174	0.110	0.003	0.085	0.004	0.004	0.005	3.53	3.95	99.9
S2.1	3	937	0.0	0	937	2.21	0.29	0.02	0.43	0.050	0.086	0.001	0.130	0.083	0.002	0.064	0.003	0.003	0.004	2.64	2.96	99.8
S1.7	1	2341	0.0	0	2341	7.30	0.96	0.08	1.40	0.166	0.284	0.002	0.429	0.272	0.008	0.211	0.010	0.010	0.012	8.70	9.74	99.7
S6.1	2	834	74.1	1472	2380	3.84	0.51	0.04	0.74	0.088	0.149	0.001	0.226	0.143	0.004	0.111	0.005	0.005	0.006	4.58	5.13	99.5
S3.7	1	191	18.9	716	926	0.91	0.12	0.01	0.17	0.021	0.035	0.000	0.053	0.034	0.001	0.026	0.001	0.001	0.001	1.08	1.21	99.5
S2.1	1	937	0.1	0	937	4.58	0.60	0.05	0.88	0.105	0.178	0.001	0.269	0.171	0.005	0.132	0.006	0.006	0.007	5.47	6.12	99.5
S6.1	1	826	79.1	1456	2361	4.39	0.58	0.05	0.84	0.100	0.170	0.001	0.258	0.164	0.005	0.127	0.006	0.006	0.007	5.23	5.86	99.5
S6.1	3	871	79.0	1473	2423	6.33	0.83	0.07	1.22	0.144	0.246	0.002	0.372	0.236	0.007	0.183	0.008	0.008	0.010	7.55	8.45	99.3
S4.2	3	490	44.9	1801	2335	4.06	0.53	0.04	0.78	0.093	0.158	0.001	0.238	0.151	0.004	0.117	0.005	0.005	0.007	4.84	5.41	99.2
S6.5	1	832	74.8	1473	2379	8.85	1.17	0.09	1.19	0.202	0.344	0.003	0.520	0.330	0.010	0.256	0.012	0.012	0.014	10.03	11.29	98.9
S4.2	1	490	45.2	1804	2338	6.38	0.84	0.07	0.85	0.145	0.248	0.002	0.375	0.238	0.007	0.184	0.008	0.008	0.010	7.23	8.14	98.7
S2.1	2	937	0.0	0	937	15.67	2.07	0.16	2.10	0.357	0.609	0.005	0.921	0.584	0.017	0.453	0.021	0.021	0.026	17.77	20.00	98.3
S5.1	1	320	33.7	586	940	5.38	0.71	0.06	0.72	0.123	0.209	0.002	0.316	0.200	0.006	0.155	0.007	0.007	0.009	6.10	6.86	98.3
S4.4	1	516	47.5	1808	2372	8.85	1.17	0.09	1.19	0.202	0.344	0.003	0.520	0.330	0.010	0.256	0.012	0.012	0.014	10.04	11.29	98.3
S4.2	2	483	45.6	1801	2330	8.31	1.10	0.09	1.11	0.189	0.323	0.003	0.488	0.310	0.009	0.240	0.011	0.011	0.014	9.42	10.60	98.3
S4.6	1	514	49.4	1813	2376	8.67	1.14	0.09	1.16	0.198	0.337	0.003	0.509	0.323	0.009	0.250	0.011	0.011	0.014	9.83	11.06	98.3
S4.1	1	489	45.5	1802	2336	9.25	1.22	0.10	1.24	0.211	0.359	0.003	0.544	0.345	0.010	0.267	0.012	0.012	0.015	10.49	11.81	98.1
S8.1	1	510	50.6	1838	2399	9.95	1.31	0.10	1.33	0.164	0.277	0.003	0.382	0.225	0.010	0.232	0.013	0.012	0.015	11.29	12.70	98.0
S8.2	1	389	38.1	1435	1862	7.93	1.04	0.08	1.06	0.130	0.220	0.002	0.305	0.179	0.008	0.185	0.011	0.010	0.012	8.99	10.12	98.0
S1.8	1	2338	0.0	0	2338	54.59	7.20	0.56	7.31	0.898	1.518	0.015	2.098	1.235	0.055	1.273	0.073	0.066	0.082	61.90	69.66	97.7
S6.3	1	808	72.9	1472	2353	19.84	2.62	0.20	2.66	0.326	0.552	0.005	0.762	0.449	0.020	0.463	0.027	0.024	0.030	22.50	25.32	97.5
S6.3	2	845	77.5	1473	2395	21.02	2.77	0.22	2.82	0.346	0.585	0.006	0.808	0.475	0.021	0.490	0.028	0.025	0.032	23.83	26.82	97.5
S6.3	3	861	79.7	1477	2417	22.41	2.95	0.23	3.00	0.369	0.623	0.006	0.861	0.507	0.022	0.523	0.030	0.027	0.034	25.41	28.60	97.4
S3.5	2	197	19.6	715	932	5.54	0.73	0.06	0.74	0.091	0.154	0.002	0.213	0.125	0.006	0.129	0.007	0.007	0.008	6.29	7.08	97.2
S8.3	1	293	29.3	1089	1411	9.49	1.25	0.10	1.27	0.156	0.264	0.003	0.365	0.215	0.010	0.221	0.013	0.011	0.014	10.76	12.11	96.8
S4.1	3	491	45.0	1800	2335	18.10	2.39	0.19	2.42	0.298	0.503	0.005	0.695	0.409	0.018	0.422	0.024	0.022	0.027	20.52	23.09	96.3
S11.1	1	498	50.5	1806	2354	19.69	2.60	0.20	2.64	0.324	0.548	0.005	0.757	0.445	0.020	0.459	0.027	0.024	0.030	22.33	25.13	96.0
S4.1	2	484	45.2	1801	2330	19.32	2.55	0.20	2.59	0.318	0.538	0.005	0.743	0.437	0.019	0.451	0.026	0.023	0.029	21.91	24.66	96.0
S5.1	2	314	32.3	578	924	13.02	1.72	0.13	1.74	0.214	0.362	0.004	0.500	0.295	0.013	0.304	0.018	0.016	0.020	14.77	16.62	95.9
S10.1	1	494	49.3	1804	2348	20.82	2.74	0.21	2.79	0.342	0.579	0.006	0.800	0.471	0.021	0.486	0.028	0.025	0.031	23.61	26.56	95.8
S3.5	1	191	18.6	711	920	8.10	1.07	0.08	1.09	0.133	0.225	0.002	0.311	0.183	0.008	0.189	0.011	0.010	0.012	9.19	10.34	95.7
S5.6	1	317	32.2	581	930	14.70	1.94	0.15	1.97	0.242	0.409	0.004	0.565	0.333	0.015	0.343	0.020	0.018	0.022	16.67	18.76	95.4
S8.4	1	199	19.7	730	949	9.41	1.24	0.10	1.26	0.155	0.262	0.003	0.361	0.213	0.009	0.219	0.013	0.011	0.014	10.67	12.01	95.3
S7.6	1	639	65.1	2324	3028	25.70	3.39	0.26	3.44	0.423	0.715	0.007	0.988	0.581	0.026	0.600	0.035	0.031	0.039	29.14	32.80	96.0
S5.1	3	309	31.6	574	915	15.79	2.08	0.16	1.52	0.255	0.314	0.033	0.419	0.241	0.013	0.197	0.017	0.016	0.011	17.30	19.55	94.9
S10.2	1	396	39.4	1441	1877	20.83	2.75	0.21	2.00	0.336	0.414	0.043	0.552	0.318	0.018	0.260	0.023	0.021	0.015	22.83	25.79	94.7
S8.5	1	165	15.8	562	743	8.70	1.15	0.09	0.84	0.141	0.173	0.018	0.231	0.133	0.007	0.108	0.009	0.009	0.006	9.53	10.77	94.7
S9.1	1	490	49.2	1824	2364	27.45	3.62	0.28	2.64	0.443	0.546	0.057	0.728	0.419	0.023	0.342	0.030	0.028	0.020	30.08	33.98	94.4
S11.2	1	396	40.2	1430	1866	22.64	2.98	0.23	2.17	0.366	0.451	0.047	0.600	0.345	0.019	0.282	0.025	0.023	0.016	24.82	28.03	94.3
S5.6	3	308	31.9	571	912	18.19	2.40	0.19	1.75	0.294	0.362	0.038	0.482	0.277	0.016	0.227	0.020	0.019	0.013	19.94	22.52	94.1
S5.6	2	312	31.8	577	921	18.63	2.46	0.19	1.79	0.301	0.371	0.039	0.494	0.284	0.016	0.232	0.020	0.019	0.013	20.42	23.07	94.0
S5.5	1	318	32.3	582	932	19.59	2.58	0.20	1.88	0.316	0.390	0.041	0.519	0.299	0.017	0.244	0.021	0.020	0.014	21.47	24.25	93.8
S9.2	1	398	41.7	1438	1877	24.62	3.24	0.25	2.36	0.398	0.490	0.051	0.653	0.375	0.021	0.307	0.027	0.025	0.018	26.98	30.48	93.8
S10.3	1	305	29.9	1087	1422	20.15	2.66	0.21	1.94	0.326	0.401	0.042	0.534	0.307	0.017	0.251	0.022	0.021	0.014	22.09	24.95	93.4
S7.1	1	499	52.6	1810	2362	29.66	3.91	0.30	2.85	0.479	0.590	0.062	0.786	0.452	0.025	0.370	0.032	0.030	0.021	32.50	36.72	94.1
S4.5	1	510	49.3	1806	2365	39.58	5.22	0.41	3.80	0.639	0.788	0.082	1.050	0.604	0.034	0.493	0.043	0.041	0.028	43.38	49.01	92.2
S7.2	2	398	39.9	1425	1863	28.30	3.73	0.29	2.72	0.457	0.563	0.059	0.750	0.432	0.024	0.353	0.031	0.029	0.020	31.02	35.04	92.9
S4.7	1	511	49.4	1810	2370	47.89	6.31	0.49	4.60	0.774	0.953	0.099	1.270	0.731	0.041	0.597	0.052	0.049	0.034	52.49	59.29	90.6
S3.2	2	193	19.5	710	922	18.56	2.45	0.19	1.78	0.300	0.369	0.039	0.492	0.283	0.016	0.231	0.020	0.019	0.013	20.34	22.98	90.4
S6.6	1	845	77.5	1471	2394	85.33	11.25	0.88	8.19	1.378	1.698	0.177	2.263	1.302	0.073	1.063	0.093	0.087	0.061	93.52	105.65	89.9
S11.3	1	297	29.9	1085	1412	29.95	3.95	0.31	2.88	0.484	0.596	0.062	0.794	0.457	0.026	0.373	0.033	0.031	0.021	32.82	37.08	89.9
S5.3	1	318	32.6	583	934	31.91	4.21	0.33	3.06	0.515	0.635	0.066	0.846	0.487	0.027	0.398	0.035	0.033	0.023	34.98	39.51	90.0

Table F-1. Emissions Measured During Propylene Steam Flare Tests for DRE (Propylen) > 60 %

Test Point	Run Number	Actual Vent Gas (VG) Flow Rates							Total Other VOCs	Other VOCs (lb/hr)										TVOC	THC	ARI
		Propylene lbs/hr	TNG lbs/hr	Nitrogen lbs/hr	Total lbs/hr	Propylene lb/hr	Methane lb/hr	Ethane lb/hr	lb/hr	Acetylene	Ethylene	Butene isomers	Formaldehyde	Acetaldehyde	Propanal	Acrolein	Methanol	Acetone	Propylene-Oxide	lb/hr	lb/hr	DRE (%)
S7.1	2	499	47.9	1806	2353	47.20	6.22	0.49	4.53	0.762	0.939	0.098	1.252	0.720	0.040	0.588	0.051	0.048	0.034	51.73	58.44	90.5
S9.3	1	306	29.9	1089	1425	32.39	4.27	0.33	3.11	0.523	0.644	0.067	0.859	0.494	0.028	0.404	0.035	0.033	0.023	35.50	40.10	89.4
S5.3	2	312	31.7	578	922	33.76	4.45	0.35	3.24	0.545	0.672	0.070	0.895	0.515	0.029	0.421	0.037	0.035	0.024	37.00	41.80	89.2
S1.9	1	2337	0.0	0	2337	263.34	34.71	2.71	25.29	4.253	5.240	0.547	6.983	4.017	0.225	3.282	0.287	0.270	0.187	288.63	326.04	88.7
S6.4	2	863	78.4	1473	2414	98.33	12.96	1.01	9.44	1.588	1.957	0.204	2.608	1.500	0.084	1.225	0.107	0.101	0.070	107.78	121.75	88.6
S5.3	3	307	31.6	572	911	37.76	4.98	0.39	3.63	0.610	0.751	0.078	1.001	0.576	0.032	0.471	0.041	0.039	0.027	41.38	46.75	87.7
S10.4	1	206	19.8	716	942	25.62	3.38	0.26	2.46	0.414	0.510	0.053	0.679	0.391	0.022	0.319	0.028	0.026	0.018	28.08	31.72	87.6
S7.2	3	379	39.0	1420	1838	46.58	6.14	0.48	4.47	0.752	0.927	0.097	1.235	0.711	0.040	0.580	0.051	0.048	0.033	51.05	57.67	87.7
S6.4	3	859	79.6	1479	2418	116.59	15.37	1.20	11.20	1.883	2.320	0.242	3.092	1.778	0.100	1.453	0.127	0.119	0.083	127.78	144.35	86.4
S4.8	1	509	48.7	1809	2367	69.20	9.12	0.71	6.65	1.118	1.377	0.144	1.835	1.056	0.059	0.862	0.075	0.071	0.049	75.84	85.67	86.4
S7.2	1	392	39.5	1443	1874	56.05	7.39	0.58	5.38	0.905	1.115	0.116	1.486	0.855	0.048	0.699	0.061	0.057	0.040	61.43	69.40	85.7
S11.4	1	202	20.3	724	946	31.43	4.14	0.32	3.02	0.508	0.625	0.065	0.834	0.480	0.027	0.392	0.034	0.032	0.022	34.45	38.92	84.4
S9.4	1	207	19.9	717	944	41.96	5.53	0.43	2.12	0.436	0.381	0.307	0.429	0.227	0.022	0.246	0.033	0.027	0.011	44.08	50.04	79.8
S4.9	1	510	49.8	1811	2371	103.43	13.63	1.06	5.22	1.075	0.938	0.757	1.058	0.559	0.055	0.606	0.081	0.066	0.028	108.65	123.34	79.7
S7.3	1	286	29.8	1083	1399	62.79	8.28	0.65	3.17	0.653	0.570	0.460	0.642	0.339	0.033	0.368	0.049	0.040	0.017	65.96	74.89	78.1
S9.5	1	163	15.4	560	739	39.21	5.17	0.40	1.98	0.408	0.356	0.287	0.401	0.212	0.021	0.230	0.031	0.025	0.010	41.19	46.76	76.0
S6.4	1	816	78.8	1453	2347	198.60	26.18	2.04	10.03	2.065	1.802	1.454	2.032	1.074	0.106	1.163	0.155	0.127	0.053	208.63	236.85	75.6
S7.3	2	297	29.9	1084	1410	77.83	10.26	0.80	3.93	0.809	0.706	0.570	0.796	0.421	0.041	0.456	0.061	0.050	0.021	81.76	92.82	73.8
S4.10	1	511	51.1	1814	2376	149.32	19.68	1.54	7.54	1.553	1.355	1.093	1.528	0.807	0.079	0.874	0.116	0.095	0.040	156.87	178.08	70.8
S5.4	1	318	32.2	579	929	99.85	13.16	1.03	5.04	1.038	0.906	0.731	1.022	0.540	0.053	0.585	0.078	0.064	0.027	104.90	119.08	68.6
S5.4	2	311	31.3	576	918	105.84	13.95	1.09	5.34	1.101	0.960	0.775	1.083	0.572	0.056	0.620	0.083	0.068	0.028	111.18	126.22	66.0
S5.4	3	304	31.2	567	901	104.99	13.84	1.08	5.30	1.092	0.953	0.768	1.074	0.568	0.056	0.615	0.082	0.067	0.028	110.29	125.21	65.4
S7.5	1	234	25.4	921	1180	88.28	11.64	0.91	4.46	0.918	0.801	0.646	0.903	0.477	0.047	0.517	0.069	0.056	0.023	92.74	105.28	62.3

Table F-2. Emissions Measured During Propylene Air Flare Test for DRE (Propylene) > 60 %

Test Point	Run Number	Actual Vent Gas (VG) Flow Rates							Total	Other VOCs (lb/hr)												
		Propylene	TNG	Nitrogen	Total	Propylene	Methane	Ethane	Other VOCs	Acetylene	Ethylene	Butene isomers	Formaldehyde	Acetaldehyde	Propanal	Acrolein	Methanol	Acetone	Propylene-Oxide	TVOC	THC	ARI DRE (%)
		lbs/hr	lbs/hr	lbs/hr	lbs/hr	lb/hr	lb/hr	lb/hr	lb/hr											lb/hr	lb/hr	
A6.1	1	118	11.9	221	351	0.35	0.05	0.00	0.07	0.022	0.011	0.000	0.016	0.011	0.000	0.006	0.001	0.000	0.001	0.41	0.46	99.71
A6.1	2	118	12.3	221	352	0.43	0.06	0.00	0.08	0.027	0.013	0.000	0.020	0.013	0.000	0.008	0.001	0.000	0.001	0.51	0.58	99.64
A3.1	2	181	18.8	703	903	0.79	0.10	0.01	0.15	0.049	0.024	0.000	0.037	0.024	0.001	0.015	0.002	0.001	0.001	0.94	1.05	99.56
A6.1	3	118	12.3	222	352	0.68	0.09	0.01	0.13	0.043	0.021	0.000	0.032	0.021	0.001	0.013	0.001	0.001	0.001	0.82	0.92	99.42
A4.6	1	297	30.3	594	921	1.74	0.23	0.02	0.34	0.109	0.053	0.000	0.081	0.053	0.002	0.032	0.004	0.002	0.003	2.08	2.32	99.41
A3.1	3	181	18.6	702	902	1.82	0.24	0.02	0.35	0.114	0.056	0.000	0.084	0.056	0.002	0.034	0.004	0.002	0.003	2.17	2.43	99.00
A4.1	3	298	30.3	594	923	5.08	0.67	0.05	0.99	0.318	0.156	0.001	0.236	0.156	0.005	0.095	0.010	0.006	0.007	6.08	6.80	98.29
A4.1	1	315	31.6	591	937	5.91	0.78	0.06	1.15	0.370	0.182	0.001	0.274	0.182	0.006	0.110	0.012	0.007	0.009	7.07	7.91	98.12
A1.1	1	919	0.0	0	919	18.00	2.37	0.19	3.51	1.126	0.553	0.004	0.834	0.554	0.017	0.336	0.036	0.021	0.026	21.51	24.07	98.04
A6.3	1	118	12.1	221	351	2.38	0.31	0.02	0.32	0.109	0.049	0.000	0.072	0.046	0.002	0.034	0.003	0.002	0.002	2.70	3.04	97.98
A3.1	1	183	18.4	701	903	3.71	0.49	0.04	0.50	0.170	0.077	0.001	0.112	0.071	0.003	0.053	0.005	0.003	0.004	4.21	4.74	97.98
A2.1	1	352	0.0	0	352	7.60	1.00	0.08	1.02	0.348	0.157	0.001	0.230	0.146	0.005	0.108	0.011	0.006	0.008	8.62	9.70	97.84
A5.1	3	71	7.6	272	351	1.82	0.24	0.02	0.24	0.083	0.038	0.000	0.055	0.035	0.001	0.026	0.003	0.002	0.002	2.07	2.33	97.44
A4.1	2	299	32.2	591	922	7.93	1.05	0.08	1.06	0.363	0.164	0.001	0.240	0.152	0.006	0.113	0.011	0.007	0.008	9.00	10.12	97.35
A2.1	2	355	0.0	0	355	10.19	1.34	0.10	1.37	0.466	0.211	0.002	0.309	0.196	0.007	0.145	0.014	0.009	0.011	11.56	13.00	97.13
A5.1	2	75	7.4	273	355	2.21	0.29	0.02	0.30	0.101	0.046	0.000	0.067	0.043	0.002	0.031	0.003	0.002	0.002	2.51	2.83	97.03
A6.3	3	119	12.4	221	353	3.88	0.51	0.04	0.52	0.177	0.080	0.001	0.118	0.074	0.003	0.055	0.005	0.003	0.004	4.40	4.95	96.75
A2.1	3	355	0.0	0	355	12.02	1.58	0.12	1.61	0.550	0.248	0.002	0.364	0.231	0.008	0.171	0.017	0.010	0.013	13.63	15.34	96.62
A3.5	1	181	18.4	701	901	6.25	0.82	0.06	0.84	0.286	0.129	0.001	0.190	0.120	0.004	0.089	0.009	0.005	0.007	7.09	7.98	96.55
A6.3	2	118	12.2	221	351	4.17	0.55	0.04	0.56	0.191	0.086	0.001	0.126	0.080	0.003	0.059	0.006	0.003	0.004	4.73	5.32	96.47
A2.3	1	352	0.0	0	352	13.60	1.79	0.14	1.83	0.622	0.281	0.002	0.412	0.261	0.009	0.193	0.019	0.011	0.014	15.43	17.36	96.14
A4.3	1	300	30.6	592	922	11.80	1.56	0.12	1.58	0.539	0.244	0.002	0.358	0.226	0.008	0.168	0.017	0.010	0.012	13.38	15.06	96.07
A2.5	3	355	0.1	0	355	14.66	1.93	0.15	1.97	0.670	0.303	0.002	0.444	0.281	0.010	0.208	0.021	0.012	0.015	16.63	18.71	95.87
A4.3	3	298	30.5	593	921	12.40	1.64	0.13	1.67	0.567	0.256	0.002	0.376	0.238	0.009	0.176	0.017	0.010	0.013	14.07	15.83	95.83
A5.5	3	72	7.5	272	351	3.25	0.43	0.03	0.44	0.149	0.067	0.001	0.099	0.062	0.002	0.046	0.005	0.003	0.003	3.69	4.15	95.45
A2.5	1	355	0.0	0	355	17.55	2.31	0.18	2.36	0.802	0.363	0.003	0.532	0.337	0.012	0.250	0.025	0.015	0.018	19.90	22.40	95.05
A5.1	1	73	7.6	275	356	3.81	0.50	0.04	0.44	0.165	0.068	0.006	0.094	0.055	0.003	0.038	0.006	0.003	0.002	4.25	4.79	94.78
A2.4	3	354	0.0	0	354	18.62	2.45	0.19	2.15	0.807	0.335	0.031	0.460	0.271	0.012	0.184	0.029	0.015	0.010	20.77	23.42	94.74
A6.2	1	118	12.1	221	352	6.23	0.82	0.06	0.72	0.270	0.112	0.010	0.154	0.091	0.004	0.062	0.010	0.005	0.003	6.95	7.83	94.74
A2.5	2	353	0.0	0	353	19.97	2.63	0.21	2.31	0.865	0.359	0.033	0.493	0.291	0.013	0.198	0.031	0.016	0.011	22.28	25.12	94.35
A6.4	3	119	12.4	221	352	6.80	0.90	0.07	0.79	0.295	0.122	0.011	0.168	0.099	0.005	0.067	0.011	0.005	0.004	7.58	8.55	94.27
A6.4	2	118	12.4	222	352	6.98	0.92	0.07	0.81	0.303	0.126	0.012	0.172	0.102	0.005	0.069	0.011	0.006	0.004	7.79	8.78	94.10
A5.5	2	71	7.4	273	352	4.32	0.57	0.04	0.50	0.187	0.078	0.007	0.107	0.063	0.003	0.043	0.007	0.003	0.002	4.82	5.43	93.96
A4.3	2	299	30.3	591	920	19.12	2.52	0.20	2.21	0.829	0.344	0.032	0.472	0.279	0.013	0.189	0.030	0.015	0.011	21.33	24.05	93.60
A5.5	1	72	7.6	274	353	5.59	0.74	0.06	0.65	0.242	0.101	0.009	0.138	0.081	0.004	0.055	0.009	0.004	0.003	6.24	7.03	92.20
A2.4	1	353	0.0	0	353	27.58	3.64	0.28	3.19	1.196	0.496	0.046	0.681	0.402	0.018	0.273	0.043	0.022	0.015	30.78	34.70	92.18
A2.4	2	354	0.0	0	354	28.44	3.75	0.29	3.29	1.233	0.511	0.047	0.702	0.414	0.019	0.282	0.044	0.023	0.016	31.73	35.77	91.97
A3.6	1	181	18.6	701	901	14.99	1.98	0.15	1.73	0.650	0.270	0.025	0.370	0.218	0.010	0.148	0.023	0.012	0.008	16.73	18.86	91.73
A4.4	3	297	30.7	595	923	25.11	3.31	0.26	2.91	1.088	0.451	0.041	0.620	0.366	0.017	0.249	0.039	0.020	0.014	28.01	31.58	91.56
A3.6	2	181	18.8	704	904	15.30	2.02	0.16	1.77	0.663	0.275	0.025	0.378	0.223	0.010	0.152	0.024	0.012	0.009	17.07	19.24	91.56
A4.4	1	301	30.6	594	926	27.22	3.59	0.28	3.15	1.180	0.489	0.045	0.672	0.397	0.018	0.270	0.043	0.022	0.015	30.37	34.24	90.96
A4.4	2	297	30.4	591	919	27.86	3.67	0.29	3.22	1.208	0.501	0.046	0.688	0.406	0.019	0.276	0.044	0.022	0.016	31.09	35.05	90.62
A6.4	1	118	12.1	221	351	11.35	1.50	0.12	1.31	0.492	0.204	0.019	0.280	0.165	0.008	0.112	0.018	0.009	0.006	12.66	14.27	90.39
A3.6	3	181	18.2	702	901	19.88	2.62	0.20	2.30	0.861	0.357	0.033	0.491	0.290	0.013	0.197	0.031	0.016	0.011	22.18	25.00	89.03
A4.5	3	299	30.9	595	925	34.33	4.52	0.35	3.97	1.488	0.617	0.057	0.847	0.500	0.023	0.340	0.054	0.027	0.019	38.30	43.18	88.52
A3.3	1	181	18.4	701	900	21.53	2.84	0.22	2.49	0.933	0.387	0.036	0.532	0.314	0.014	0.213	0.034	0.017	0.012	24.02	27.08	88.12
A6.5	1	118	12.1	221	351	14.24	1.88	0.15	1.65	0.617	0.256	0.024	0.352	0.208	0.010	0.141	0.022	0.011	0.008	15.89	17.92	87.91
A4.5	1	299	30.1	592	922	36.75	4.84	0.38	4.25	1.593	0.661	0.061	0.907	0.536	0.025	0.364	0.057	0.029	0.020	41.00	46.22	87.72
A5.3	2	72	7.5	273	352	9.01	1.19	0.09	1.04	0.390	0.162	0.015	0.222	0.131	0.006	0.089	0.014	0.007	0.005	10.05	11.33	87.54
A4.5	2	300	30.3	594	924	37.96	5.00	0.39	4.39	1.645	0.683	0.063	0.937	0.553	0.025	0.376	0.059	0.030	0.021	42.36	47.75	87.34

Table F-2. Emissions Measured During Propylene Air Flare Test for DRE (Propylene) > 60 %

Test Point	Run Number	Actual Vent Gas (VG) Flow Rates							Total	Other VOCs (lb/hr)												
		Propylene	TNG	Nitrogen	Total	Propylene	Methane	Ethane	Other VOCs	Acetylene	Ethylene	Butene isomers	Formaldehyde	Acetaldehyde	Propanal	Acrolein	Methanol	Acetone	Propylene-Oxide	TVOC	THC	ARI DRE (%)
		lbs/hr	lbs/hr	lbs/hr	lbs/hr	lb/hr	lb/hr	lb/hr	lb/hr											lb/hr	lb/hr	
A5.4	1	72	7.5	274	354	11.74	1.55	0.12	1.36	0.509	0.211	0.019	0.290	0.171	0.008	0.116	0.018	0.009	0.007	13.09	14.76	83.64
A4.2	1	299	30.3	591	920	49.50	6.52	0.51	5.73	2.145	0.890	0.082	1.222	0.721	0.033	0.490	0.077	0.040	0.028	55.22	62.26	83.43
A6.6	1	119	12.4	221	352	20.75	2.73	0.21	2.40	0.899	0.373	0.034	0.512	0.302	0.014	0.205	0.032	0.017	0.012	23.15	26.09	82.50
A5.3	3	71	7.5	271	350	12.63	1.67	0.13	1.46	0.548	0.227	0.021	0.312	0.184	0.008	0.125	0.020	0.010	0.007	14.10	15.89	82.27
A5.3	1	72	7.5	274	354	13.53	1.78	0.14	1.57	0.586	0.243	0.022	0.334	0.197	0.009	0.134	0.021	0.011	0.008	15.10	17.02	81.23
A3.4	1	181	18.3	701	900	41.86	5.52	0.43	2.58	0.912	0.388	0.201	0.531	0.288	0.017	0.161	0.049	0.020	0.008	44.43	50.38	76.90
A3.4	2	181	18.5	704	903	42.49	5.60	0.44	2.61	0.926	0.394	0.204	0.539	0.292	0.017	0.163	0.050	0.021	0.009	45.10	51.14	76.56
A3.4	3	181	18.5	702	902	42.85	5.65	0.44	2.64	0.934	0.397	0.206	0.543	0.295	0.017	0.165	0.050	0.021	0.009	45.49	51.58	76.36
A5.2	1	72	7.7	274	354	22.64	2.98	0.23	1.39	0.493	0.210	0.109	0.287	0.156	0.009	0.087	0.027	0.011	0.005	24.03	27.25	68.68
A3.2	2	181	18.8	702	902	59.65	7.86	0.61	3.67	1.300	0.553	0.286	0.756	0.411	0.024	0.229	0.070	0.029	0.012	63.32	71.80	67.08
A3.2	1	181	17.9	699	898	63.87	8.42	0.66	3.93	1.392	0.592	0.307	0.810	0.440	0.026	0.245	0.075	0.031	0.013	67.80	76.88	64.76
A3.2	3	181	18.6	702	902	65.52	8.64	0.67	4.03	1.428	0.608	0.315	0.831	0.451	0.026	0.252	0.077	0.032	0.013	69.55	78.86	63.85

Appendix G

Method of Determining Vent Gas Composition and Flow Rate

Method Used to Determine Actual Vent Gas Composition and Flow Rate

The test matrix was designed so that changes in the vent gas composition and flow rate occurred only when desired, i.e., between test runs when there was sufficient time for the vent gas flow to reach stable conditions before the next test run began or at the start or end of the day when no tests were occurring. The design of the instrumentation used to measure these two parameters was also critical so that accurate data could be provided for the carbon balance analysis. The vent gas composition was always composed of a combination of either propylene or propane and Tulsa natural gas and nitrogen. Therefore the method used determines the actual concentration and flow rate of each component.

Composition

To determine the composition of the flow to the flare, a sampling line (1/16" internal diameter) continuously extracted 1 liter per minute from the vent gas flow line. The sample extraction line was connected to the vent gas line immediately prior to the vent gas entering the base of the flare. The sample line was insulated and shielded to prevent heating from the flare. The sampling line went to the TRC mobile laboratory. The sample was not diluted in the line. Once every five minutes during a test, this sample line was directed to a gas chromatograph (GC) in the TRC mobile laboratory dedicated to analysis of the vent gas for this study. The GC would provide two analyses of the vent gas flow during each test run. The average of these two analyses were used to calculate the vent gas composition for each test run. These analyses provided volume concentrations of propylene or propane, methane and ethane.

In addition to the TRC GC gas analyses, a sample of the Tulsa natural gas (TNG) was taken and analyzed by J-W Measurement Company, a local analytical laboratory in Tulsa, Oklahoma every day that natural gas was used for a test run. The GC analysis conducted by the J-W Measurement Company provided mol percent concentrations for constituents in the TNG, which included methane, ethane, propane, butanes, pentanes, hexanes, nitrogen, and carbon dioxide. The TNG analyses were used to determine the ratio of the mol percent of the other components in the natural gas to the mol percent of ethane in the natural gas. Since the ethane volume concentration in the vent gas flow was measured by TRC, the ratios of the mol percents of the other components in the natural gas were used to determine the volume concentrations of the other TNG constituents in the vent gas flow using Equation G.1.

$$\text{Volume Concentration } (X)_{VG} = \frac{\text{mol \% } (\text{X})_{\text{TNG}}}{\text{mol \% (ethane)}_{\text{TNG}}} \times \text{Volume Concentration (ethane)}_{\text{VG}}$$

Eq. G.1

where

Volume Concentration $(X)_{VG}$ = the volume concentration (%) of species X in the vent gas flow
mol % $(X)_{TNG}$ = the mol % of species X per the TNG analysis of J-W Measurement Company
mol % $(ethane)_{TNG}$ = the mol % of ethane per the TNG analysis of J-W Measurement Company

Volume Concentration $(\text{ethane})_{VG}$ = the volume concentration (%) of ethane in the vent gas flow as measured by TRC

Once the volume concentrations of propylene or propane, methane, ethane (from TRC), and each of the species listed in the TNG analysis were determined using Equation G.1, the volume concentration of nitrogen was then assumed to be the balance of the flow since it was the only other component in the vent gas.

Vent Gas Flow Rate

The John Zink Company measured the flow rates of propylene, propane, TNG and nitrogen using orifice plates. The accuracies of these plates were: propylene/propane = ± 27 lb/hr, TNG = ± 1 lb/hr and nitrogen = ± 19 lb/hr. The most accurate of these orifice plates for the range of flows that would be used was the nitrogen plate with accuracies ranging from 8.6% at the low nitrogen flow rate of 221 lb/hr and 1.1% at the higher flow rates of 1800 lb/hr. Since the nitrogen flow always represented the largest flow rate of the constituents in the vent gas, the nitrogen flow rate was used for the nitrogen flow and the flow rate of the other constituents, which contained the carbon compounds, would be determined using the ratio of their volume concentration to that of nitrogen using Equation G.2.

$$\text{Flow rate } (X)_{VG} = \frac{\text{Vol \% } (X)_{VG}}{\text{Vol \% (Nitrogen)}_{VG}} \times \frac{\text{MW } (X)}{\text{MW (Nitrogen)}} \times \text{Flow rate (Nitrogen)}_{VG} \qquad \text{Eq. G.2}$$

where

Flow rate $(X)_{VG}$ = flow rate of vent gas component X, lb/hr
Vol % $(X)_{VG}$ = volume concentration (%) of vent gas component X as determined from either Eq. G.1 or as measured by TRC
Vol % $(\text{Nitrogen})_{VG}$ = volume concentration (%) of nitrogen as determined above
MW (X) = molecular weight of component X, lb/lb-mol
MW (Nitrogen) = molecular weight of nitrogen, lb/lb-mol
Flow rate $(\text{Nitrogen})_{VG}$ = flow rate of nitrogen, lb/hr, measured by John Zink Company

Using this approach, the carbon fractions used would be those measured directly using GC analysis and the flow rates would be proportional to the vent gas component with the largest flow rate.

Estimation of Uncertainty in Vent Gas Flow Rates

In order to assess the propagation of errors in estimating the make-up of waste and carrier/diluent gases comprising the vent gas going to the flare, the following steps were taken. First, an assumption was made that the vent gas would be composed only as follows:

- Tulsa natural gas (TNG), propane waste gas, and nitrogen diluent gas; or
- TNG, propylene (propene) waste gas, and nitrogen diluent gas.

The mass flows are shown in Figure G-1. Note that propane will always be in the mass flow as a small constituent of TNG, and propylene (propene) will only be introduced from the propylene standard. In addition, the mass flow for the nitrogen diluent will always exceed the combined mass flow for TNG and propane or propene.

The uncertainty in flow estimates was incorporated as follows. The measured flow rate of nitrogen was assumed to be accurate to ±19 lb/hour, regardless of actual flow rate. This confidence interval was assumed to be interpretable as saying that if the programmed mass flow is set at N lbs/hour, then we believe that the probability is at least 95 percent that the actual mass flow is no more than 19 lbs/hour higher or lower of the value N lb/hour. The auto-GC measurements of propane (or propylene) and the TNG species (methane, ethane, and other alkanes) were assumed to be accurate to either ±10 percent of the measured concentration as per the stated compliance with EPA method 18 (VOC by GC), or ± 200 ppm for each species based on TRC's quality assurance work. As described above, ± 200 ppm 95 percent confidence interval for, say, ethane, means one is 95 percent confident that the true ethane concentration is within 200 ppm of the measured ethane concentration.

A further assumption was that the assessment of the TNG composition from J-W Measurement Company was known with no uncertainty. An example of TNG composition on a molar basis, is shown in Table G-1. The mole percentages may have varied from sample to sample, but the example shown in Table G-1 was used for this assessment. Because nitrogen gas was used as a diluent, and the mass flow for nitrogen gas diluent always exceeded the combined flow for TNG, the contribution of nitrogen from TNG to the total mass flow for nitrogen was small. One lb of TNG has 0.5 mol of N_2, and one lb of N_2 diluent has 16.2 mol of N_2, so given one lb of each the TNG contributes less than 3 percent. Recall, however, that the amount of N_2 diluent always exceeds TNG, further constraining the N_2 contribution from TNG. Similarly, because propane was used as a test gas, it is assumed that if it was employed in a test run it always exceeded the mass flow for propane in TNG, so the contribution of propane from TNG to the total mass flow for propane was small. One lb of TNG has 0.09 mol of propane, and one lb of propane gas has 10.29 mol of propane, so given one lb of each the TNG contributes less than 1 percent.

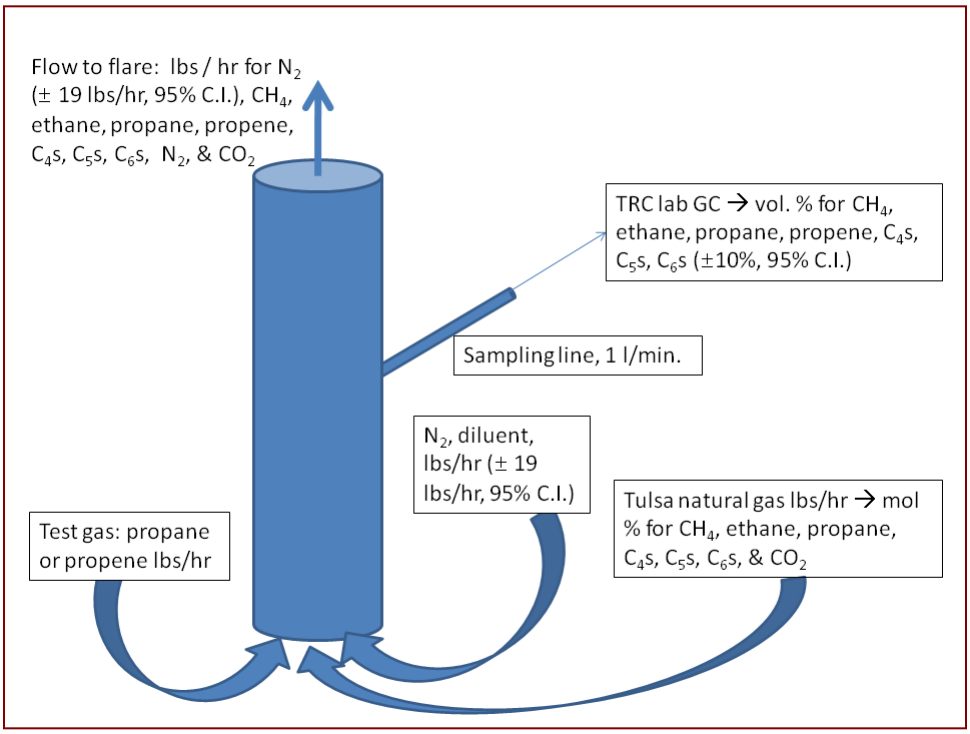


Figure G-1. Mass flow model for TNG, propane (or propylene), and nitrogen gas

Table G-1. Tulsa natural gas composition by mol percentage

Species	Mol %	Mol in 1lb TNG
methane	93.7933	25.03717
ethane	3.5259	0.94120
propane	0.3448	0.09204
iso-butane	0.0189	0.00505
n-butane	0.0488	0.01303
iso-pentane	0.0053	0.00141
n-pentane	0.0068	0.00182
hexanes	0.0103	0.00275
CO_2	0.3114	0.08313
N_2	1.9345	0.51640
Total	100.0000	26.69

Equations G.1 and G.2 were coded into a Monte Carlo simulation program that stepped through five N_2 flow rates, four propane (or propene) volume percent concentrations, and four ethane volume percent concentrations (representing TNG) in the Figure G-1 scenario. The trial N_2 flow rates and hydrocarbon volume percent concentrations are in Table G-2. The uncertainty in N_2 flow rate was treated during each iteration in the simulation by adding a random shock value from a standard normal distribution with mean zero and standard deviation of 9.69 lb/hour. This

was based on the assumed 19 lb/hour 95 percent confidence interval, which implies one standard deviation of 19/1.96 = 9.69 lb/hour. Similarly, the ± 10 percent uncertainty in the propane, propene, and ethane concentrations as measured by the TRC auto-GC were treated in the simulation by adding a random shock value from a standard normal distribution with mean zero and standard deviation of 5.1 percent based on the 10 percent 95 percent confidence interval (10/1.96 = 5.10). The ± 200 ppm uncertainty posited by TRC is addressed separately at the end of this section.

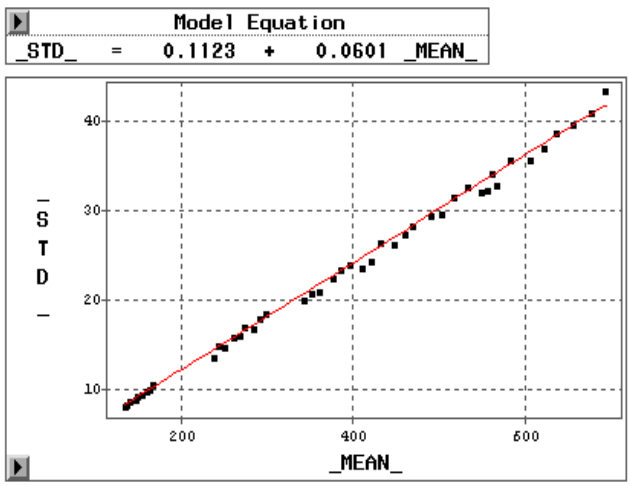
Table G-2. Base flow and base volume percentages (before random shocks)

Level	N_2 lb/hour	Propane %	Propene %	Ethane %
1	560	0.0	0.0	0.0
2	1,001	12.73	14.32	0.1132
3	1,442	13.77	20.43	0.1865
4	1,883	14.81	26.54	0.2598
5	2,324			

The Monte Carlo simulation results are probability distributions for the mass flow rates for the various species created for each of the 80 different combinations of N_2, propane, and ethane, and for each of the 80 different combinations of N_2, propene, and ethane. The statistical summary of each distribution provides a heuristic estimation of the results of having propagated the errors in nitrogen diluent flow estimation and the TRC auto-GC hydrocarbon measurement. The simulations were run for 1,000 trials at each combination of a hydrocarbon level and a nitrogen level from Table G-2 in order to estimate the resulting mass flow in lb/hour for each species under each of the combinations. The sample statistics on species mass flow were then calculated, and the resulting means and standard deviations have been graphed in Figures G-2, G-3, and G-4. The mean value for each combination of species represents the expected value for the mass flow under that combination, and the standard deviation represents the uncertainty imparted by the earlier described uncertainty in N_2 mass flow and hydrocarbon auto-GC measurements. Figure G-2 shows the regression fit for the standard deviation for 1,000 trials at 80 combinations of N_2, propane, and ethane (which implies TNG) from Table G-2. The figure shows a near perfect straight line fit for sample standard deviation as a function of sample mean for propane lbs/hour mass flow rate. Similar results appear in Figures G-3 (for propene) and 4 (for ethane). The results for ethane were more scattered with propane than with propene, so the propane related fit is used. The results for ethane are directly extendable to the other natural gas hydrocarbons. A summary of the results appears in Table G-3.

Figures G-2, G-3, and G-4 show the results of fitting a variable representing the *spread* of values (STD) against the *average* value for mass flow (MEAN) at 80 different points described above. Additional statistics for the fit of the line using ordinary least squares (OLS) also appear in the figures. The *Model Equation* in each figure provides the best fit linear equation for STD as a function of MEAN. Under the *Summary of Fit*, the *Mean of Response* is the average value of STD across all 80 observations. In Figure G-2, the model is STD = 0.1414 + 0.595 MEAN. One can think of the difference between the left and right sides of this equation being the *error* in the

model fit at a given point. The *Root MSE* (mean square error) is the standard deviation of this error calculated from the model, so the smaller the value, the better the fit. *R-Square* is percentage of the amount of variation in the y-variable that is reduced by the line fit – i.e., 1 minus the ratio of the variance of the residuals in the regression to the actual variance in the y-value. A perfect fit has R-Square = 1.0. The *Adj R-Sq* applies a factor in more complicated models, but is equal to R-Square in this one-variable regression model. The *Parameter Estimates* table shows the statistical significance for the slope and intercept in the linear model. The *t Stat* is the number of standard deviations away from a "no effect" response for a parameter, and it is directly related to the *p-Value* representing the probability that "no response" would generate a parameter value as large as the one calculated. Thus, a low p-value (< 0.05) suggests the probability of observing a slope as large as 0.0595, in Figure G-2, if there really is no relationship between STD and MEAN, is very small, in this case < 0.0001. In contrast, the t Stat for the intercept is small, and the p-value is > 0.05, suggesting the intercept is not statistically significantly different from zero.



Model Equation

STD = 0.1123 + 0.0601 _MEAN_

Parameter Estimates

Variable	DF	Estimate	Std Error	t Stat	Pr >|t|
Intercept	1	0.1123	0.2214	0.51	0.6146
MEAN	1	0.0601	0.0005	114.70	<.0001

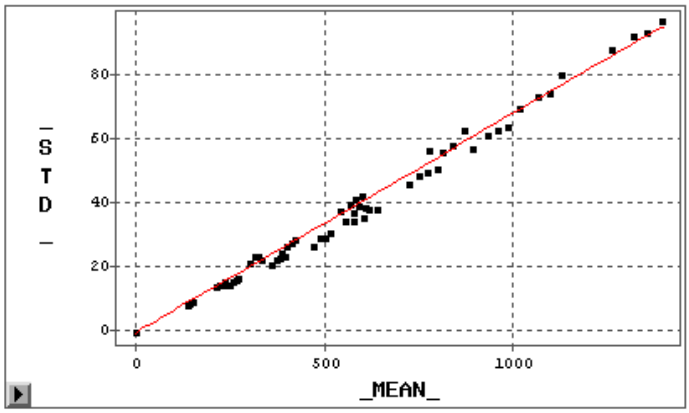
Summary of Fit

Mean of Response	23.3605	R-Square	0.9967
Root MSE	0.5984	Adj R-Sq	0.9967

Figure G-2. Regression fit for the standard deviation of random-shocked *propane* mass flow lb/hour as a function of the mean expected mass flow. Slope = 1/16.6, 95% C.I. = ± 11.8%

Model Equation

STD = - 0.8825 + 0.0686 _MEAN_



Summary of Fit

Mean of Response	29.9731	R-Square	0.9939
Root MSE	2.0902	Adj R-Sq	0.9939

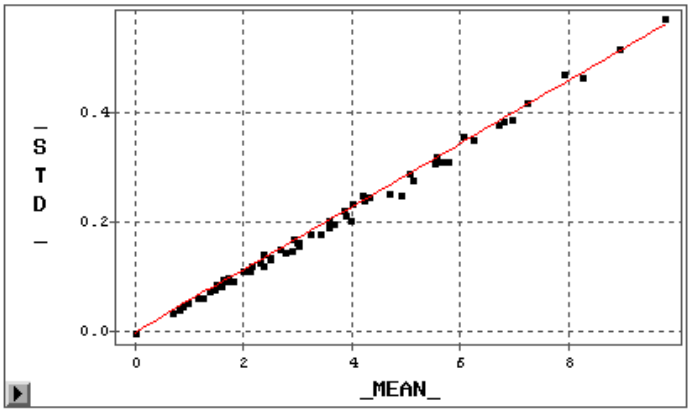
Parameter Estimates

Variable	DF	Estimate	Std Error	t Stat	Pr >|t|
Intercept	1	-0.8825	0.3591	-2.46	0.0162
MEAN	1	0.0686	0.0006	113.15	<.0001

Figure G-3. Regression fit for the standard deviation of random-shocked *propylene* mass flow lb/hour as a function of the mean expected mass flow. Slope = 1/14.6, 95% C.I. = ± 13.4%

Model Equation

STD = - 0.0020 + 0.0575 _MEAN_



Summary of Fit

Mean of Response	0.1586	R-Square	0.9973
Root MSE	0.0075	Adj R-Sq	0.9973

Parameter Estimates

Variable	DF	Estimate	Std Error	t Stat	Pr >|t|
Intercep	1	-0.0020	0.0013	-1.61	0.1115
MEAN	1	0.0575	0.0003	170.75	<.0001

Figure G-4. Regression fit for the standard deviation of random-shocked *ethane* mass flow lb/hour as a function of the mean expected mass flow. Slope=1/17.4, 95% C.I.=±11.3%

Table G-3. Summary results from slopes in Figures G-2, G-3, and G-4 converted to 95 percent confidence intervals on mass flow lb/hour

Species	Slope	1/slope	95% C.I.
propane	0.0899	16.8	11.7%
propene	0.1059	14.6	13.4%
ethane	0.0814	17.4	11.3%
methane, butanes, pentanes, hexanes	0.0814	17.4	11.3%

As was mentioned above, TRC's stated accuracy of the auto-GC instrument is expressed in absolute concentration terms of ± 200 ppm for each species. Also, as stated above, it was assumed that the composition of TNG was known with zero uncertainty. These two assumptions allow one to determine the mass flow uncertainty for all TNG species based on the measurement of methane, which is the largest component of TNG, and propane (or propene) and the mass flow measurement of the diluent. During the project, the measured volume percent of methane in mass flow ranged from 3.1106 to 6.2855 percent by volume. This related directly to a concentration range of 31,106 ppm to 62,855 ppm. A ± 200 ppm 95 percent confidence interval on the low end of this range is 0.645 percent. Thus, any of the TNG species concentrations would have confidence interval of less than 1 percent, and uncertainty for mass flow would be dominated by the uncertainty in the N_2 mass flow. At N_2 mass flow of 560 lb/hour, with uncertainty ±19 lb/hour, the diluent uncertainty represents 3.3 percent uncertainty in mass flow. At most 1 percent additional uncertainty is introduced based on independent error in the methane concentration, combining to produce an approximate ±5 percent uncertainty for species with fixed, known ratio to methane.

When propane or propylene are added to the mixture, and measured to ± 200 ppm 95 percent confidence interval by the auto-GC, then an error in mass flow can be assessed as follows. The volume concentration of propane ranged from 12.7291 to 14.8143 percent by volume, and propene ranged from 14.3194 to 26.5419 percent by volume. At 12.7291 percent of propane one has 12,729 ppm, with ± 200 ppm presenting 1.57 percent uncertainty, and at 14.3194 percent of propene one has 14,319 ppm, with ± 200 ppm presenting 1.40 percent uncertainty. Thus, assuming the ±200 ppm auto-GC accuracy and ±19 lb/hour N_2 flow accuracy, worst case mass flow for individual hydrocarbon species would likely be in range of ± 5 percent uncertainty (95 percent confidence interval).

Appendix H

Daily Variation in Tulsa Natural Gas (TNG)

Prior to the start of the test series, a question was raised about the variation in Tulsa Natural Gas (TNG) composition. To account for any variation in the TNG composition, a sample of the natural gas was collected around midday on every day that TNG was used in the vent gas mixture by a local natural gas analysis laboratory and analyzed. The results of these analyses are plotted in Figure H-1. The results of the sample analyses are shown in Table H-1. Copies of the data sheets from the laboratory, including chain of custody documentation, are included in Appendix J in the John Zink Final Report section. The actual concentrations from the analyses results in Table H-1 are used in the vent gas composition analyses in the report.

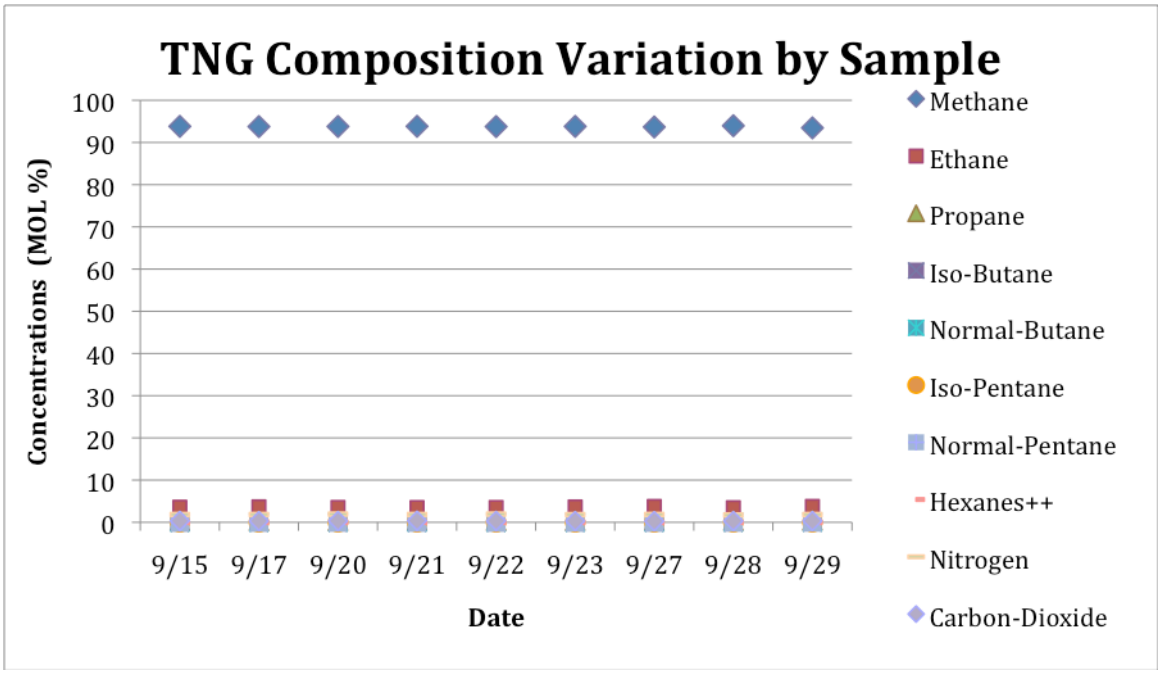


Figure H-1. Results of Tulsa Natural Gas Analyses

Table H-1. Analysis of Tulsa Natural Gas

Date	9/15	9/17	9/20	9/21	9/22	9/23	9/27	9/28	9/29		
Component					Mol %					Average	Std Dev
Methane	93.8225	93.7742	93.7933	93.8344	93.7714	93.8128	93.6768	93.9737	93.4638	93.769	0.138
Ethane	3.5835	3.6694	3.5259	3.4991	3.5098	3.6351	3.7635	3.4597	3.7681	3.602	0.114
Propane	0.3447	0.3476	0.3448	0.3541	0.3751	0.3681	0.3535	0.3896	0.4759	0.373	0.042
Iso-Butane	0.0119	0.0141	0.0189	0.017	0.0185	0.0141	0.0178	0.0167	0.0277	0.017	0.005
Normal-Butane	0.0365	0.0415	0.0488	0.0415	0.0454	0.0443	0.0435	0.0554	0.0739	0.048	0.011
Iso-Pentane	0	0	0.0053	0.007	0.0044	0	0.0047	0.0109	0.0105	0.005	0.004
Normal-Pentane	0	0.0063	0.0068	0.0058	0	0.0085	0.0058	0.0145	0.0107	0.006	0.005
Hexanes++	0.0056	0.0085	0.0103	0.0145	0.0079	0.0104	0.0053	0.0141	0.018	0.011	0.004
Nitrogen	1.8457	1.8451	1.9345	1.8452	1.932	1.8115	1.8516	1.747	1.8332	1.850	0.057
Carbon-Dioxide	0.3497	0.2932	0.3114	0.3814	0.3324	0.2954	0.2772	0.3182	0.3183	0.320	0.032
Oxygen	0	0	0	0	0	0	0.0004	0	0	0	0
Totals (%)	100.000	100.000	100.000	100.000	99.997	100.000	100.000	100.000	100.000	100.000	0.001

Appendix I

Method of Determining the Destruction Removal Efficiency and Combustion Efficiency Using the Flare Plume Extractive Sampling System and Quality Assurance Procedures Employed During Field Tests

Appendix I: Method of Determining Destruction and Removal Efficiency and Combustion Efficiency Using the Flare Plume Extractive Sampling System and Quality Assurance Procedures Employed During Field Tests

Prepared by Scott Herndon, W. Berk Knighton, Jon Franklin, William Brooks, Ed Fortner, Ezra Wood, Joda Wormhoudt and Charles Kolb
Aerodyne Research, Inc.

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Method to calculate flare characteristics from time series analysis of in-situ sampled composition

The overall goal of the project was to determine flare performance characteristics using a combination of in-situ extractive composition measurements as well as open path methodologies for several operational parameters. The primary hydrocarbon of interest for the majority of the tests was propene and so it is specifically named in the discussion below. For the tests where other hydrocarbon species were measured, analogous relationships were computed. The flare performance characteristic quantities of interest include the *destruction and removal efficiency* (DRE) and *combustion efficiency* (CE) defined below. These are the same formula that have appeared in various sections of the report. This derivation is repeated here with additional discussion.

$$\mathrm{DRE} = \left(1 - \frac{\mathrm{propene_{out}}}{\mathrm{propene_{in}}}\right) \times 100 \qquad \text{(I-1)}$$

$$\mathrm{CE} = \left(\frac{\mathrm{CO_2}(exhaust)}{\mathrm{CO_2}(exhaust) + \mathrm{CO}(exhaust) + \sum \mathrm{hydrocarbons}(exhaust)}\right) \times 100 \qquad \text{(I-2)}$$

The methodology for computing flare performance characteristics using the extractive sampling time series data is outlined in following material. The description focuses on the derivation and assumptions used to compute the DRE for propene but similar procedures are used for other hydrocarbons or combustion performance characteristic quantities.

The quantities, $\mathrm{propene_{out}}$ and $\mathrm{propene_{in}}$, in the DRE definition in (I-1) may take the form of different units (e.g. pounds of propene per hour) depending on the usage context. For the purposes of this discussion here, we initially define them simply as moles of propene.

$$\mathrm{DRE} = \left(1 - \frac{\mathrm{propene_{out}}(moles)}{\mathrm{propene_{in}}(moles)}\right) \times 100 \qquad \text{(I-1a)}$$

Carbon is conserved during combustion and as a result the total number of carbon atoms going into the flare will be equal to the number of carbon atoms emitted to the atmosphere following some extent of combustion. At various other points in the report, the terminology, “carbon balance” has been used to describe the conservation of carbon. Because $C_{in} = C_{out}$, the numerator and denominator of the propene ratio in (1a) can be divided by C_{out} and C_{in} without changing the expression. The unit conversion of propene moles to moles of carbon is also performed below.

$$\mathrm{DRE}/100 = 1 - \frac{\dfrac{\mathrm{propene}_{out}(moles)}{\mathrm{C}_{out}(molesC)} \times \dfrac{3\ (molesC)\ \text{as propene}}{\text{mole of molecular propene}}}{\dfrac{\mathrm{propene}_{in}(moles)}{\mathrm{C}_{in}(molesC)} \times \dfrac{3\ (molesC)\ \text{as propene}}{\text{mole of molecular propene}}} \qquad \text{(I-3)}$$

The numerator and denominator in the $\mathrm{propene}_{out}/\mathrm{propene}_{in}$ term can be expressed as the fraction of carbon in the subscripted phase (in or out) that exists in the form of propene.

$$\mathrm{DRE}/100 = 1 - \frac{\left[\dfrac{\mathrm{propene}_{out}(molesC)}{\mathrm{C}_{out}(molesC)}\right]}{\left[\dfrac{\mathrm{propene}_{in}(molesC)}{\mathrm{C}_{in}(molesC)}\right]} = 1 - \frac{\mathrm{CF}^{\mathrm{propene}}(out)}{\mathrm{CF}^{\mathrm{propene}}(in)} \qquad \text{(I-4)}$$

When considering the propene "carbon fraction" for the vent gas, the "in" portion, or $\mathrm{CF}^{\mathrm{propene}}(in)$, it is known since the vent gas is well mixed. Thus, sampling a particular volume will be indicative of all volumes. When each of the moles of carbon expressions in the $\mathrm{CF}^{\mathrm{propene}}(in)$ term are divided by a volume, simple unit conversion converts moles of carbon to parts per million by volume of carbon (ppmC). In this case, the CF can be computed as follows;

$$\mathrm{CF}^{\mathrm{propene}}(in) = \frac{\mathrm{propene(ppm\,C)}}{\mathrm{propene(ppm\,C)} + \sum \text{other carbon (ppm C)}} \qquad \text{(I-5).}$$

In (I-5) the total carbon term C_{in} has been broken into two terms, the contribution to total carbon by propene and the sum of all other contributions.

When considering the propene carbon fraction for the exhaust gas, there are several important considerations and assumptions that warrant discussion, here and further examination in the dataset, later. This form of combustion is unconstrained by physical boundaries. The turbulent diffusion flame is likely to have more combustion inhomogeneities than other forms of premixed flame or internal combustion. The measurements are conducted on real world flares, subject to real atmospheric forces. When computing $\mathrm{CF}^{\mathrm{propene}}(out)$ the sample volume implicit in the expression noted below is a dynamic variable. This can be observed by looking at the time series of sample boom temperature and combustion CO_2.

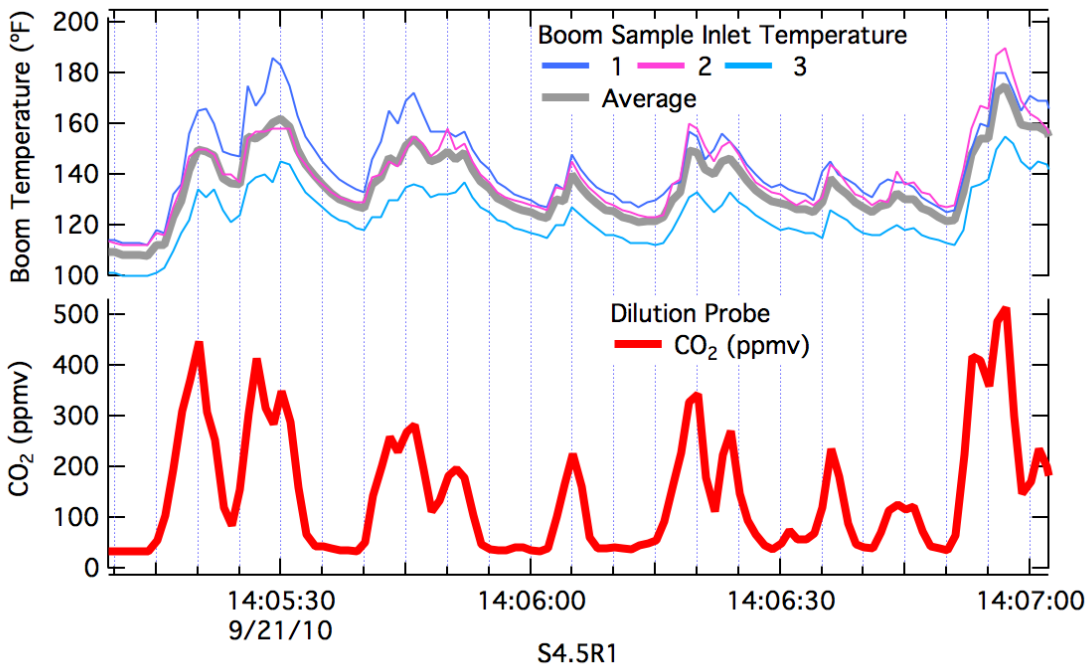


Figure I-1 Time Series of boom temperature and CO_2 mixing ratio on the dilution probe for S4.5R1. In the upper panel, the temperature of the three thermocouples on the inlet sample boom (discussed in Section 4 and Appendix B) are in the listed pastel colors. An average of these three is also shown in the grey trace. The CO_2 time series measured on the dilution probe is depicted in the lower panel in red.

For the depicted time series in Figure I-1, there are ~ 10 periods where the sample volume is more influenced by the flare combustion and ~8 periods where the sample volume is less influenced by the flare combustion. Note that the thermal mass of the sample boom relative to its ability to shed heat is less than the volumetric flow rate that ventilates the sample collector. This is the likely reason for the smearing of the recorded temperature relative to the gas composition.

$$CF^{propene}(out) = \frac{propene(ppm\,C)}{propene(ppm\,C) + CO_2 + CO + \sum \text{other carbon (ppm C)}} \qquad \text{(I-6a)}$$

$$CF^{propene}(out) = \frac{propene(ppm\,C)/CO}{propene(ppm\,C)/CO + CO_2/CO + 1 + \sum \text{other carbon (ppm C)/CO}} \qquad \text{(I-6b)}$$

The quantities noted in (I-6a) refer only to the quantities with the flare process combustion and not the entrainment of ambient carbon species. The derivation of how the quantity $CF^{propene}$ *(out)* will be computed during the extractive sampling will be continued, but first it is important to

discuss how the quantities in (I-6a and 6b) will be computed so they reflect *post-combustion-flare-plume* values and are not contaminated by whatever the ambient levels may be.

The method used to distinguish the flare plume constituents from the ambient is based on time series analysis. The measurement at each of the continuous instruments will be a comprised of a mixture of flare combustion and ambient mixing ratios.

$$[X]_{measured} = f \times [X]_{post-combustion-plume} + (1-f) \times [X]_{ambient} \qquad \text{(I-7)}$$

In expression (I-7), let f represent the time dependent volume fraction of exhaust that is being sampled. The quantity $f(t)$ is modulated by the sampling scheme or the combustion phenomenon itself under most circumstances. Should $f(t)$ be zero for an entire sampling period, there will be no capacity to estimate $[X]_{post\text{-}combustion\text{-}plume}$ with the dataset.

To illustrate how (I-7) can be used to deduce $[X]_{post\text{-}combustion\text{-}plume}$ the time series for two real measured quantities (during the flare testing), labeled "vector a" and "vector b" are depicted in Figure I-2. The apparent baseline magnitudes for each of these species are equivalent to the values measured when the flare is off and no process gas is being directed to the flare. The increases in both of vector a and b occur during time periods when the infrared camera suggests

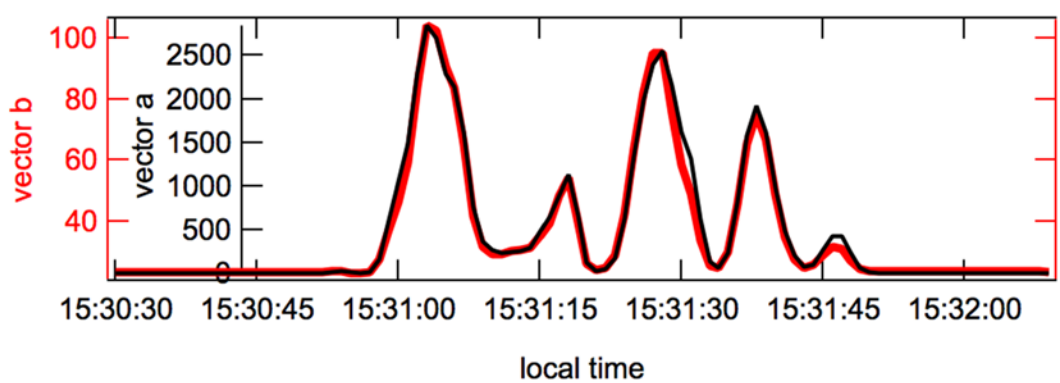


Figure I-2 Time series of sampled concentrations for two different species.

that hot exhaust, beyond the visible luminous flame front are being sucked into the sample collector (see description of experiment schematic). The thermocouples mounted on the inlet of the sample collector also register elevated temperatures (rising from ~80 °F to 110 °F) suggesting the sample collector is entraining a mixture of ambient and combustion exhaust. The data depicted in Figure I-2 is characterized by plume encounters that last ~5 to 12 seconds from the initial onset to an apparent return to near ambient levels.

Using equation (I-7) for compounds a and b, it can be shown that for a time series containing time periods from non zero values of $f(t)$ the relationship between two species in the exhaust can be determined by,

$$\frac{[a]_{measured}-[a]_{ambient}}{[b]_{measured}-[b]_{ambient}}=\frac{[a]_{post-combustion-plume}-[a]_{ambient}}{[b]_{post-combustion-plume}-[b]_{ambient}}=m \qquad \text{(I-8)}$$

If the time response of both species a and b are matched in time and any potential lag between the two measurements accounted for, when the measurement of a is plotted against the measurement of b, for a time interval that contains non-zero *f*(*t*) a linear fit of the correlation plot will yield a slope, *m*, in (I-8).

If the time series of the measurement of compound a and b placed on the same time base are plotted against one another (Figure I-3), the slope is related to the desired quantity, the ratio of a to b in the post-combustion-exhaust by (I-9).

$$\frac{[a]_{post-combustion-plume}}{[b]_{post-combustion-plume}}=m\left(1-\frac{[b]_{ambient}}{[b]_{post-combustion-plume}}\right)+\frac{[a]_{ambient}}{[b]_{post-combustion-plume}} \qquad \text{(I-9)}$$

The left hand term in (I-9) is the quantity needed in order to compute the terms in (6b). During the process of computing $CF^{propene}(out)$, only species such as CO and CO_2 are used. As a result, the ratios of ambient to undiluted post combustion exhaust values in (I-9) are small numbers. The error introduced by assuming $[b]_{ambient}/[b]_{post\text{-}combustion\text{-}plume}$ is much less than one and that $[a]_{ambient}//[b]_{post\text{-}combustion\text{-}plume}$ is much less than *m* will be discussed in the result section. Under the least favorable circumstances of the test the ratio of the difference between *m* and $[a]_{post\text{-}combustion\text{-}plume}/[b]_{post\text{-}combustion\text{-}plume}$ is less than 2%.

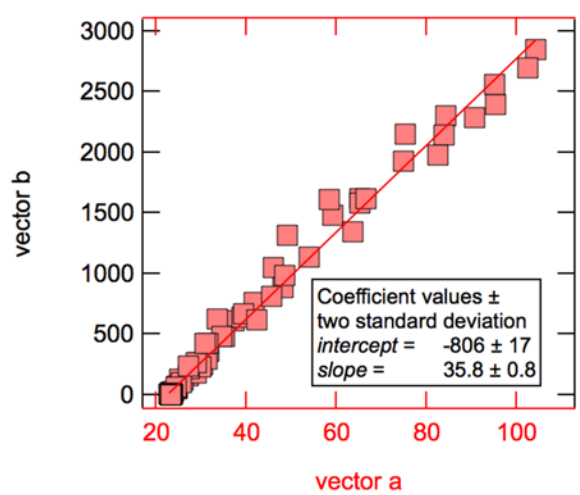


Figure I-3 The time series in the example data for this derivation are plotted against one another.

The ratio of carbon containing species in the flare plume to CO is determined by fitting the time series of data for the stable period of the test to a line where the dependent variable is the mixing ratio of the compound in question and the independent variable is CO. The collection of flare plume ratios for all species monitored is used to compute the DRE, however as has been illustrated in the main report, the dominant species that contain carbon are; propene, methane, CO and CO_2. For the supplemental tests where propane was used a total ppmC measurement was performed by passing the sample into a catalytic converter and monitoring CO_2 that was produced. The total ppmC measurements compare favorably with the combination of the CO_2, CO and the results from the flame ionization detection (FID) of hydrocarbons during the propane tests.

Several of the time series depicted here and elsewhere in the report, show that the sample collector was modulating the extent of plume capture with a characteristic time of 5-20 seconds. During the modulation the flare plume would modulate "in" and *f* (defined in I-7) would peak for few seconds and then drop to zero (implying the measurement is strictly ambient). When the concomitant increase of all species was invariant regardless of the time window (10's of seconds as a minimum) this is an indication that the sample collector system was working as designed to mix a large volume and blur any spatial/temporal inhomogeneity in the flare plume.

In order to characterize the variability the following procedure was used. Rather than use the standard error of the slope parameter in the fit as a basis for error bars, the tabulated error attempts to quantify the test condition variability. The 1-Hz residuals in the ratio of propene to CO was computed for the fit to all data during the test point. The residuals were used to produce two dataset populations, the points that had a positive residual and those that had a negative residual, corresponding to a dataset that had relatively more propene to CO than the total dataset trendline and a second dataset that was relatively deficient in propene to CO. These two populations were then fit independently through all flare plume ratios and used to compute an upper and lower limit in the observations. In this manner, the intratest variability is quantified by a common metric. This is referred to as the propene-CO *tendency* in some of the discussion in Section 7.

Quality Assurance Documentation for Analytical Methods

This section describes the results of the quality assurance procedures for the TCEQ Comprehensive Flare Study (2010). The sections will begin with the measurement of the hydrocarbon fuel components (e.g. propene (propylene), Tulsa Natural Gas (methane plus other compounds), and propane). The subsequent sections will describe the partial products of combustion, ethyne (acetylene), ethene (ethylene), formaldehyde and other oxygenated species. It will describe the quality assurance procedures for the measurement of black carbon soot mass in the particle phase, particle number measurements and the chemical composition of the particulate measurements. The results of the quality control procedures for the measurement of molecular oxygen, O_2 will be described. Finally the quality assurance documentation for the higher products of combustion carbon monoxide, water and carbon dioxide will be discussed.

Quality Assurance for the Measurements of Propene

Propene Part 1: Gas Chromatographic Separation/Flame Ionization Detector

This section includes a technical overview and calibration methods used for the measurement of propene by the SRI-8610 gas chromatograph with a flame ionization detector (GC-FID) deployed to the TCEQ Comprehensive Flare Study in September of 2010. Need details on adsorbent trap, length of trapping time, oven program ramp etc. The chromatograph was deployed with a 6 foot porapak-Q packed column. Propene was calibrated using two different calibration standards (50 ppmv and 100 ppmv) provided by TRC. Calibrations were performed by either introducing the calibration gas directly to the GC-FID inlet or by having the GC-FID sample from a known dilution of the calibration gas added to tip of the dilution probe and distributed through the entire Aerodyne Mobile Lab gas phase manifold. The FID response was calibrated from the slope of standard curves produced by plotting the integrated peak area response versus the concentration of propene is discussed later, in Figure QA-8. This response factor was applied to the determination of all of the species measured by the GC/FID. Figure QA-1 is a sample chromatogram of a propene calibration and shows the elution time for propene (~5.8 minutes).

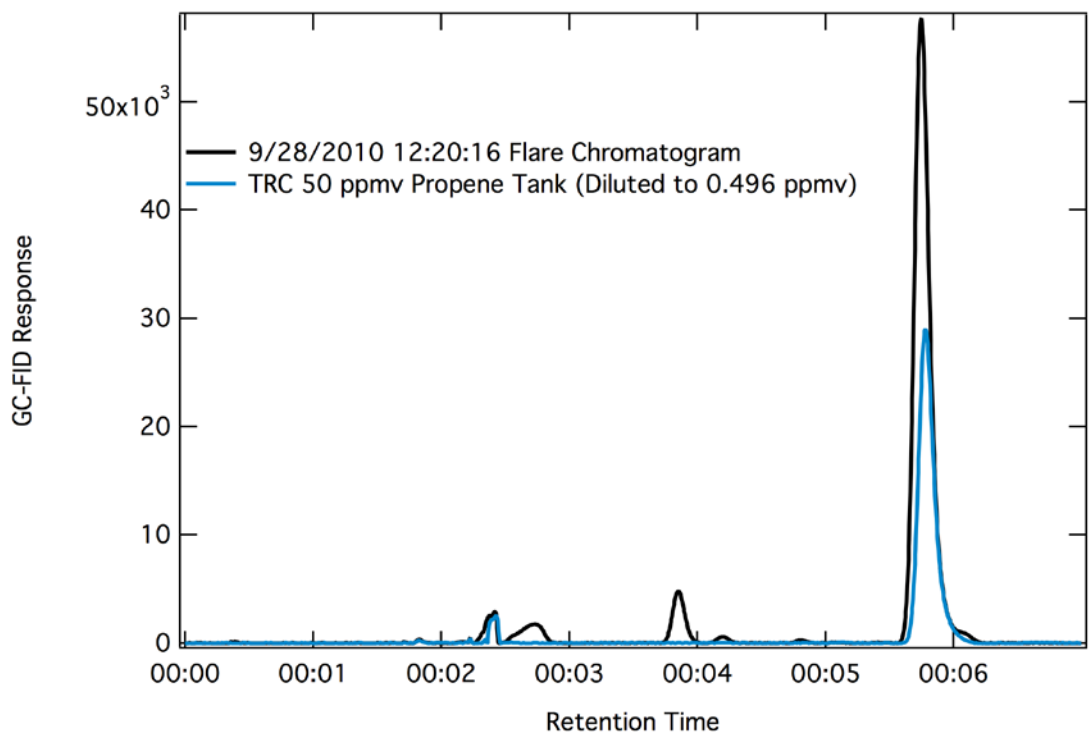


Figure QA-1. Flare chromatogram from 9/28/2010 12:20:16 and Calibration chromatogram.

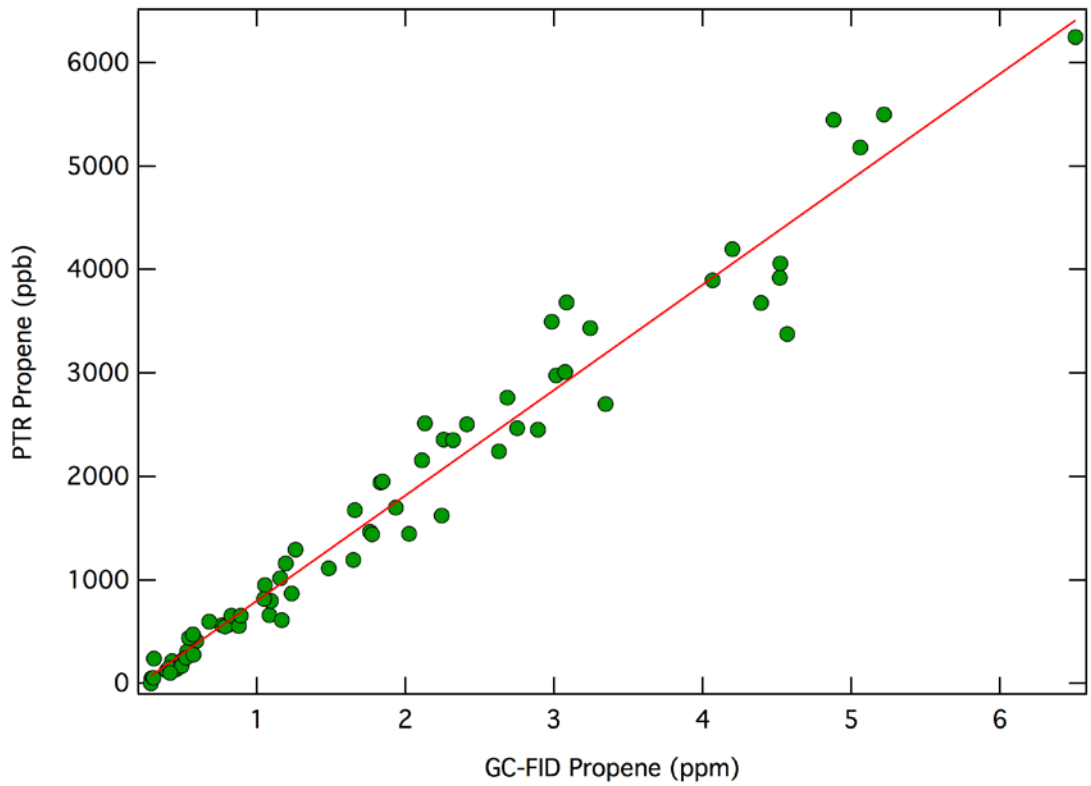


Figure QA-2 Comparison of PTR-MS propene values (ppb) to GC-FID propene (ppm) over three days of testing.

Figure QA-2 shows that the GC-FID agrees with the PTR-MS measurement of propene within 2%. The 1-Hz PTR data was averaged to produce a single value during the 30 second collection time in the GC data. Some of the observed variability in this comparison plot is due to uncertainty in the time offset between the two instrument data records. Although the data acquisition time stamp was rigorously aligned, there is some uncertainty (±2 s) in the relative flow sample time. Despite this limitation, the data suggest that the quantification procedures used to quantify the flare plume propene content using the PTR are quite good compared to the GC methodology. This result is based on comparing the chromatograms that were collected with sample data points and is an indicator that the PTRMS method can accurately quantify propene in the flare plume matrix.

Propene Part 2: Proton Transfer Reaction Mass Spectrometry, overview and GC-PTR description

Method Overview

Proton transfer reaction mass spectrometry (PTR-MS) is a chemical ionization mass spectrometry technique that utilizes H_3O^+ as the principal reagent ion. H_3O^+ reagent ions are generated in an external hollow cathode ion source through direct ionization of water vapor. These reagent ions are electrostatically injected into a drift tube reaction region where they merge with the gas to be sampled that has been reduced in pressure (~ 2 mbar). The drift tube reaction region is formed by a series of concentric stainless steel rings compressed between Teflon o-rings, which serve to electrically isolate the drift rings and provide a vacuum seal. The drift rings are electrically connected via a series of resistor. An electric potential applied to the top of the drift tube forms a uniform electric field which transports any positive ions through the drift tube. The H_3O^+ reagent ions as they are pulled through the sample gas by the electric field will react upon collision with any molecule having a proton affinity greater than that of water. It is important to note that the primary components of air: N_2, O_2, Ar, CO_2, and the alkanes all have proton affinities less than water and thus do not react with H_3O^+. Most other organic substances except for acetylene and ethene react with H_3O^+ via a proton transfer reaction, reaction 1.

$$H_3O^+ + R \xrightarrow{k} RH^+ + H_2O \qquad \text{(R1)}$$

The proton transfer reaction forms the protonated molecule RH^+, which is a stable reaction product in many cases. Fragmentation of the RH^+ ion does occur in the case of propene and leads to multiple product ions. The drift tube reaction region is terminated by a plate that contains a small aperture through which a fraction of the unreacted reagent ions and product ions are extracted, focused into a quadrupole mass spectrometer and detected using a secondary electron multiplier. The resulting mass spectrum contains quantitative information regarding the composition of the gas sample, providing that the composition of the sample is known or can be deduced. The next sections discuss these key points.

Quantification

Quantification of the PTR-MS ion signals is possible directly from first principles, but is most reliably done via calibration with certified gas standards. In this test the concentrations reported for propene, acetaldehyde, benzene and methanol were evaluated from calibrated response factors. Minor combustion by-products for which gas standards were not available were quantified using estimated sensitivity factors.

The standard equation for quantifying a target compound, designated generically as (R) is shown in equation PTR-1.

$$[R] = \left(\frac{1}{S_R}\right)\left(\frac{I_{RH^+} \bullet 10^6}{I_{H_3O^+} + X_R I_{H_3O^+(H_2O)}}\right) \qquad \text{(PTR-1)}$$

The term [R] represents the concentration of R in ppbv. S_R is the sensitivity factor expressed as normalized counts per second (ncps) per ppbv. The term $\left(\frac{I_{RH^+} \bullet 10^6}{I_{H_3O^+} + X_R I_{H_3O^+(H_2O)}}\right)$ represents the product ion response expressed in ncps, which is the mass spectral intensity of RH^+ measured in cps per 1-million reagent ions. This normalization step accounts for any variation in the product ion intensity resulting from changes in the reagent ion intensity. The intensity of H_3O^+ is too large to measure directly and its intensity is determined by measurement of the O-18 isotope of this ion detected at m/z 21, which is then multiplied by 500 to correct for the isotopic dilution. Measurement of the intensity of $H_3O^+(H_2O)$ is measured directly at m/z 37. Some components react with both H_3O^+ and $H_3O^+(H_2O)$ while others do not. The X_R term is a factor between 0-1 that accounts for the reactivity difference between $H_3O^+(H_2O)$ and H_3O^+ towards R.

Most applications of the PTR-MS are for trace level detection where the substrate concentrations are low, < 1 ppmv. Under these conditions the reagent ion population (intensity) is not significantly altered by Reaction 1 and can be considered to remain at a constant level. During the Comprehensive Flare Test, however, the propene concentration was often very high > 10 ppmv and reached levels where the reagent ion intensity was notably depleted. Under these measurement conditions Equation PTR-1 is not valid and a modified formula most be used for accurate quantification. This modified equation is shown in Equation PTR-2.

$$[R] = \left(\frac{1}{S_R}\right)\left(\frac{I_{RH^+} \bullet 10^6}{\sum I_{R_iH^+}}\right) \bullet \ln\left(\frac{\sum I_{R_iH^+} + I_{H_3O^+} + X_R I_{H_3O^+H_2O}}{I_{H_3O^+} + X_R I_{H_3O^+H_2O}}\right) \qquad \text{(PTR-2)}$$

The only new term in this equation is the $\sum I_{R_iH^+}$ term, which reflects the sum of all product ions. This equation reduces to Eq PTR-1 when the sum of the product ion intensity becomes small relative to the total reagent ion intensity. All of the concentrations reported using the PTR-MS in this project were computed using PTR-2. While this equation mathematically corrects for the affect of reagent ion depletion, it should be noted that reported concentrations determined when reagent ion depletion occurs will be lower than the true concentration. The reported concentrations are lower because the product ion count rate reaches such a high level that it exceeds the linear dynamic range of the secondary electron multiplier detector. At this point the detector begins to count multiple ions as a single event leading to a lower measured count rate.

Calibration

Calibrations were performed by dynamically diluting certified gas standards with dry N_2 obtained from the headspace of liquid N_2. Several gas standards were employed. Propene calibrations were performed using single component standards borrowed from TRC. Sensitivity factors for all other components were evaluated using a multi-component standard (Apel-Reimer) owned by MSU. The stated accuracy of standards is +/- 5%. Table 1 provides composition information on the gas standards used.

Table 1 Gas standards employed in the calibration of the PTR-MS and GC/FID

during the Comprehensive Flare Study		
Gas Standard Identifier	Components	Concentration
TRC-50	propene in N_2	50.06 ppmv
TRC-100	propene in N_2	99.99 ppmv
MSU-multicomponent	methanol in N_2	520 ppbv
	acetonitrile in N_2	520 ppbv
	propene in N_2	480 ppbv
	acetaldehyde in N_2	490 ppbv
	acetone in N_2	500 ppbv
	isoprene in N_2	440 ppbv
	methacrolein in N_2	410 ppbv
	benzene in N_2	510 ppbv
	toluene in N_2	500 ppbv
	styrene in N_2	480 ppbv
	p-xylene in N_2	480 ppbv
	1,3,5-trimethylbenzene in N_2	480 ppbv
	alpha pinene in N_2	410 ppbv

Flows of the gas standards and the N_2 dilution gas were controlled using mass flow controllers. The outflow from the mass flow controllers was mixed together and delivered to the sample inlets of the two PTR-MS instruments and GC/FID. On several occasions, calibration experiments were performed by adding the calibration gases at the sample inlet. These experiments were conducted to verify that there were no sample line perturbations. In all cases, the two PTR-MS instruments and the GC/FID were all calibrated using the same gas mixtures. Representative calibrations are depicted in figure shown below.

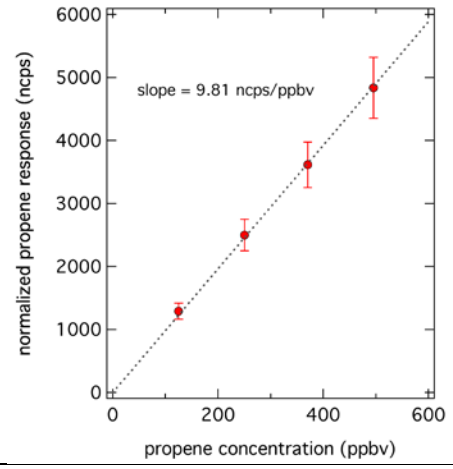


Figure QA-3. Representative calibration curve for propene. The slope of plot represents the PTR-MS sensitivity factor for propene. Error bars reflect and uncertainty of +/- 10%

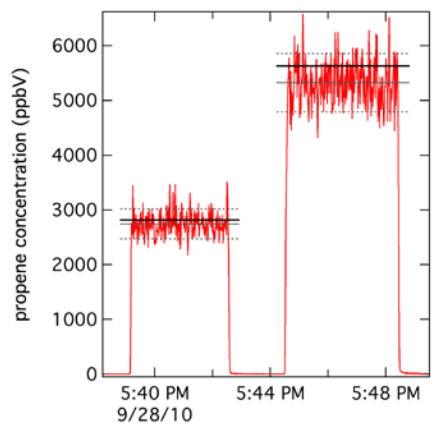


Figure QA-4. Representative results from calibrations performed at the sample tip of the extraction probe. The solid grey line represents average concentration with the dotted lines showing the +/- 10% uncertainty level. The solid black line reflects the propene concentration delivered to the sample line.

Calibration checks on the PTR-MS were performed daily. On most days calibration checks were made prior to the start of testing, between the morning and afternoon tests and after the conclusion of the tests. There were problems with calibration experiments conducted on 9/17/2010 and these results have been omitted. Figure QA-5 shows the results for the propene calibrations over the course of the study. Day to day variations are attributed to statistical variability of the method and an average sensitivity factor, shown as the dotted line, was employed to compute the reported concentrations. The calibration factors employed in this study are reported in Table 2.

Estimation of Uncertainty

The PTR-MS technique does not have any official adopted protocol for evaluation of measurement uncertainty. Measurement uncertainty arises from two main sources: 1) the measured ion intensities and 2) the calibration factors S_R and X_R. The precision of the sensitivity factors derived from the individual calibration experiments generally falls within the +/-10% level. Evaluation of the uncertainty in the ion intensity measurements requires defining a specific time base. A single 1-second measurement will have a greater uncertainty than a time averaged series or ensemble of data points. Rather than specifically deriving an uncertainty value it is more appropriate to provide an estimate. Inspection of the PTR-MS response in Figure QA-4 indicates that the variability of signal is on the order of +/- 10%. Since Poisson statistics governs the variability in the ion intensity measurements the noise in the ion signal scales in proportion to the magnitude of the response. This means the relative uncertainly remains essentially constant and independent of sample concentration. Assuming a 10% uncertainty to both the ion intensity measurements and the calibration factors leads to an overall uncertainty of approximately 15%.

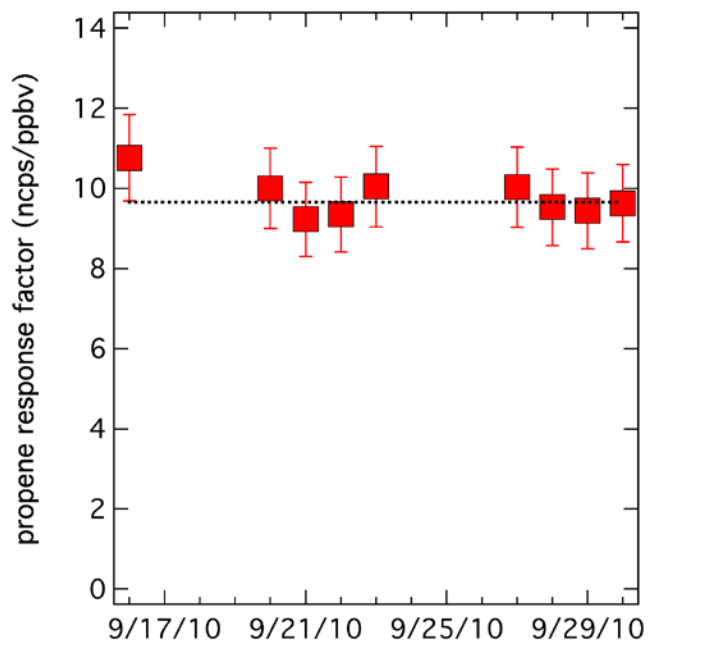


Figure QA-5. Record of propene sensitivity factors for the PTR-MS evaluated during the Comprehensive Flare Study. Error bars reflect +/- 10%. The average value of all the calibrations, shown as the dotted line, was employed to compute the reported concentrations.

Table 2. PTR-MS calibration factors used in the Comprehensive Flare Study

Compound	ion quantified	S_R (ncps/ppbv)	X_R
propene	m/z 43	9.66	0
methanol	m/z 33	19.6	1
acetaldehyde	m/z 45	25.0	1
acetone	m/z 59	37.8	1
benzene	m/z 79	20.1	0.1

Verification of compound identity

The PTR-MS technique detects and records the response associated with ions at a specified mass-to-charge (m/z) ratio. For instance, propene is detected at m/z 43 while benzene is detected at m/z 79. While it is easy to establish via standards what ions are formed via the proton transfer reaction a more difficult task is confirming that a given ion is unique to a specific compound. During the Comprehensive Flare Study a second PTR-MS was deployed that had an associated GC. The GC/PTRMS system allows us to determine whether there are any other components present in the flare emissions that form an ion an m/z 43.

The GC/PTR-MS system was operated in parallel to the primary PTR-MS. Both instruments sampled off the same sample line. The GC/PTR-MS could be operated as either a normal PTR-MS or as the detector for the GC. A brief description of how this second instrument was operated in the GC-PTR mode is given here. When instructed a portion of the sample is pulled through a Teflon loop that is immersed in liquid N_2, which traps the condensable components in the sample. The trapping time is variable but usually lasts for 2 minutes. At the conclusion of the trapping cycle, 6-way valve is used to sweep the contents trapped within the sample loop onto the chromatographic column. Immediately after a 6-way valve is switched the sample loop is withdrawn from the liquid N_2 and is immersed in hot water to desorb the condensable components within the sample loop. A 3-way valve on the PTR-MS is switched so that the instrument samples the outflow from the GC instead of the normal sample line. The GC oven temperature is ramped from 40 – 100 ^{o}C. A typical GC run lasts about 7 minutes.

Propene – m/z 43

Figure QA-6 shows two m/z 43 chromatograms, a reference standard generated during a calibration and a study sample taken during test point A6.1. Both chromatograms show a single peak at the same retention time that corresponds to the presence of propene. This result confirms that the signal measured at m/z 43 has only one source and that source is propene. A total of 75 chromatographic runs under a variety of operational flare conditions were conducted during the study. In all cases the m/z 43 chromatogram exhibited only a single peak, which had a retention time corresponding to propene. On the basis of this result, it is concluded that m/z 43 signal is due solely to the presence of propene and that are no other compounds present in the flare emission matrix that interfere with this measurement.

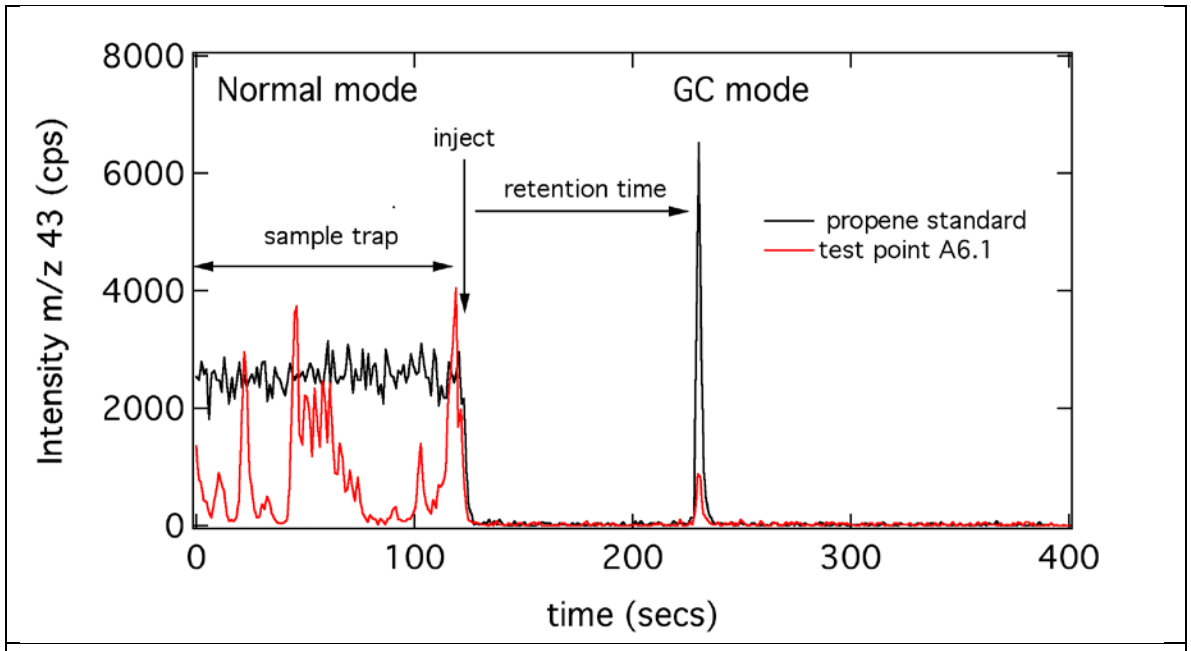


Figure QA-6. Chromatograms for m/z 43 for a propene reference standard and for an air flare sample. These chromatograms demonstrate that the m/z 43 signal is comprised of a single component, which is propene.

The GC/PTR-MS monitored 6 other ion signals; m/z 33, m/z 45, m/z 55, m/z 57, m/z 59 and m/z 79. Several general statements can be made for these species, which are valid except for conditions under where extremely high (>100 ppm) propene concentrations were encountered. The signals measured at m/z 33 (methanol), m/z 45 (acetaldehyde) and m/z 79 (benzene) showed only a single peak in their respective chromatograms, which had retention times consistent with the neutral component identified in parentheses. The remaining ion signals m/z 55, m/z 57 and m/z 59 all showed multiple peaks in the respective ion chromatograms. The identities of all of these peaks have not been confirmed, but several of the peaks have been tentatively assigned. These are 1,3-butadiene (m/z 55), butene (m/z 57), acrolein (m/z 57), propylene oxide (m/z 59), propanal (m/z 59) and acetone (m/z 59). For these compounds their distribution is dependent on combustion condition and any further interpretation must be made on a case-by-case basis.

Quality Assurance: GC-FID for other compounds at the Flare Study

This section discusses the SRI 8610C GC-FID deployed to the TCEQ Comprehensive Flare Study in September and October of 2010 and its measurements of methane, ethane, ethene, ethyne, and propane. The GC-FID was calibrated for the above species using a 100 ppm alkane (methane, ethane, propane, butane) cal standard provided by TRC as well as a cal standard with methane, ethene, and ethyne provided by Aerodyne Reasearch. Calibrations were taken by either over blowing the GC-FID inlet with the cal gas or having the GC-FID sample from a known dilution of a cal gas fed either through the entire Aerodyne Mobile Lab gas phase manifold. Figure QA-7 shows the retention times for the above species from a flare sample as well as calibration chromatograms.

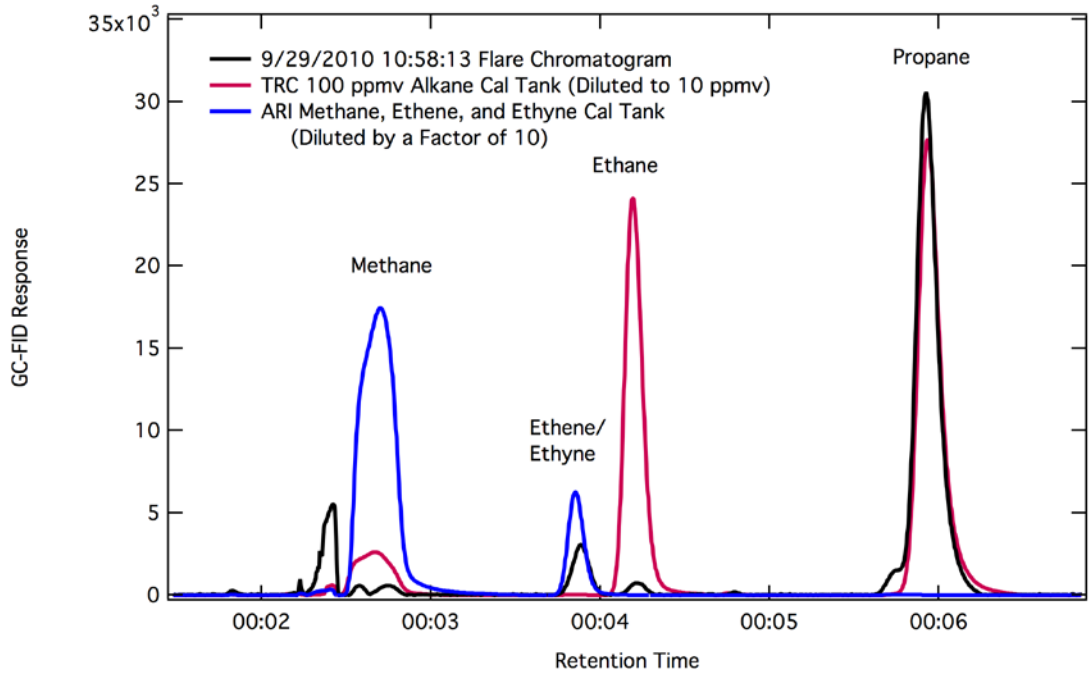


Figure QA-7. Flare Chromatogram with calibration chromatograms overlaid.

A calibration curve for the GC-FID was created by first converting all calibration concentrations from ppmv to ppmC. A calibration curve, Figure QA-8 was then created to convert peak integration to ppmC, and eventually ppmv. Peak integrations were calculated by the SRI gas chromatogram software, Peak Simple.

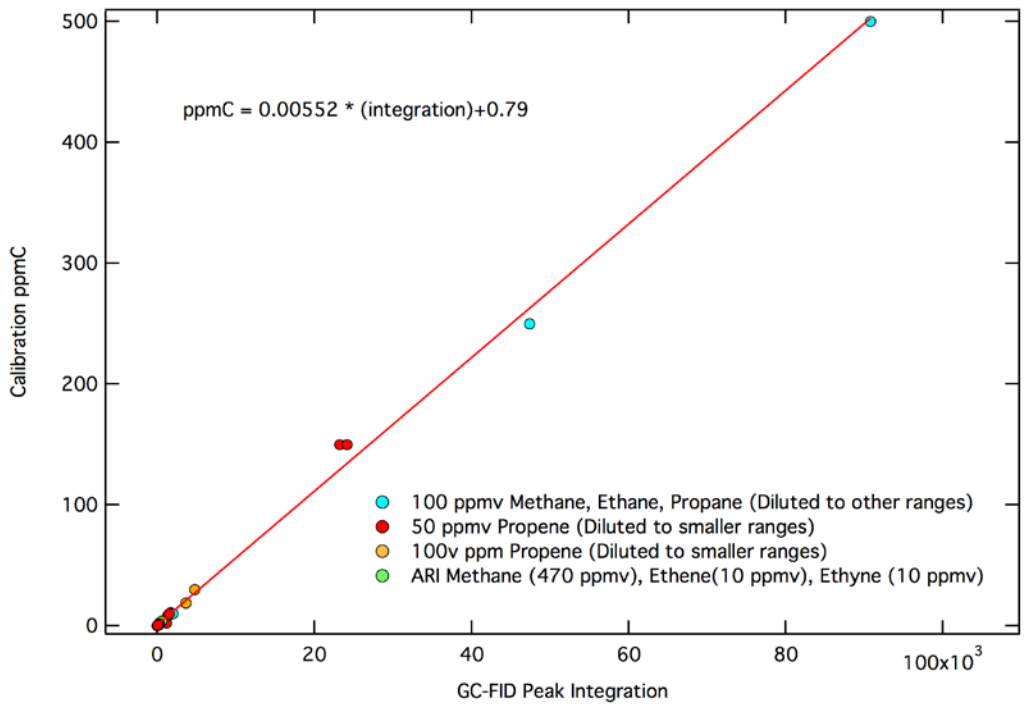


Figure QA-8 Calibration ppmC vs GC-FID integration for different standards used during the TCEQ comprehensive flare study.

Quality Assurance: QCL Methane and Ethyne

This section includes a technical description of the methane isotope & ethyne spectrometer deployed to the TCEQ Comprehensive Flare Study in September and October 2010 as well as the results of the in-field calibration as part of the QA/QC procedures for the project. This section will also account for the details of an analogous instrument that uses the same analytical approach to determine the ethene (or Ethylene) mixing ratio in the sample stream.

The instruments documented in this section employ Tunable Infrared Laser Differential Absorption Spectroscopy (TILDAS) as the fundamental analytical method for quantifying trace compounds. Although TILDAS methods using tunable diode lasers have been widely used for a variety of trace gas measurements [*Sachse, et al.*, 1987; Bergamaschi et al., 1994; *Zahniser, et al.*, 1995] the requirement for cryogenic cooling of lasers and detectors and the uneven quality of lead salt diode lasers has limited wider application of TILDAS methods. Improvements in engineering led to the development of the instrument deployed to the flare study, a robust and portable instrumentation that can operate without cryogenic cooling of the laser [Herndon et al., 2007; Jimenez et al., 2005; McManus et al., 2005; Nelson et al., 2004; Nelson et al., 2002]. Applications to detection of isotopes of CO_2 [*Nelson et al.*, 2008; Tuzson *et al.*, 2008a; Tuzson *et al.*, 2008b] demonstrate the ultimate in precision using this technique.

During the TCEQ Comprehensive flare study deployment, the first of two lasers in this dual CWRT[1] laser system was used to measure $^{13}CH_4$ and $^{12}CH_4$. An example spectrum is depicted in the inset (Figure QA-10).

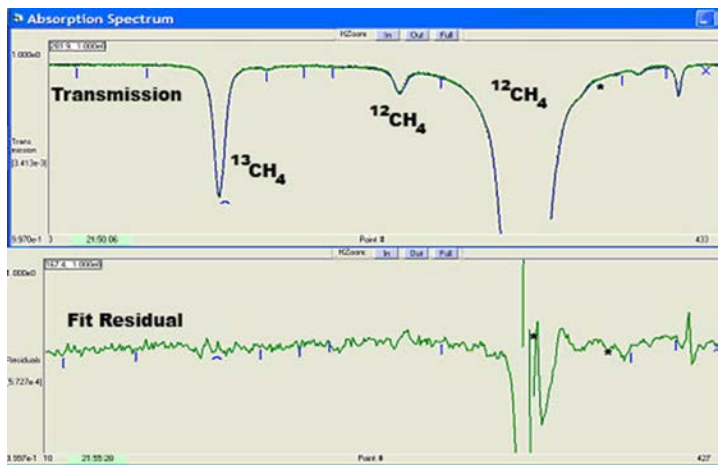


Figure <QA-10 Experimental spectrum with 210 m pathlength, 30 Torr, and CH_4 mixing ratio of 1870 ppb with an averaging time of 30 s. The upper panel shows experimental spectrum (points) and fit (solid line) to the data using HITRAN spectral lines for $^{12}CH_4$ (peak absorbance 0.07) and $^{13}CH_4$ (peak absorbance 0.0022). The lower panel shows the residuals to the fit with a root-mean-square deviation of 10^{-5} absorbance units.

The deployed optical system uses direct absorption to measure $^{13}CH_4$ and $^{12}CH_4$ using spectral lines around 1294 cm^{-1} [Zahniser et al, 2009]. The experimental spectrum using the 210 m pathlength absorption cell is shown in QA-10. There is excellent agreement between the fit based on the HITRAN database and the experimental data as shown by the low residual deviation between the data and fit. Even in the region of the strong $^{12}CH_4$ line, the residual deviation is less than 1% of

[1] continuous wave room temperature

the absorbance (0.07) of the major peak. The rms noise in a 1 second data stream under these conditions corresponds to 3 ppb for the $^{13}CH_4$ peak or 1.4 ‰ of ambient mixing ratio.

The TCEQ Comprehensive Flare Study required sensitive, selective and fast measurements of potentially uncombusted methane at potentially higher than ambient mixing ratios. As a result, calibrations were performed at various times to check the instrument performance with known standard concentrations. The data depicted in Figure QA-11 shows the calibration performance check of the instrument using a diluted standard.

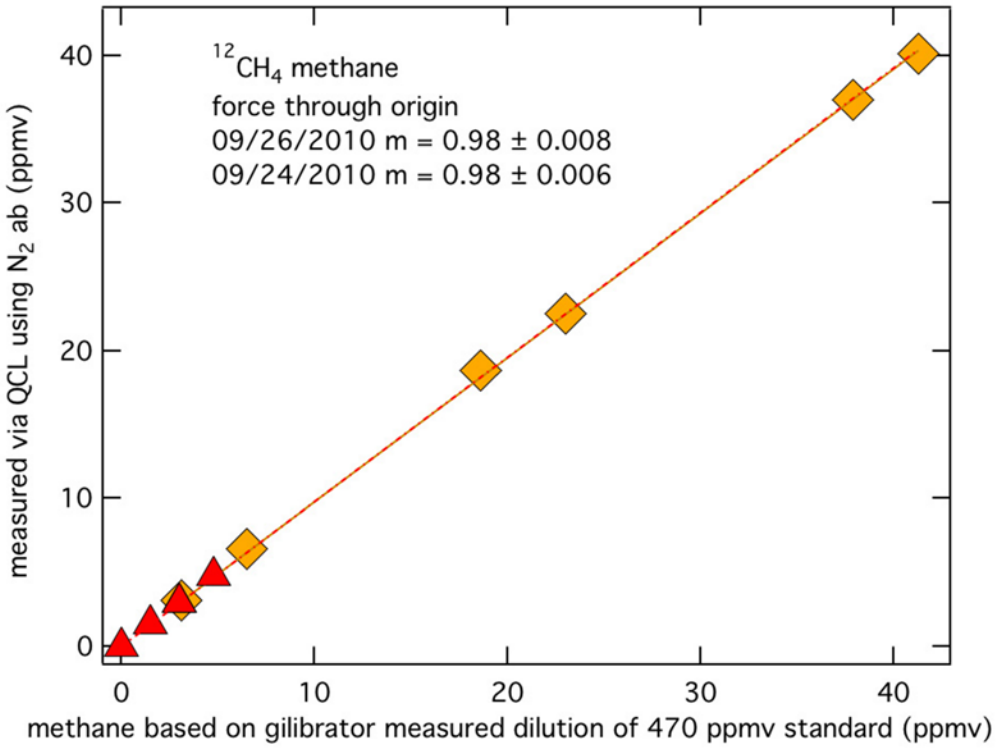


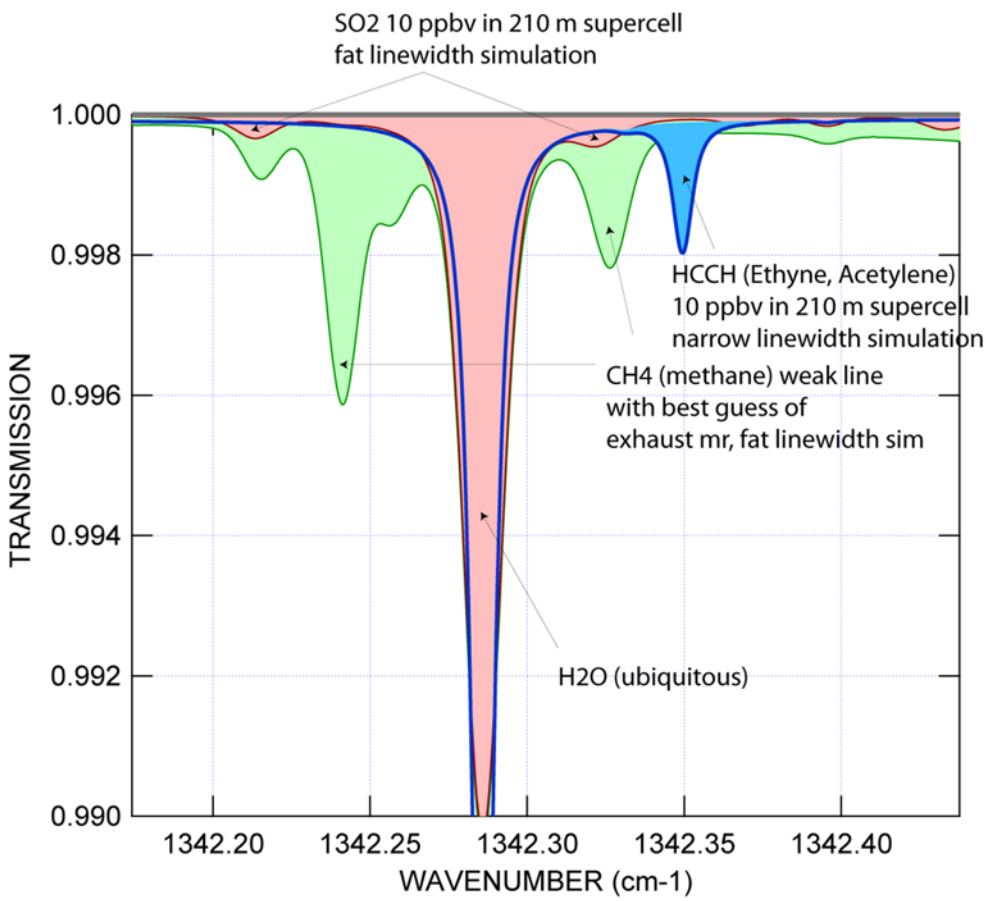
Figure QA-11. The results from the QCL measurement of methane are plotted vs. the expected mixing ratio determined by dilution of the methane standard. The dilution levels for the points noted as orange diamonds were generated using two gilibrator based flow measurements. The dilution levels for the points noted by the red triangles were determined using the in-lab dilution and calibration system.

When it was apparent that the concentrations that would occasionally be encountered during the test were greater than the mixing ratio that the dilution/calibration system in the mobile laboratory could routinely generate, alternate calibration methods were performed. The data in Figure QA-11 shows results of two calibrations; the red triangles using the flow meter pair in the dilution box and the orange diamonds using two gilibrator measurements of flow to determine dilution levels. The agreement between both methods is excellent and values of methane measured with the spectrometer have not been adjusted by the factor 1.02 suggested by the

calibration procedure. This provides a citable calibration based strictly on the well-researched and documented spectroscopy behind the HITRAN database (Rothman et al., 2008). The overall systematic uncertainty in the methane instrument is estimated to be 6%, based in part on the linestrength literature for these methane absorption lines and in part on the agreement with the independent calibration performance check documented here.

The second laser system employed in the CWRT instrument was used to measure ethyne. The figure QA-12 depicts the HITRAN simulations showing the rotation-vibration spectroscopy for the known absorbers in this narrow region of the 7.5 µm wavelength region. Absorption lines of water, methane, sulfur-dioxide are all important in this wavelength band. Isolated, reasonably strong, absorption lines for acetylene also are present. The figure depicts contrast and resolution needed to measure acetylene when the exhaust matrix also contains SO_2 and CH_4.

Figure QA-12 Spectroscopic simulation of methane, SO_2 and acetylene rotation-vibration absorption lines near 1342 cm^{-1}.



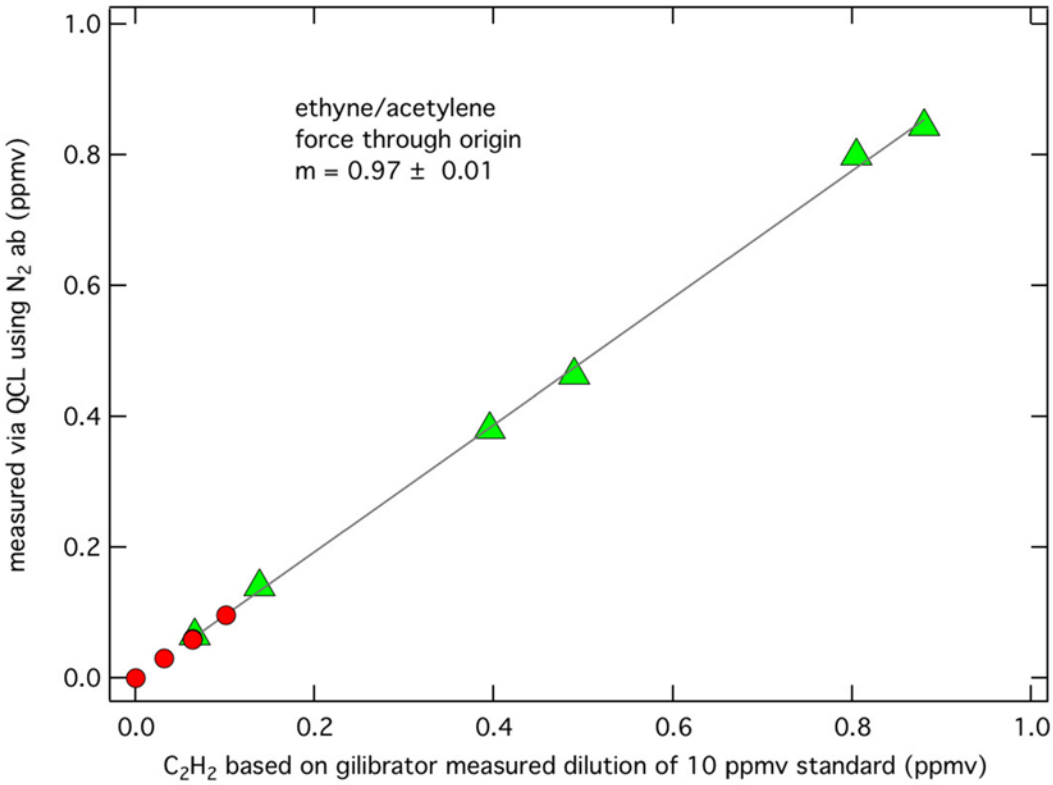


Figure QA-13. The measured ethyne mixing ratios are plotted vs the concentration of the diluted standard. The two sets of points represent two different dilution schemes (green triangles = dual gilibrator dilution; red circles = automatic dilution calibration system)

Analogous to the description of the methane calibration, the ethyne calibration depicted in Figure QA-13 was conducted using two different dilution systems. The standard used contained both methane and ethyne so these calibration results are discussed together. The literature is not as certain on the absolute spectroscopy for ethyne and as a result the systematic certainty of this measurement is conservatively estimated at 10%.

Quality Assurance: QCL HCHO, CO, and Ethylene

Ethylene (ethene), formaldehyde, and carbon monoxide were measured using different QCL instrument chassis. The ethene instrument employed a pulsed laser device (as opposed to the continuous wave used for methane and ethyne). The primary ethene absorption lines at 951.372 cm^{-1} were used in a 76 meter cell. The CO/HCHO QCL instrument also utilizes a 76 meter cell and the primary absorption lines for CO and HCHO are 1764.902 and 2169.20 respectively.

The accuracy of the HCHO measurement (using QC-TILDAS) is checked by sampling the output of a well-characterized permeation tube at a known dilution rate. This was done on 7/25/2010 during an ARI field experiment in Berkeley, CA.

The permeation flow was diluted into a total flow of 3.11 LPM as measured with a recently calibrated gilibrator flow meter. The reported concentration at cell pressures of both 26 Torr and 14 Torr was 17.73 ppbv. The calculated mixing ratio, based on a permeation rate of 62 ± 8 ng/min, atmospheric pressure of 735 Torr and ambient temperature of 298 K, is

{1.24E15 molecules/min / 3.11 liters/min} × {1 liter/1000 cm^3} / 2.38E9 molecules/cm3 = 1.675E-8, or 16.75 ppb.

The different of 0.98 ppbv out of 16.75 ppbv is 5.9%, well within the uncertainty of the HCHO permeation rate (12.9%).

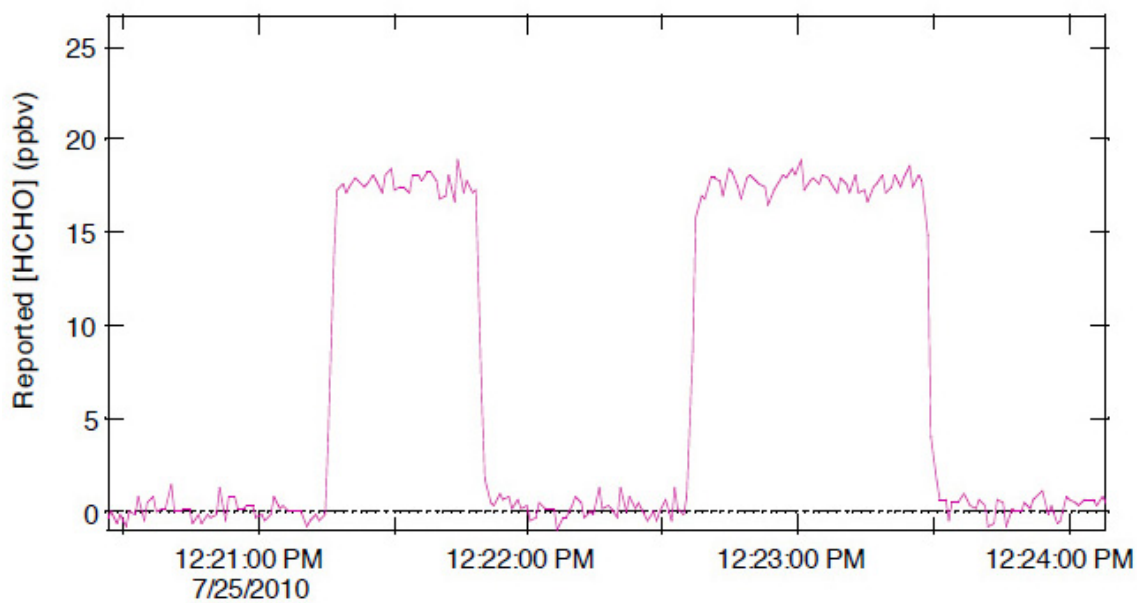


Figure QA-14 The "top-hat" appearance of the time-series data shown in the figure above results from sudden introductions of the permeation tube flow (HCHO standard) into the total instrument flow.

The same compressed gas cylinder contained the standards for methane, acetylene, and ethylene, thus calibrations for all three species were executed simultaneously. Figure

QA-15 shows the excellent agreement (1%) between the QCL instrument's internal spectroscopic quantification of ethene and the calibration mixture prepared from the standard cylinder.

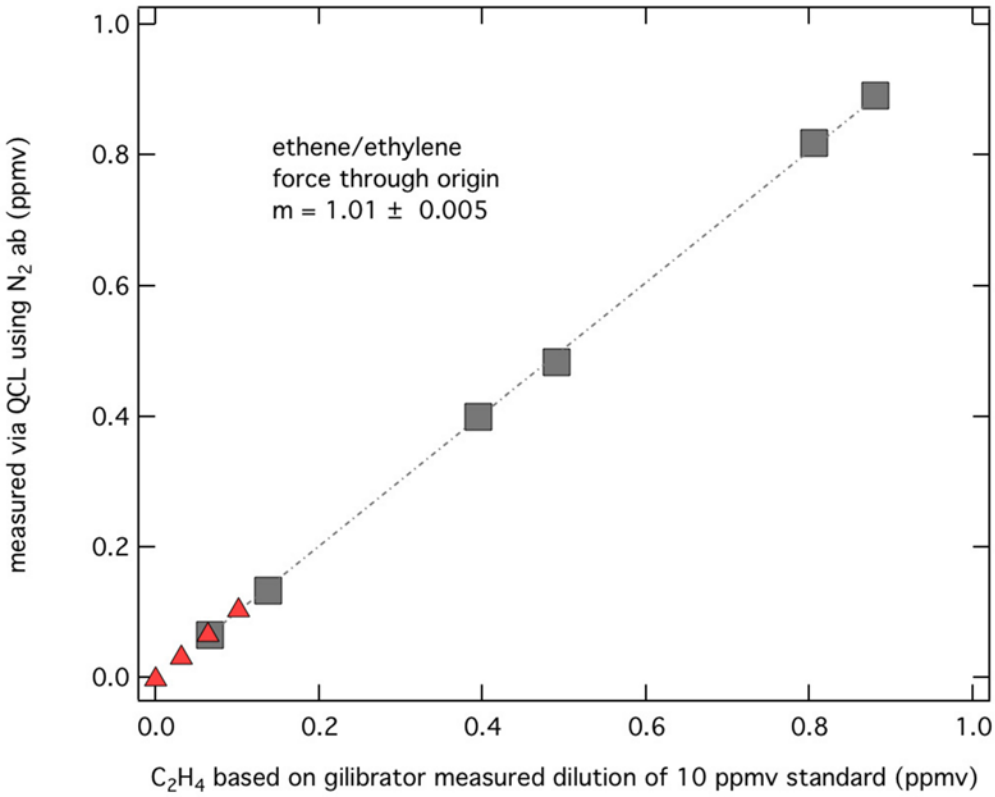


Figure QA-15. The measured ethene mixing ratios are plotted vs the concentration of the diluted standard. The two sets of points represent two different dilution schemes (gray squares = dual gilibrator dilution; red triangles = automatic dilution calibration system)

The CO measurement was calibrated in a similar fashion to the ethene/methane/ethyne calibrations but using a separate gas standard. Unlike the other species, a significant correction (16%) is required to have the spectroscopic quantification match the tank-based standard (see figure QA-16).

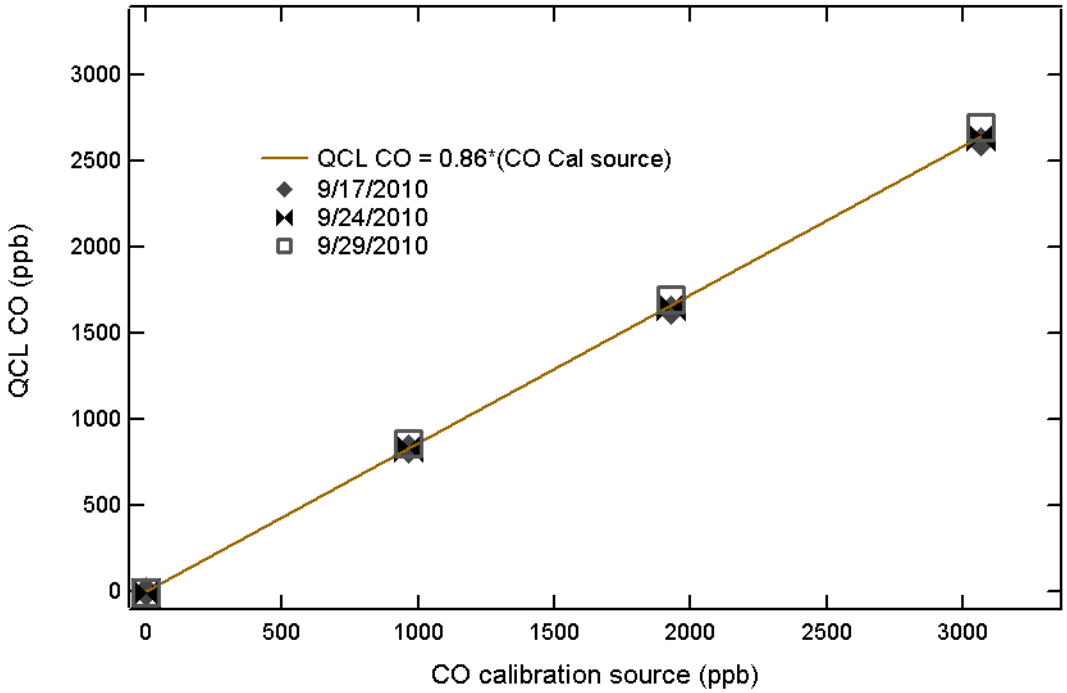


Figure QA-16 In field calibration procedure used for CO.

The correction indicated by similar calibrations using the same laser and same calibration source over the past several years have slowly increased in value (from 3% to 16%), indicating that either the laser is undergoing a slow deterioration or that the concentration of CO in the standard is decreasing. This second possibility is unlikely due to the stability and inertness of CO, but was investigated during the July 2010 campaign in Berkeley, CA (in which a 14% correction was used for the CO data). Our collaborators from the University of California, Berkeley used a CO standard cylinder from Scott-Marin (a supplier) with a NIST-traceable uncertainty of 1%. QCL measurements (incorporating the 14% correction indicated by calibrations with our CO source) of a sample of their 10.21 ppm calibration gas read 10.35 ppm – a difference of only 1%. This supports the accuracy of our calibrated CO measurements and implicates imperfections in our laser. These pulsed quantum cascade lasers have a broader linewidth compared to the cw lasers, and a lineshape is not always symmetric. Any multi-mode character in the laser would also contribute to the QCL measurement being low.

Quality Assurance Description for the Particulate Measurements

The SP-AMS is a real-time instrument and therefore does not require sample handling and storage procedures. A record of all SP-AMS activities was kept in notes on the SP-AMS computer.

The methods for collecting data from AMS instruments (including SP-AMS that was used for this project) has been extensively developed and tested and is published in the scientific literature (e.g. basic principles – [*Jayne, et al.*, 2000]; size-resolved chemistry – [*Jiménez, et al.*, 2003]; calibrations and error analysis – [*Allan, et al.*, 2003]; chemical analysis methods – [*Allan, et al.*, 2003]; particle beam characterization – [*Huffman, et al.*, 2005]; TOF-AMS principles – [*Drewnick, et al.*, 2005]; high resolution analysis – [*DeCarlo, et al.*]). AMS data gathering methods used followed the standards established in the published literature.

Data obtained using an AMS in MS and PTOF modes of operation consist of average mass spectra that are converted into particulate mass loadings and size-dependent mass spectra that are converted into particulate mass distributions. Thus, the two finished data streams generated are chemically-speciated mass loadings and mass distributions. The calibrations and quality control procedures of these data (e.g. flow rate calibration, m/z calibration, peak tuning, size, and ionization efficiency calibrations) have been published (Allan et al., 2003; Jayne et al., 2000; Jiménez et al., 2003).

For this project, the deployed AMS will be a high resolution instrument that can operate as a standard HR-TOF-AMS and in a new mode for black carbon particle detection with the intracavity laser operating (SP-AMS) [*Onasch et al.*, 2010]. Both AMS operational modes (HR-AMS and SP-AMS) operate in the same manner, with the only difference being the particle vaporization techniques. The standard HR-AMS utilizes a heated tungsten vaporizer that flash vaporizes impacting particles. The SP-AMS utilizes an intense intracavity laser that is absorbed by sampled black carbon particles, causing the absorbing particles to volatilize. The SP-AMS deployed for this study will have both vaporization techniques installed. When the intracavity laser is OFF, the SP-AMS operates as a standard HR-AMS and when the laser is ON, the SP-AMS provides an additional measure of the black carbon mass loading and size distributions. Discriminating between the organic and inorganic chemical species measured by an AMS (SP-AMS with laser OFF) and the new refractory carbon mass spectral information provided by the SP-AMS (with laser ON) is accomplished using high resolution Mass Spectral analysis software developed for standard HR-AMS analysis [*DeCarlo, et al.*, 2006]. The SP-AMS was operated with a 50% duty cycle of laser ON/OFF for the first two weeks then was changed to ~80% for the final week.

The calibrations and quality control procedures of the SP-AMS data are very similar to the standard HR-AMS data (e.g. flow rate calibration, m/z calibration, peak tuning, size, and ionization efficiency calibrations), which have been extensively described in peer-reviewed literature [*Allan, et al.*, 2003; *Jayne, et al.*, 2000; *Jiménez, et al.*, 2003]. Thus, the SP-AMS sensitivity can be calibrated using the standard AMS procedures with the addition of a relative

ionization efficiency calibration for black carbon. The SP-AMS mass spectra and size distribution data are acquired and analyzed using the copyrighted software: Aerodyne Aerosol Mass Spectrometer Control, Data Acquisition, Analysis, and Display Software, © 2003 and updates. The ionization efficiency of particles in the SP-AMS must be calibrated in order for the instrument to report quantitative information. In these calibrations a known concentration of aerosol is sampled into the SP-AMS and the resulting ion signal is measured and referenced to the sampled mass concentration. Calibration particles are generated by atomizing a dilute NH_4NO_3 solution and a dilution dispersion of black carbon particles suspended in water. A known mass concentration of these particles is then generated by size selecting with a differential mobility analyzer (DMA) and counting with condensation particle counter (CPC) or directly measured using the MAAP. An example of this procedure is depicted in Figure QA-17. The ammonium nitrate calibration provides the quantitative ionization efficiency calibration, whereas the direct comparison with the MAAP provides the relative ionization efficiency of the SP-AMS to sampled black carbon particles. Calibrations were performed in the field before, during and after the three weeks of measurements.

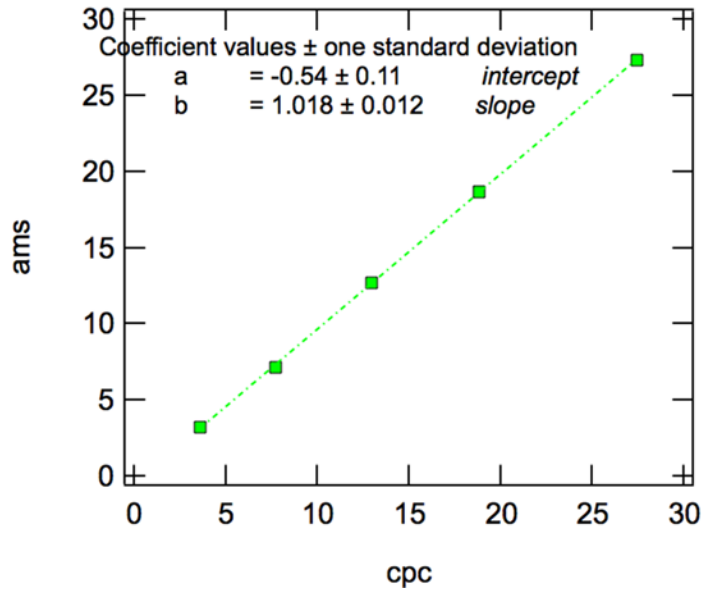


Figure QA-17 Ammonium Nitrate Calibration. The AMS mass signal response is plotted vs the CPC instrument based determination of the prepared mass standard. The data depicted in this calibration is applied to AMS signals to compute nitrate-equivalent mass loadings.

The quantification of uncertainties in AMS measurements are published by Allan et al. [*Allan, et al.*, 2003] and detection limits for different AMS configurations are published by DeCarlo et al. [*DeCarlo, et al.*, 2006]. The major uncertainty in AMS measurements is due to the particle collection efficiency. The collection efficiency of standard AMS measurements (particle bounce off the heated vaporizer prior to detection) is discussed in detail by Huffman et al. [*Huffman, et al.*, 2005] and Matthews et al. [*Matthew, et al.*, 2008]. The collection efficiency issue specific to the SP-AMS is quantifying the overlap region between the intracavity laser and the sampled particle beam (compared with overlap with the heated vaporizer) [*Onasch et al.*, 2010]. This overlap can be determined by conducting particle beam walk and beam width probe (wire) experiments. Both of these procedures were developed for standard AMS instruments and described in the literature [*Huffman, et al.*, 2005]. These overlap tests were done prior to the start of the campaign.

The most direct quantification of the collection efficiency is through in situ comparisons with other instruments. Thus, in addition to instrument specific QC procedures, the measurements from the SP-AMS will be rigorously compared with other, simultaneous measurements of particle mass (e.g. MAAP). Chemical composition evaluation will have to be performed using the instrument response factors derived from campaigns where additional dataset were available to ensure data quality and consistency (Takegawa et al., 2005). Essentially, the particulate instrumentation suite did not collect alternative forms of chemical composition during the flare testing. Thus, the SP-AMS dataset is the single metric for deducing the chemical composition of the particulate matter during this test. The data will be compared to other SP-AMS datasets for consistency.

Key data parameters for the major fine PM measurements (the SP-AMS and MAAP) are measured mass loadings of specific PM components expressed in $\mu g/m^3$ or ng/m^3 along with estimated uncertainties based on measurement precision as determined by standard deviations from known particle calibration measurements and estimates of systematic errors of the specific measurement. However, for the TSI Condensation Particle Counter (CPC) instrument, the key data parameter is the number density of particles within the instruments measurement range (~10 to 1000 nm diameter) expressed as particles/cm^3.

The commercial TSI CPC and Thermo Environmental MAAP instruments are factory calibrated and are periodically returned for refurbishment and recalibration.

Quality Assurance: Molecular Oxygen

This section is a technical overview of the oxygen sensor deployed to the TCEQ Comprehensive Flare Study in September and October of 2010. The sensor deployed was a California Analytical Instruments CAI600P oxygen sensor. The reported resolution of the instrument is 0.1% of full scale.

The instrument was calibrated using a 100% oxygen tank diluted through a Thermo Electron Model 146i Dynamic Gas Calibrator. The O_2 sensor inlet was then overblown with the dilution gas. The calibration range spanned from 0 to 3% oxygen, which completely covered the sampling concentrations. The sample concentrations depended on the extent of dilution used for the particular experiment.

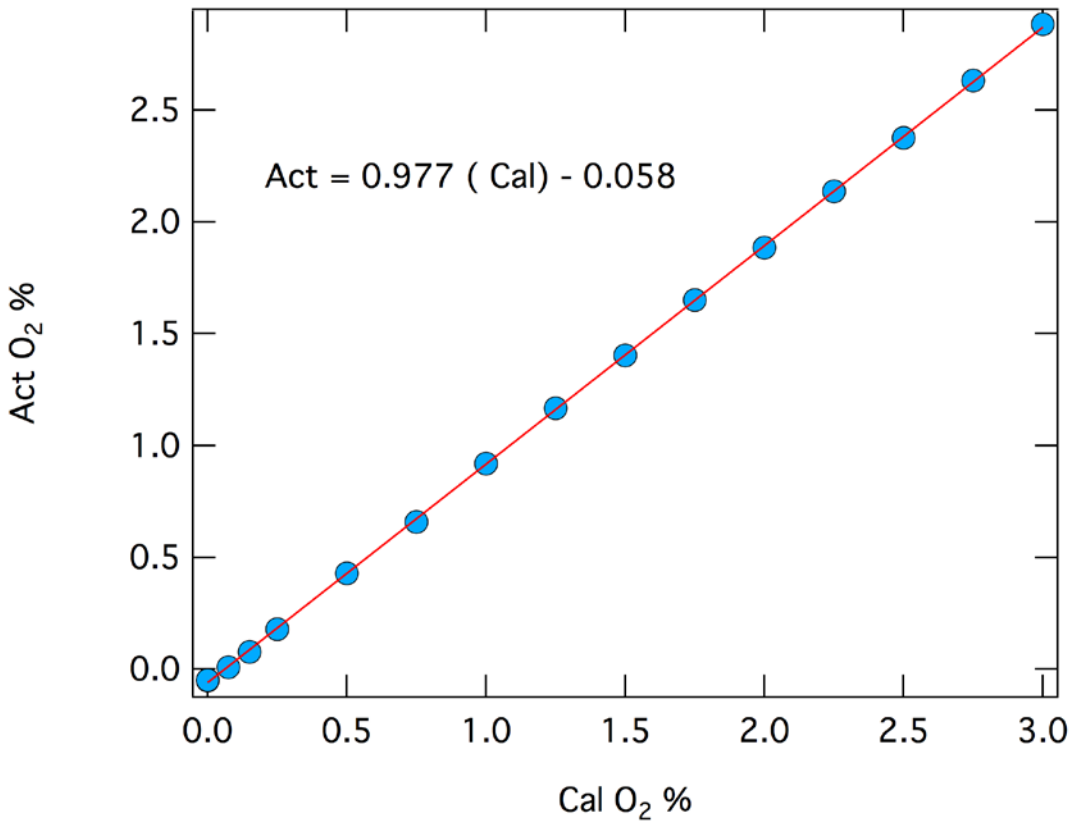


Figure QA-18. Calibration Curve for CAI600P oxygen sensor

Quality Assurance Description for Carbon Dioxide

This section includes a technical description of the different carbon dioxide measurment instruments deployed in the TCEQ Comprehensive Flare Study in September and October of 2010. Three different measurements of carbon dioxide were made; one in the gas phase sample line, one in the particle line manifold, and the last as part of a total carbon measurement.

Three different carbon dioxide instruments, a LiCor 820, LiCor 6262, and LiCor 7000 were deployed at the TCEQ Comprehensive Flare Study. The LiCor instruments are non-dispersive infrared gas analyzers and have precisions under 1 ppm for the 820 and 6262, and 0.16 ppm for the 7000. Zeroes and spans were taken by overblowing the inlet to the instrument with either N_2 or Span gas. The data shown in Table <CO_2 Span> shows the zeros and spans of the CO_2 instruments. The instruments were corrected to the span values after the readings were taken. All spans, except for the initial setup calibration, were within 1% of the span value, which was gas taken from a tank certified to 1000 ± 20 ppm by the manufacturere (Scott Specialty Gases) and certified to 994 ppm by an ARI absolute CO_2 measurement (accurate to 1%). Intercomparisons of this CO_2 standard with a 1% accuracy tank (Scott Marin gases) owned by University of California, Berkeley showed that both standards agreed within 0.7%.

Table <CO_2 Span>. Spans and readings of the three LiCor CO_2 measurements. All values are measured in ppm.

Date	Span	PM LiCor 6262	PM LiCor 820	Gas LiCor 6262
9/14/10 14:40	0	2	1.3	1
9/14/10 14:40	994	979	992	992
9/16/10 13:20	0			-1.9
9/16/10 14:06	994	999	985	994
9/24/10 12:30	0	-1.2	-4	-1.2
9/24/10 12:30	994	994	999	994

Appendix J

Wind Speed and Direction Variation for Test Series S3, S4, S5, S6, A3, A4, A5, and A6

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Wind Speed and Wind Direction Variation

The ambient wind speed and direction for each of the core test run periods are graphed on the following pages. The graphs plot 11 second averages, i.e., the average for each eleven second period. The 11 second averages are plotted at the center of the 11 second period. The average wind speed and direction for the each test run is tabulated with the other test data in Appendices D and E, Tables D-1 and E-1.

Steam Flare Tests Graphs

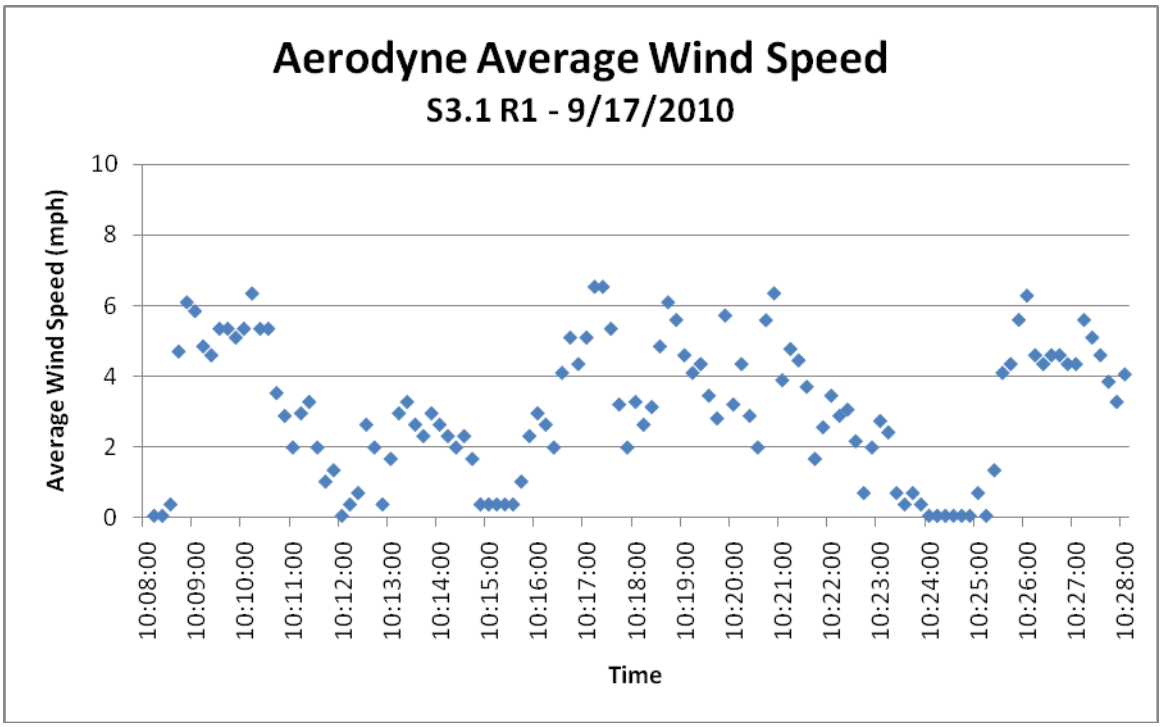


Figure J-1a. Wind Speed vs Time for Steam Flare Test S3.1R1

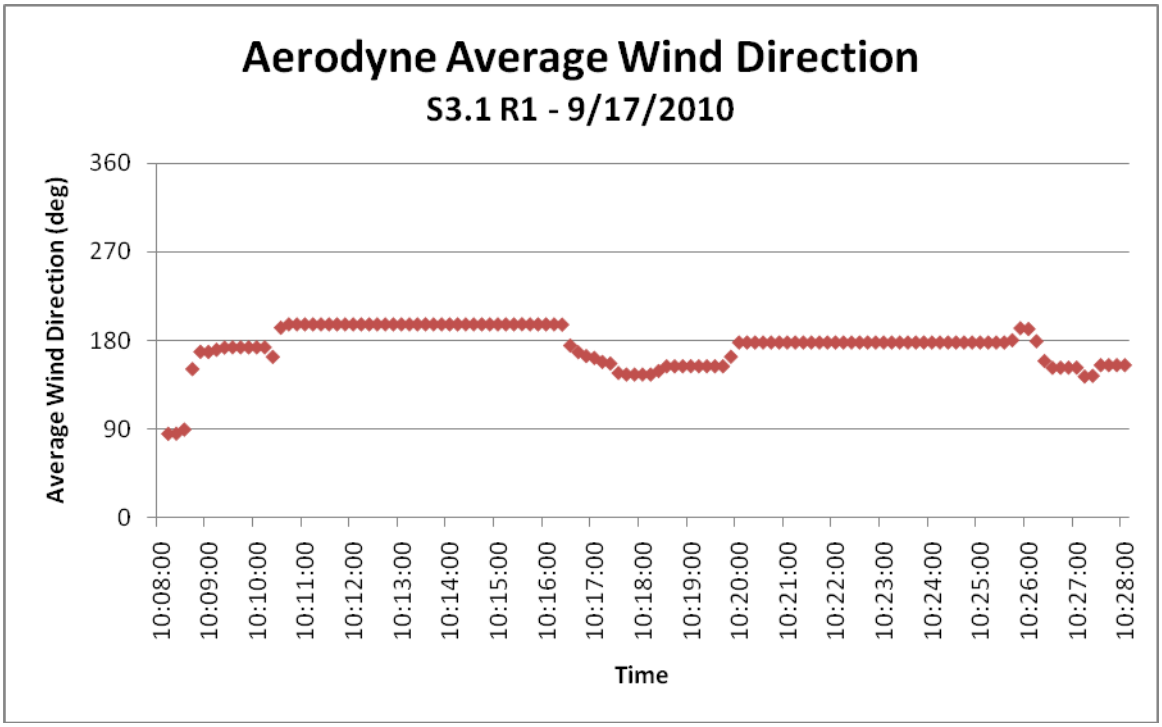


Figure J-1b. Wind Direction vs Time for Steam Flare Test S3.1R1

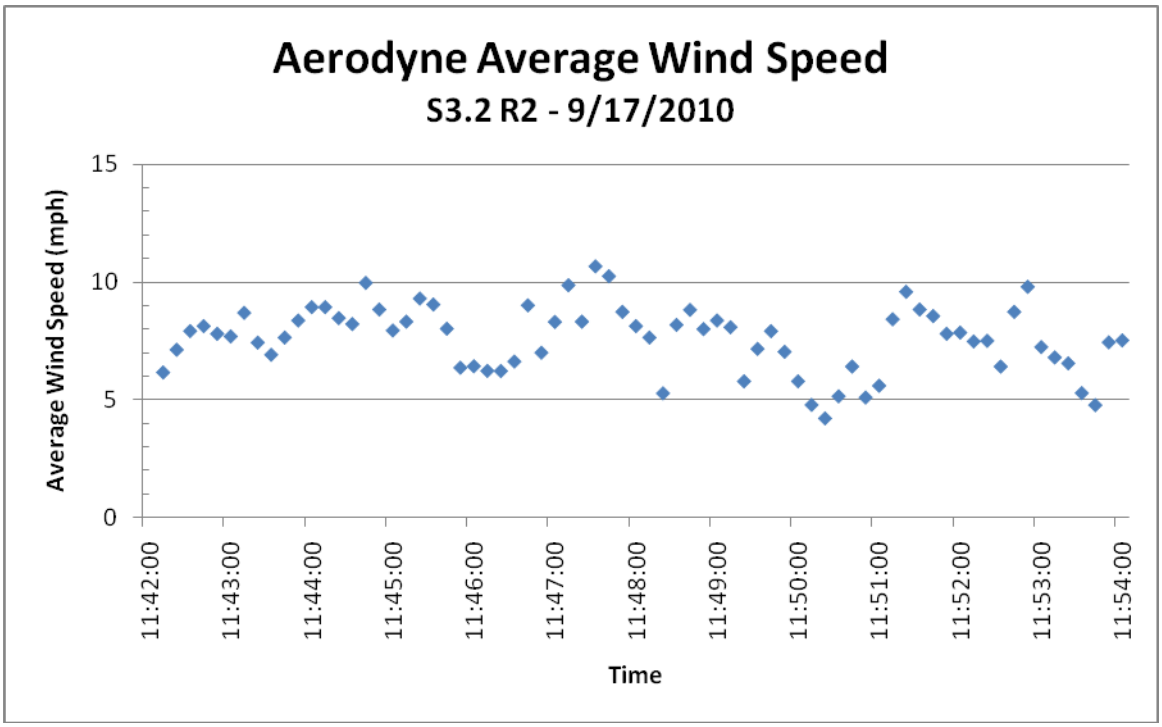


Figure J-2a. Wind Speed vs Time for Steam Flare Test S3.2 R2

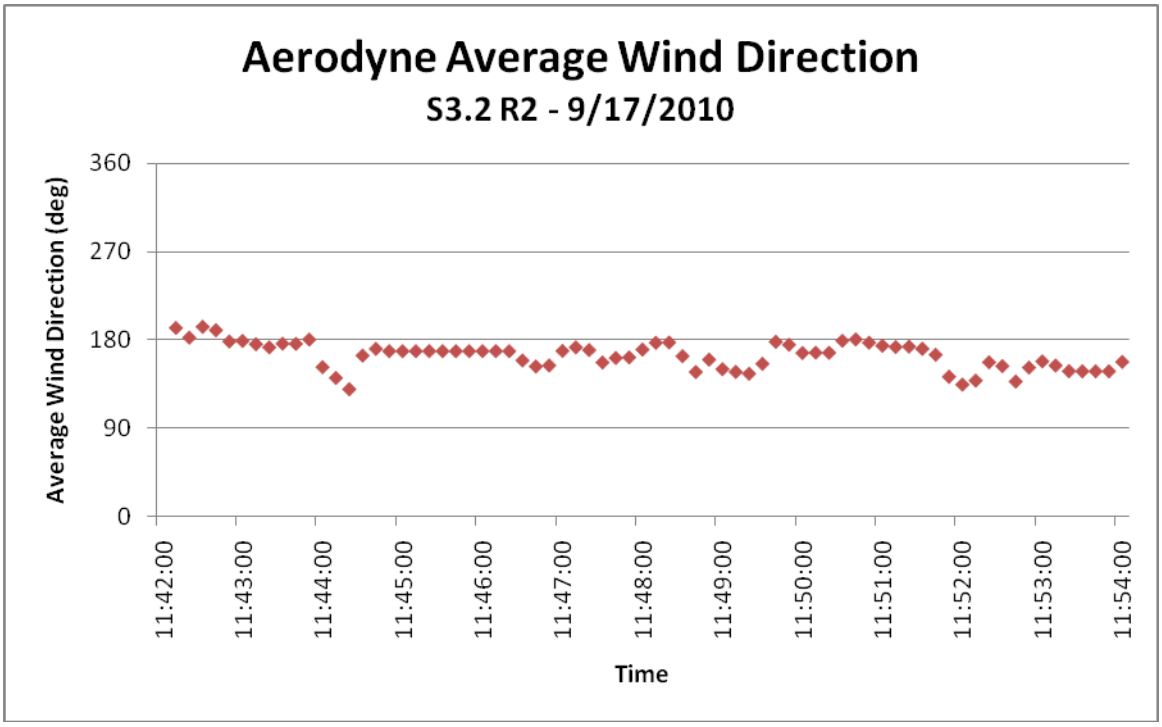


Figure J-2b. Wind Direction vs Time for Steam Flare Test S3.2 R2

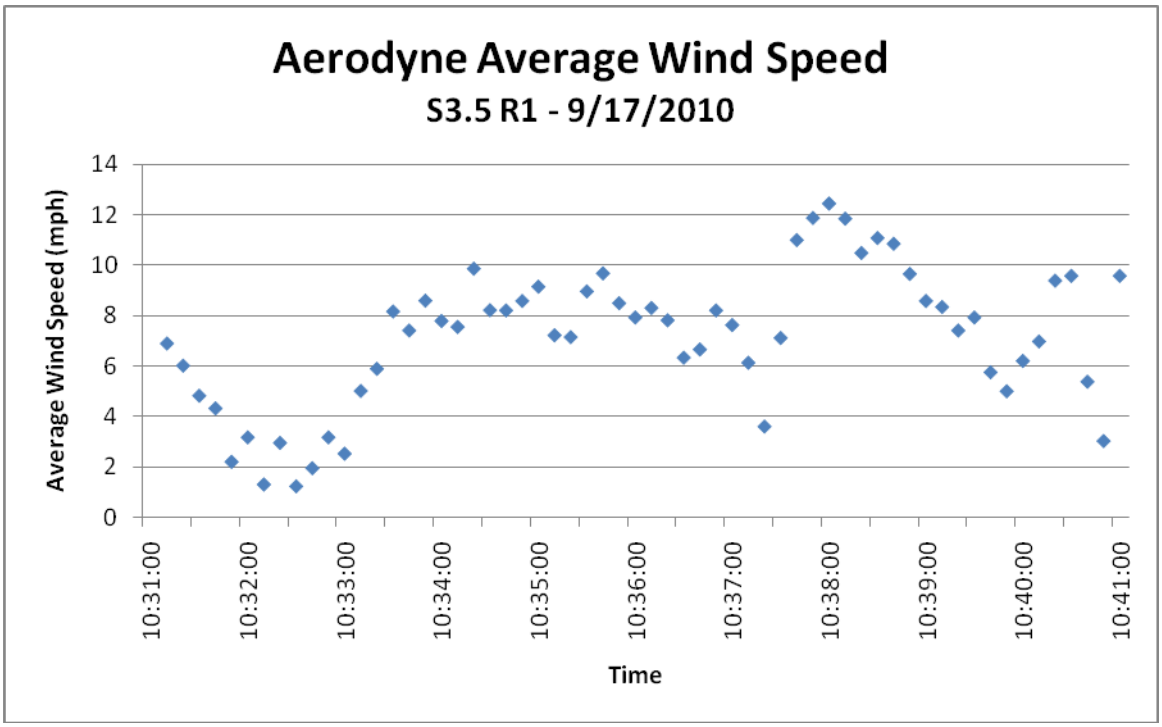


Figure J-3a. Wind Speed vs Time for Steam Flare Test S3.5 R1

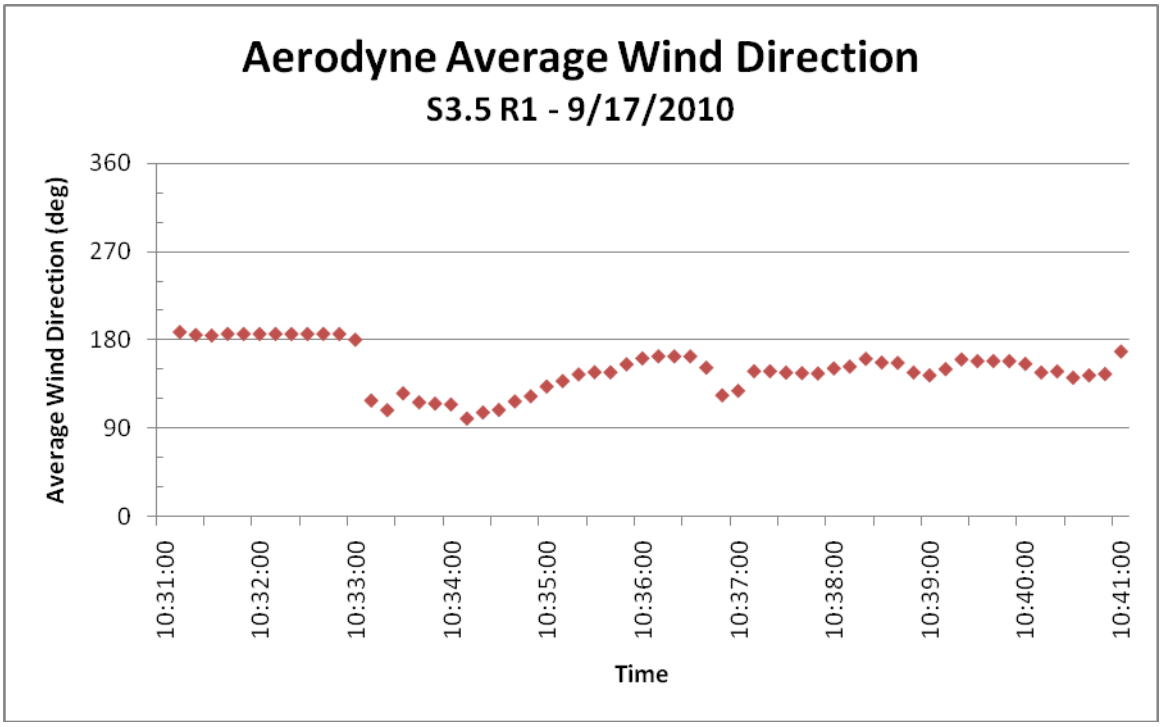


Figure J-3b. Wind Direction vs Time for Steam Flare Test S3.5 R1

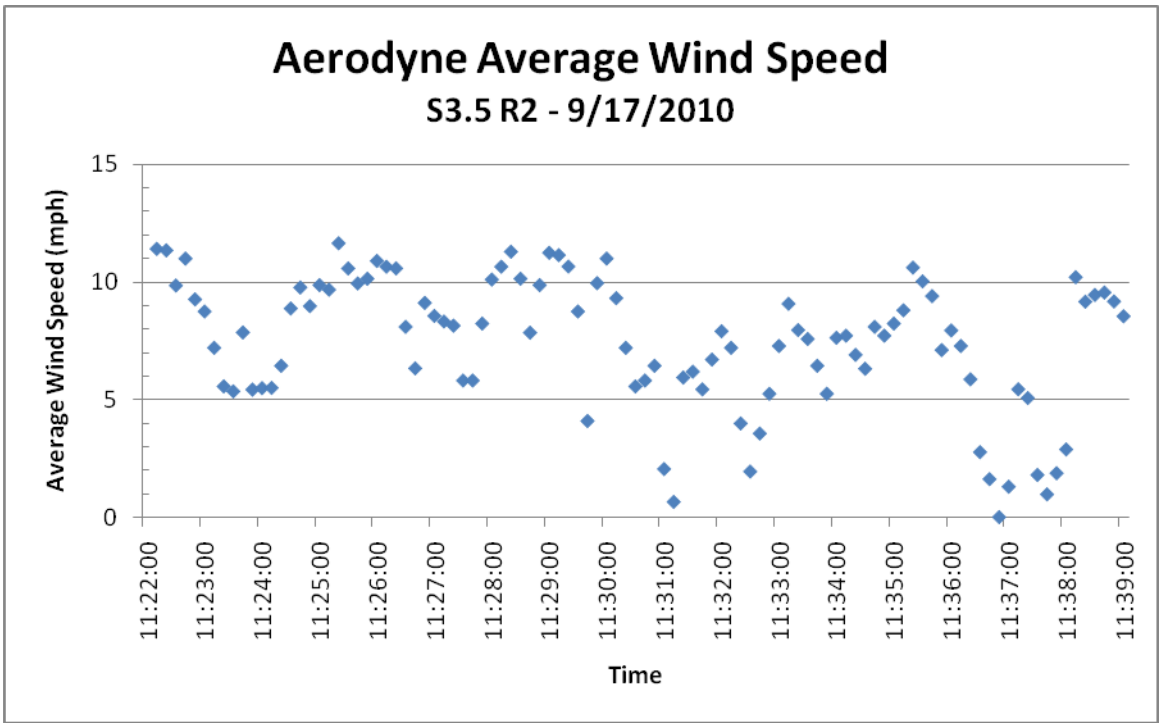


Figure J-4a. Wind Speed vs Time for Steam Flare Test S3.5 R2

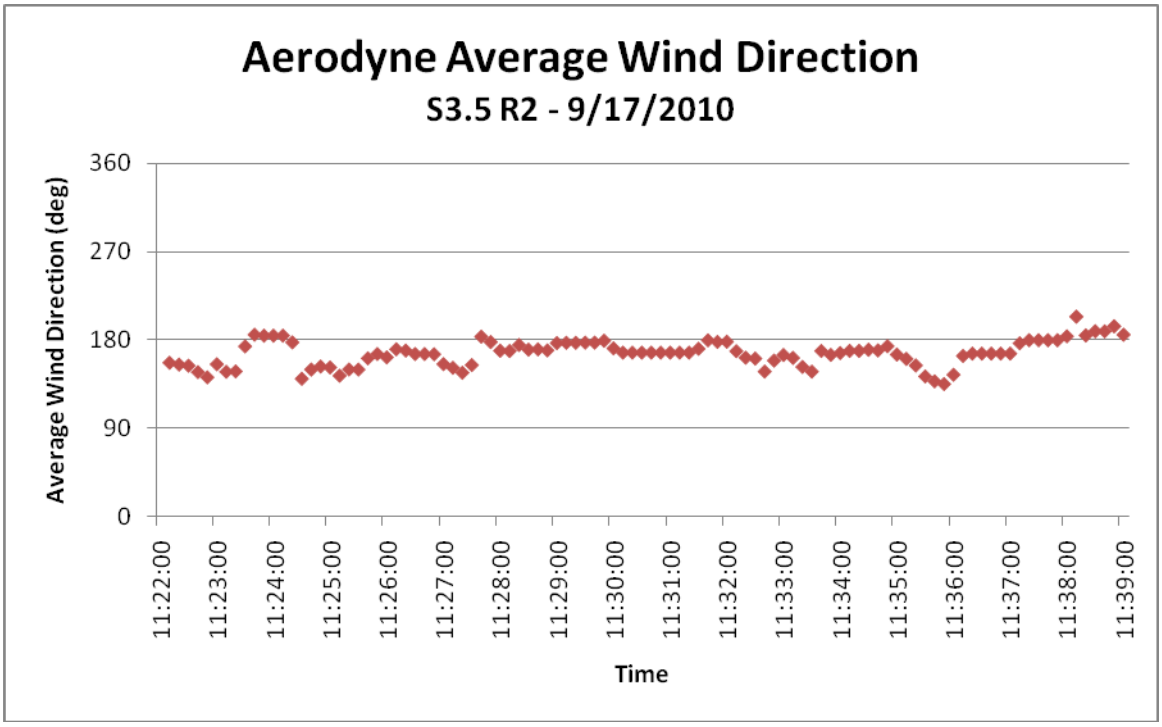


Figure J-4b. Wind Direction vs Time for Steam Flare Test S3.5 R2

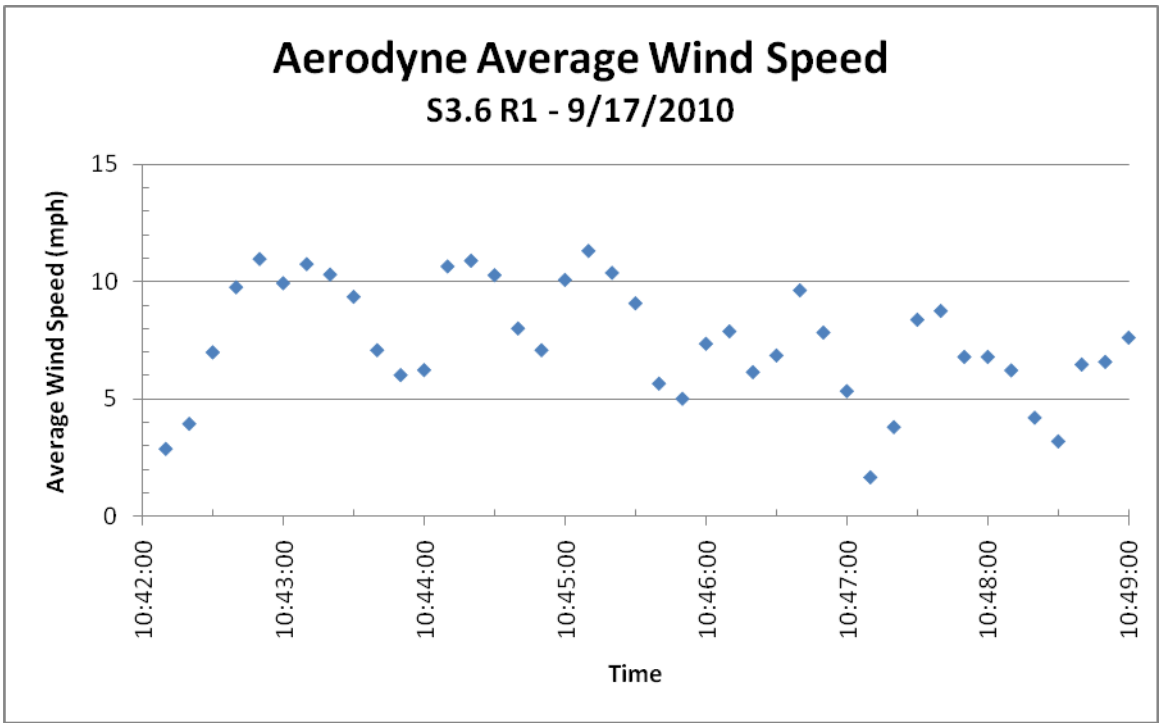


Figure J-5a. Wind Speed vs Time for Steam Flare Test S3.6 R1

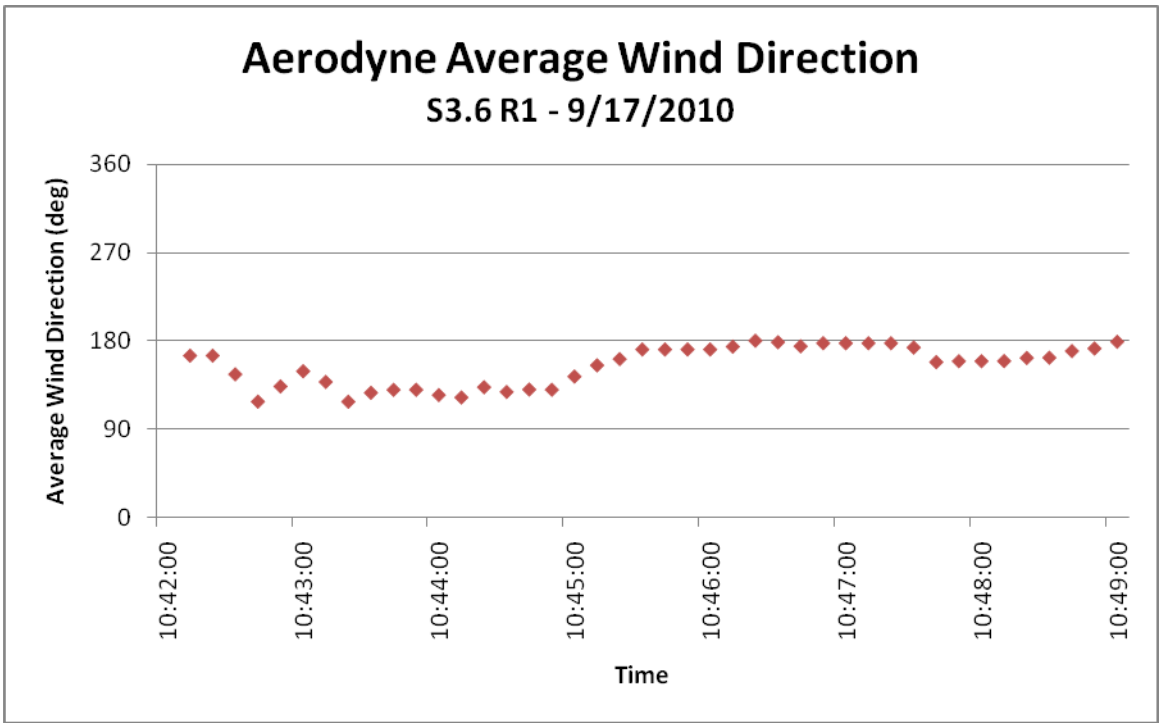


Figure J-5b. Wind Direction vs Time for Steam Flare Test S3.6 R1

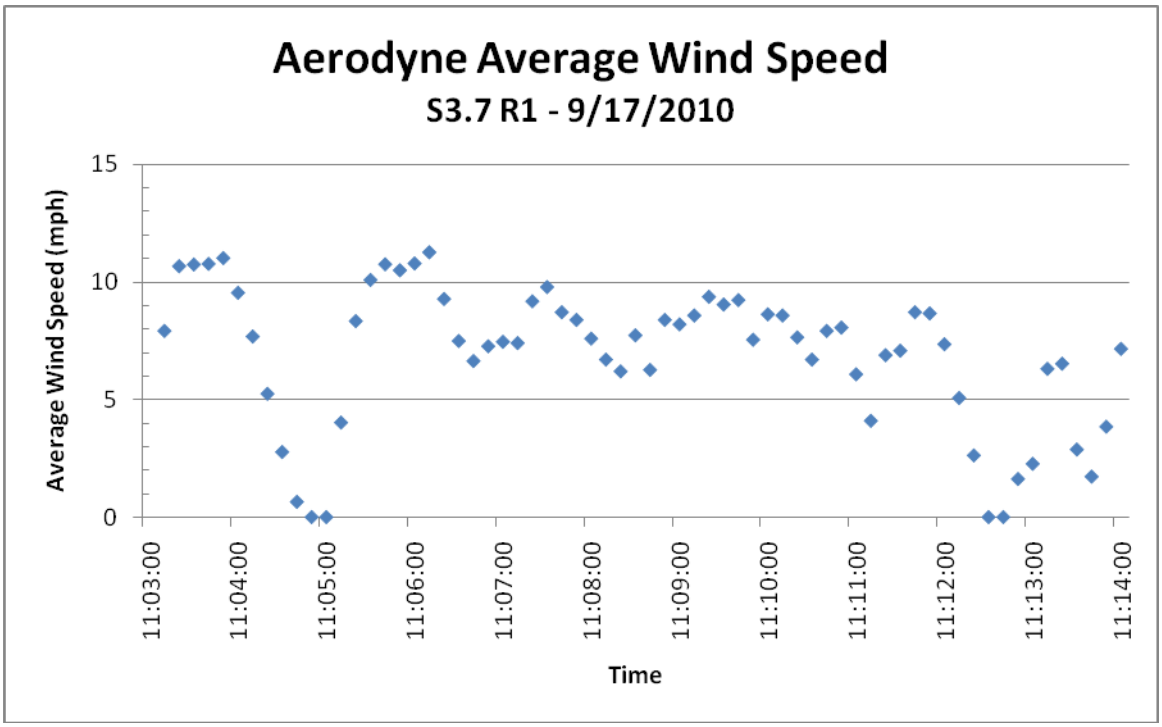


Figure J-6a. Wind Speed vs Time for Steam Flare Test S3.7 R1

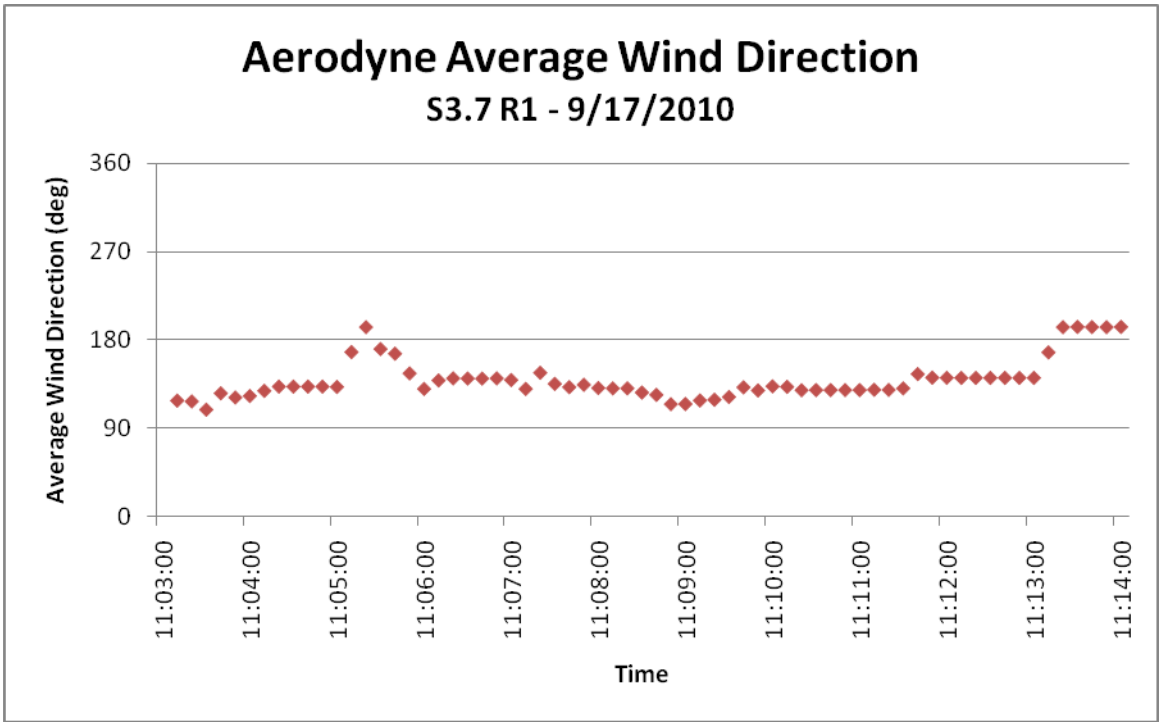


Figure J-6b. Wind Direction vs Time for Steam Flare Test S3.7 R1

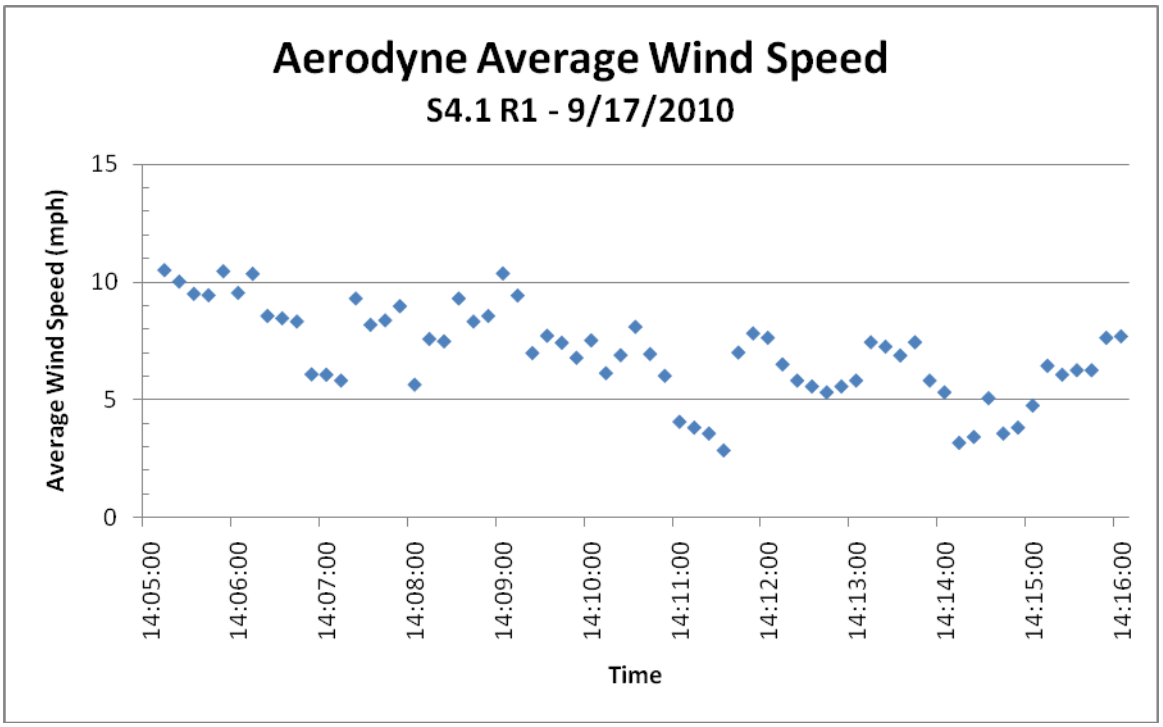


Figure J-7a. Wind Speed vs Time for Steam Flare Test S4.1 R1

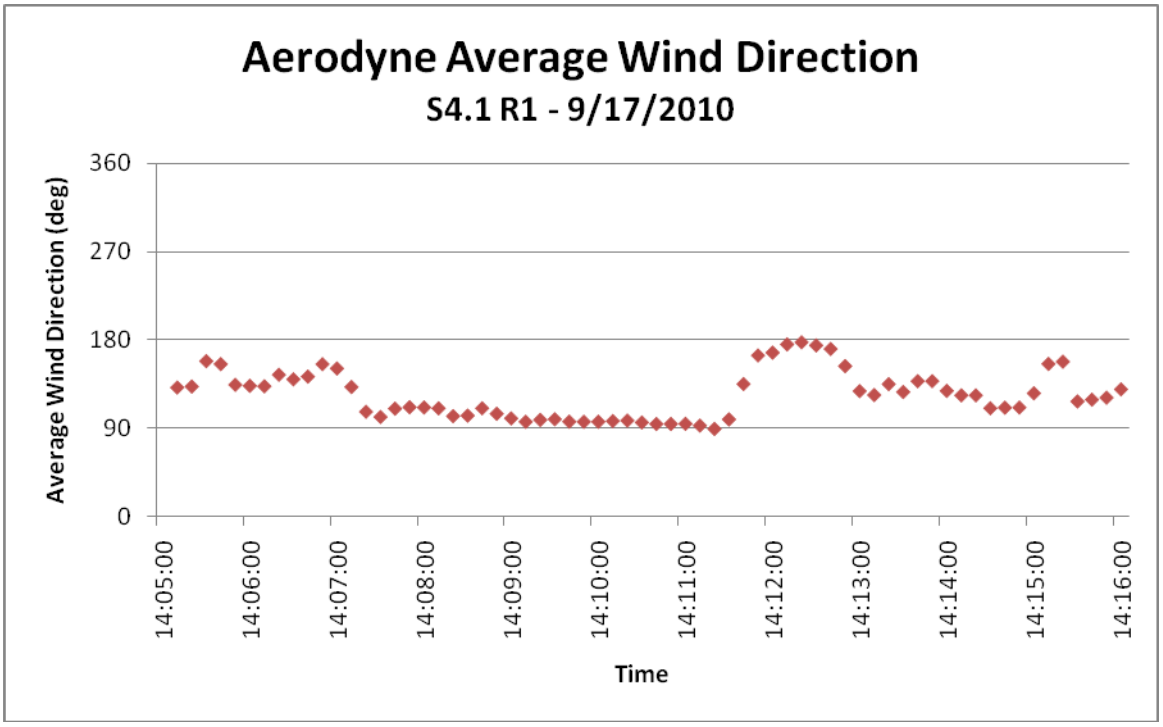


Figure J-7b. Wind Direction vs Time for Steam Flare Test S4.1 R1

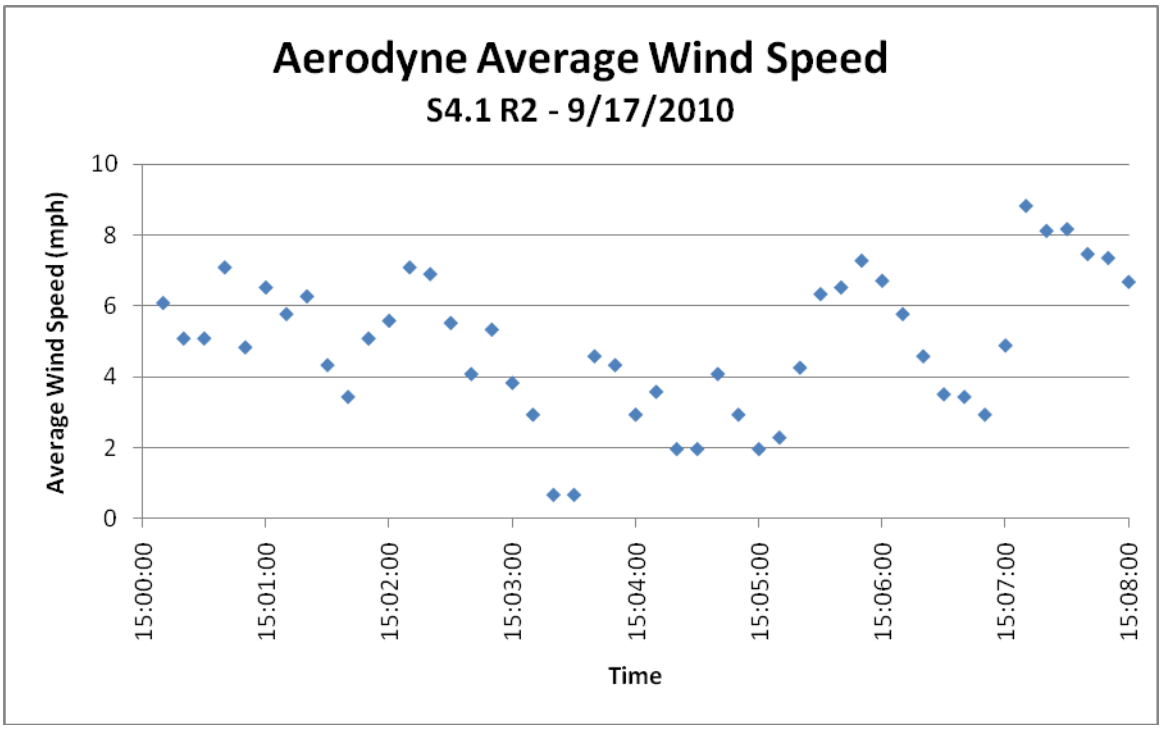


Figure J-8a. Wind Speed vs Time for Steam Flare Test S4.1 R2

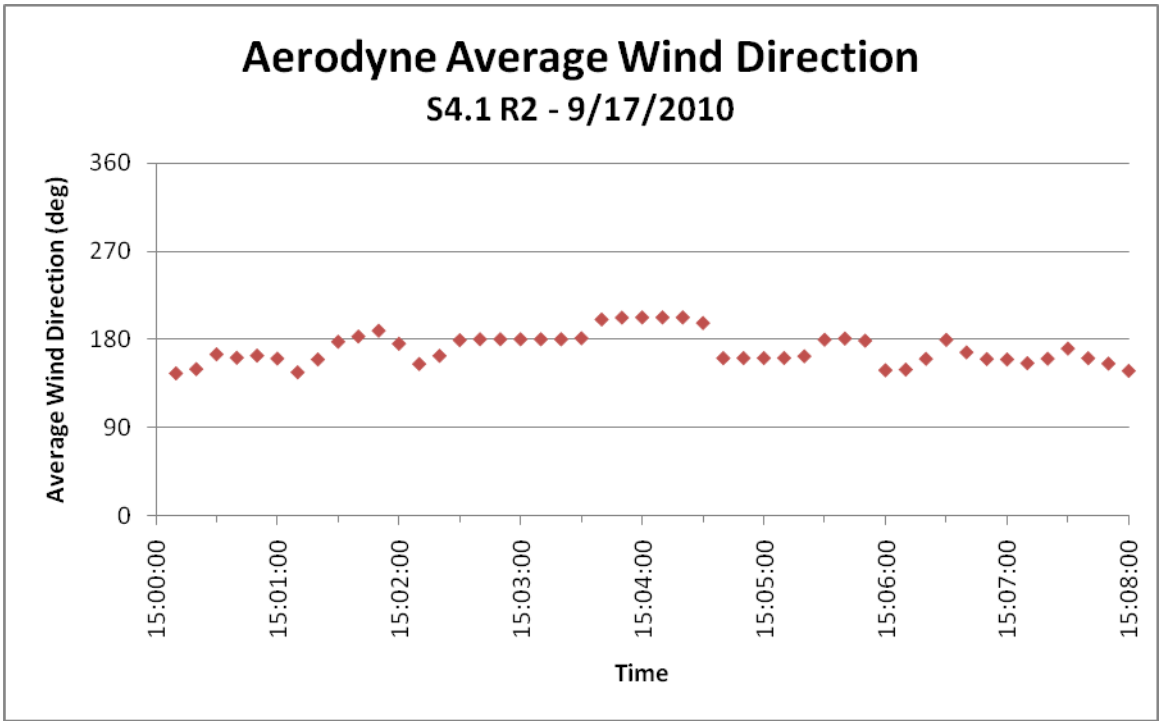


Figure J-8b. Wind Direction vs Time for Steam Flare Test S4.1 R2

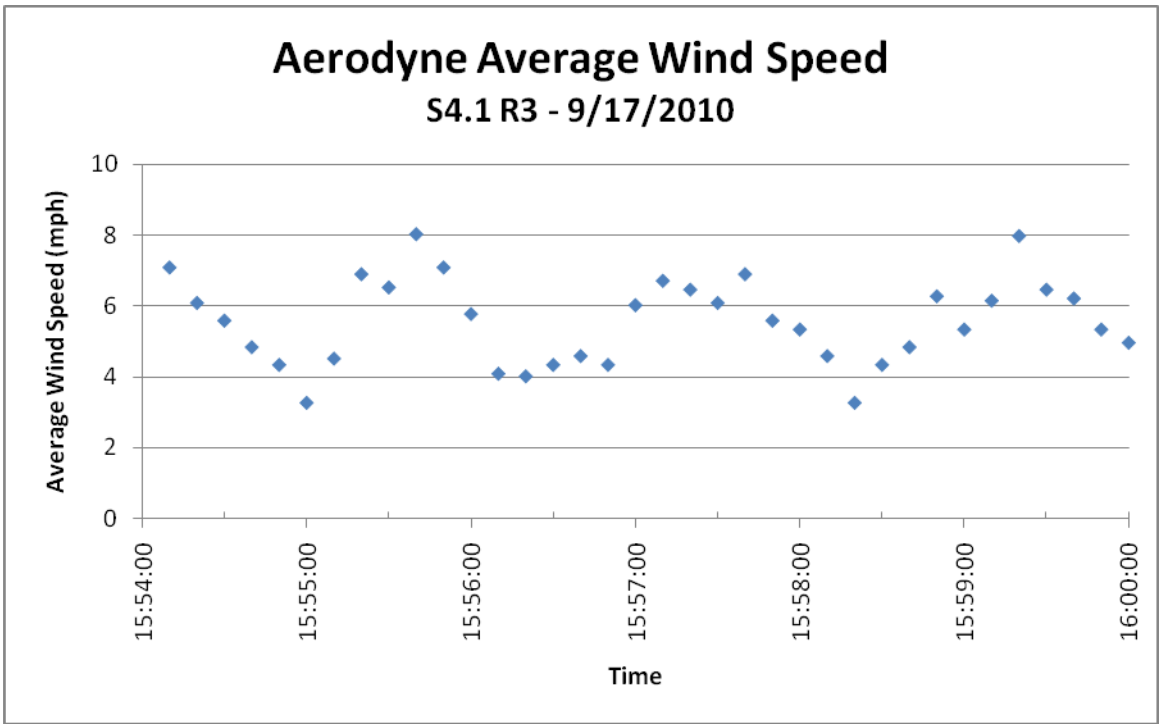


Figure J-9a. Wind Speed vs Time for Steam Flare Test S4.1 R3

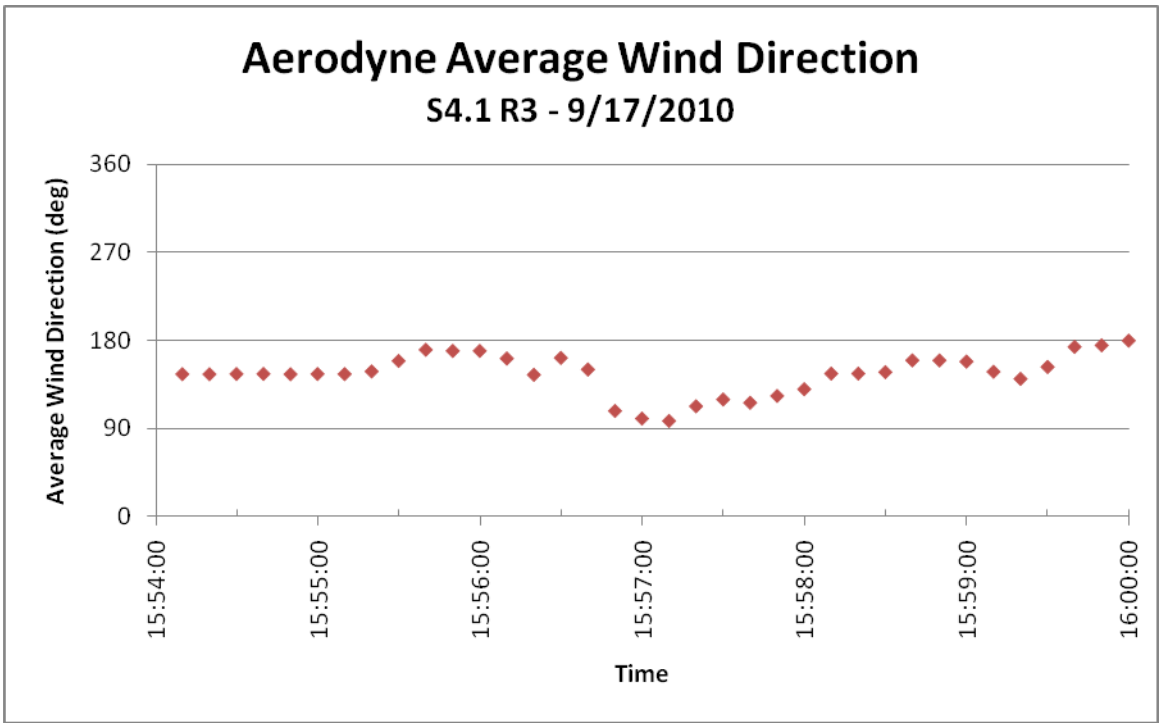


Figure J-9b. Wind Direction vs Time for Steam Flare Test S4.1 R3

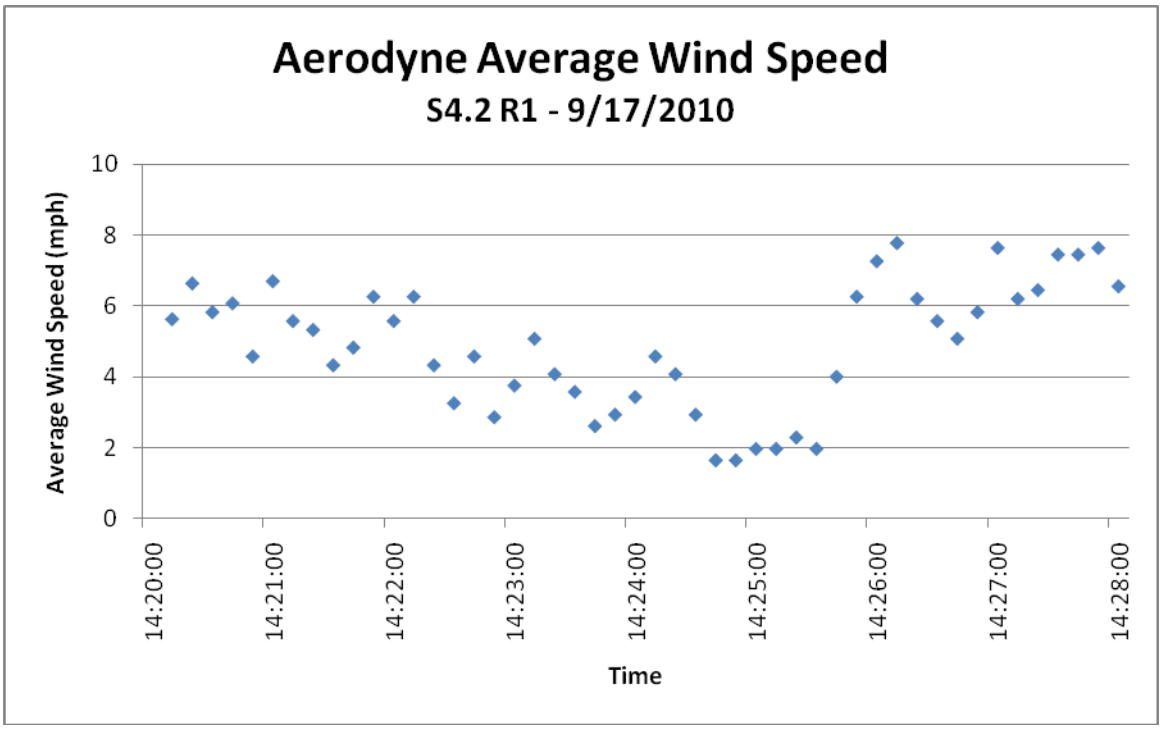


Figure J-10a. Wind Speed vs Time for Steam Flare Test S4.2 R1

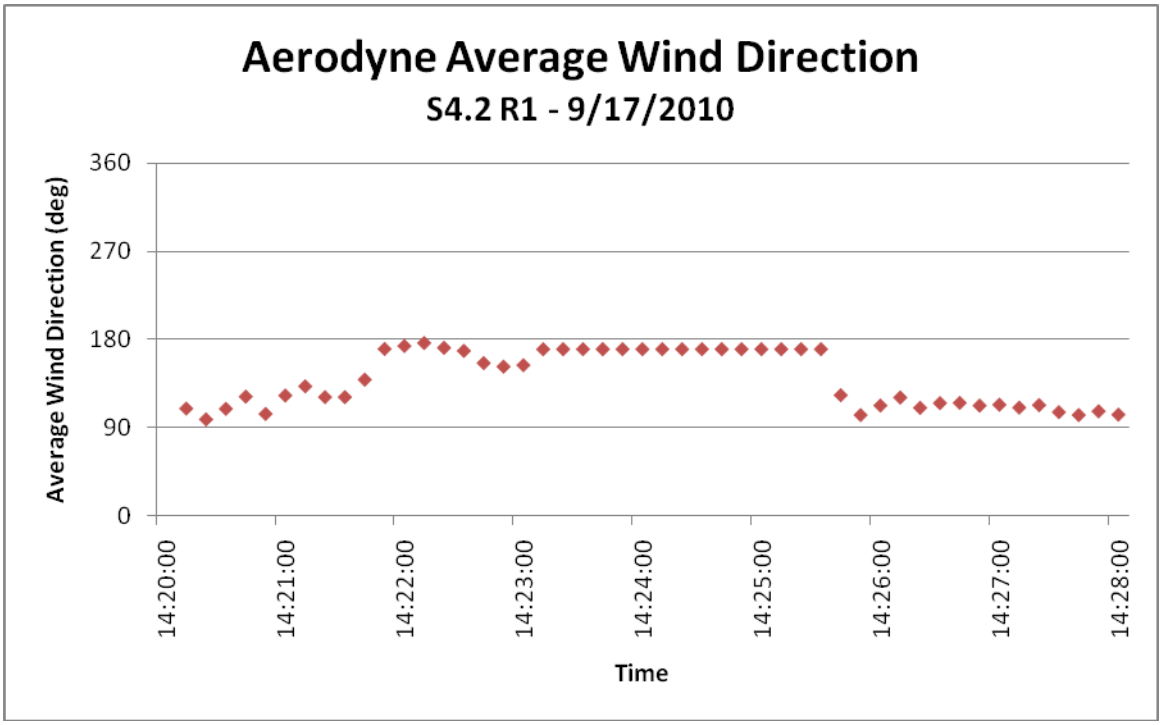


Figure J-10b. Wind Direction vs Time for Steam Flare Test S4.2 R1

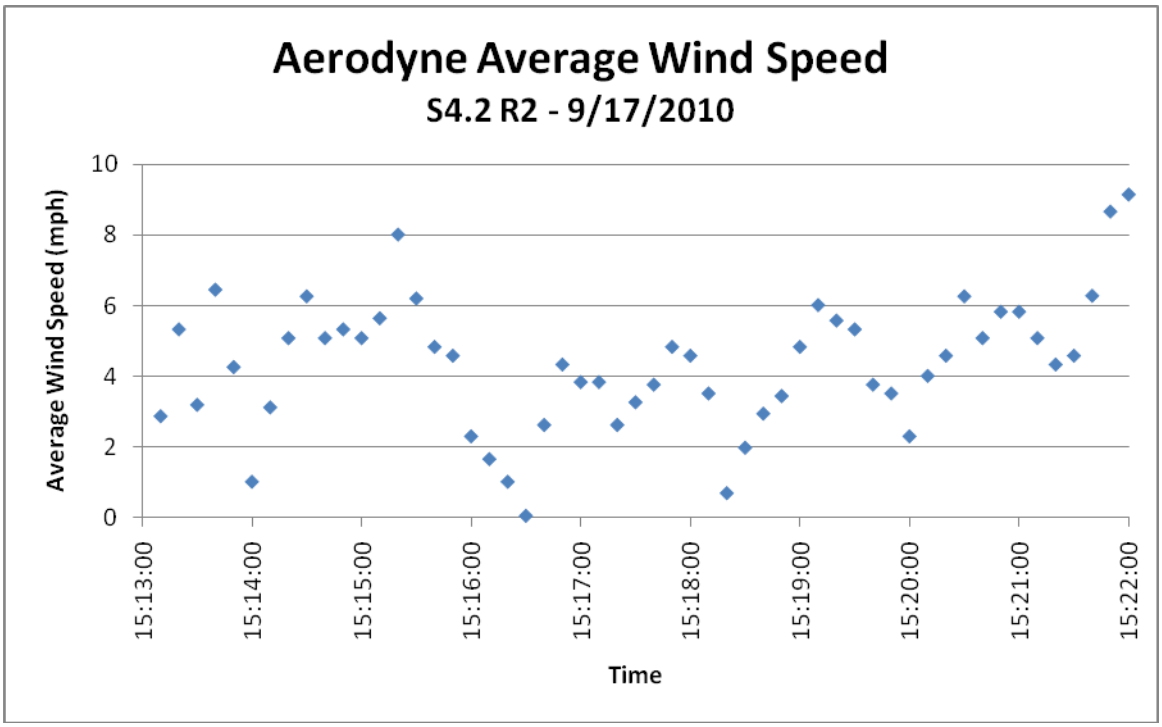


Figure J-11a. Wind Speed vs Time for Steam Flare Test S4.2 R2

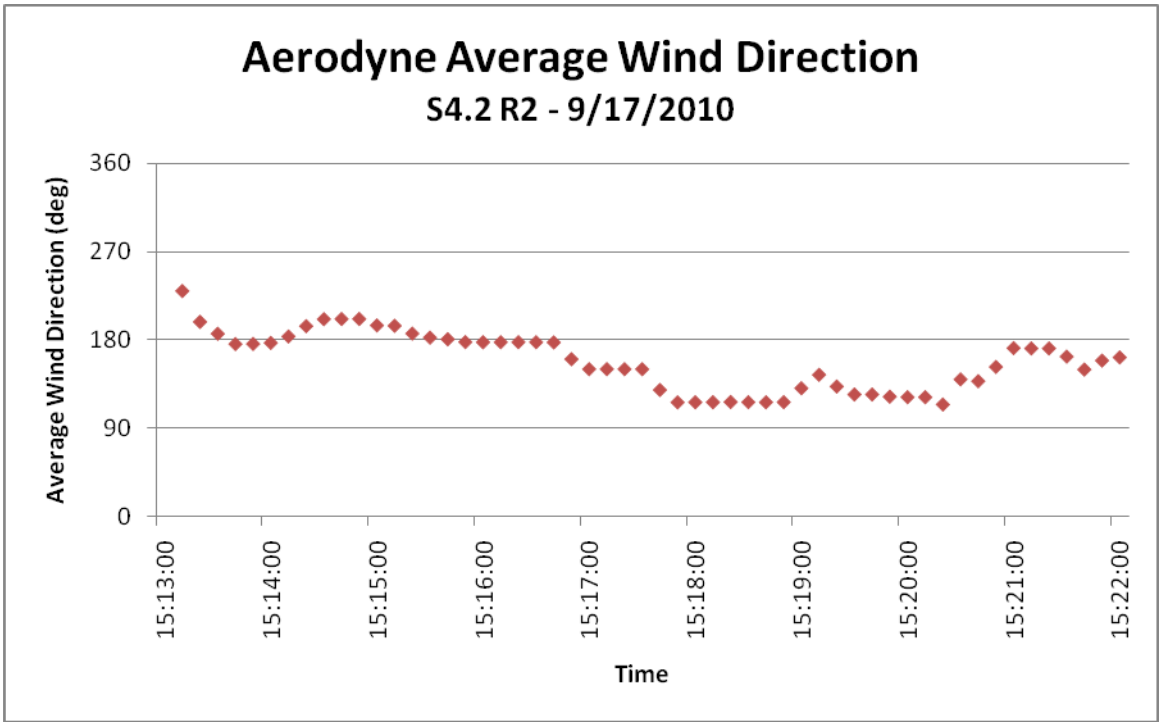


Figure J-11b. Wind Direction vs Time for Steam Flare Test S4.2 R2

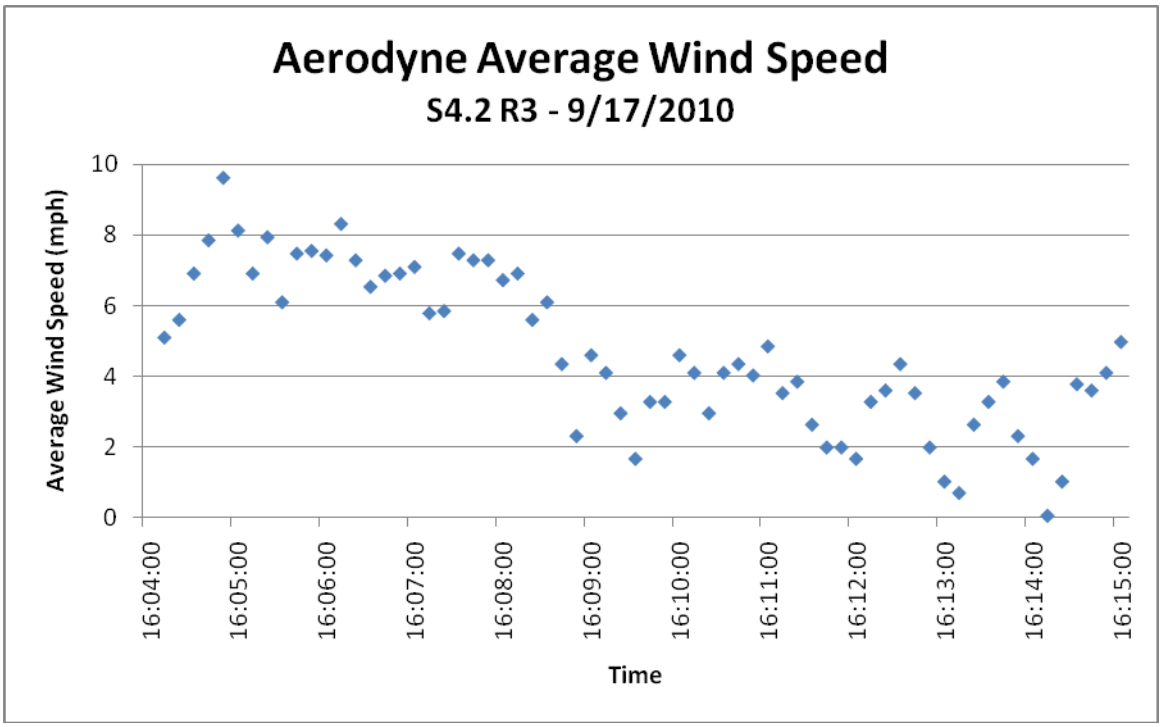


Figure J-12a. Wind Speed vs Time for Steam Flare Test S4.2 R3

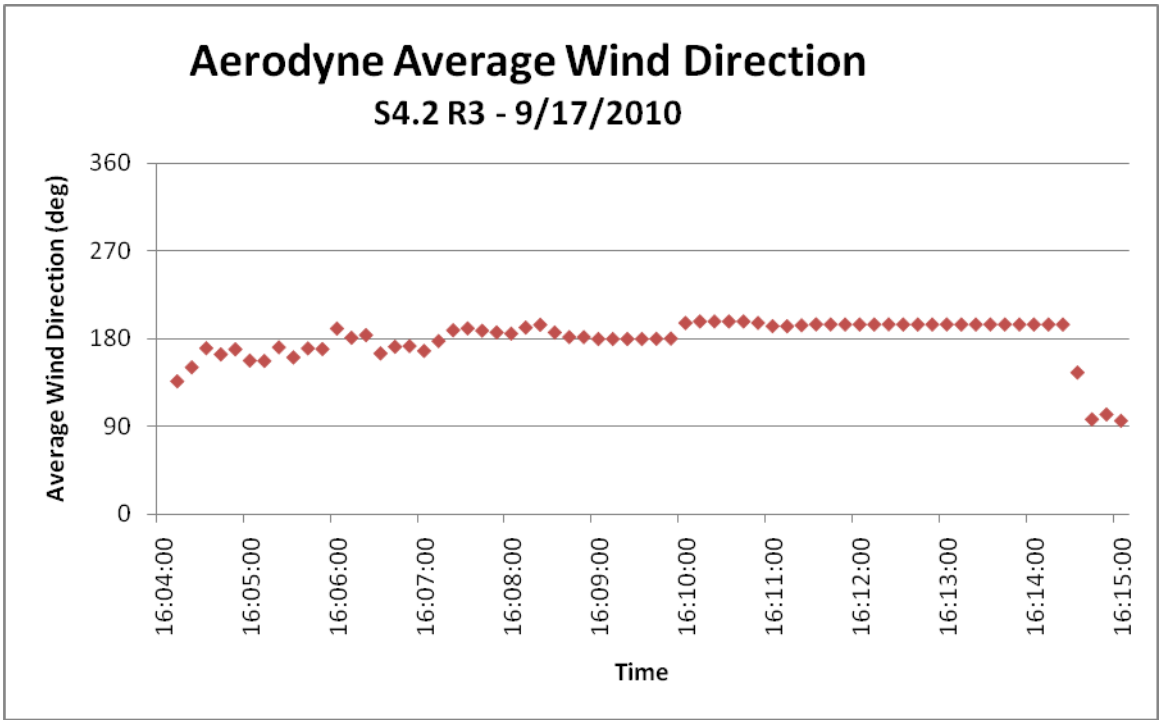


Figure J-12b. Wind Direction vs Time for Steam Flare Test S4.2 R3

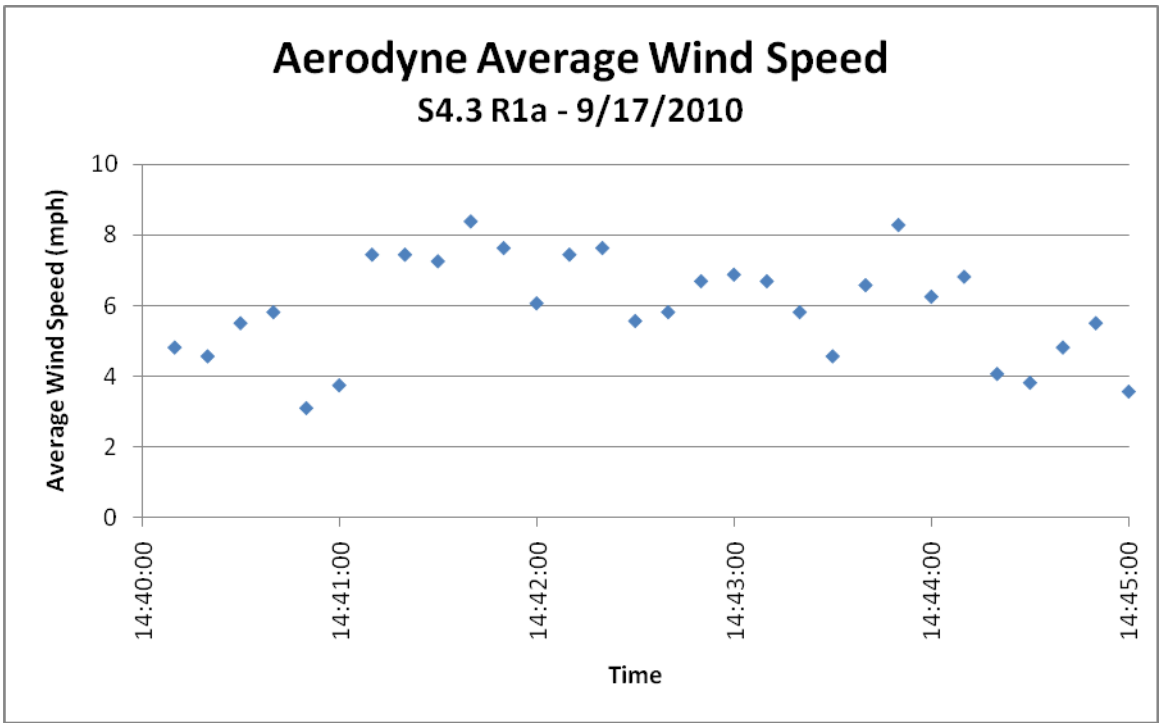


Figure J-13a. Wind Speed vs Time for Steam Flare Test S4.3 R1a

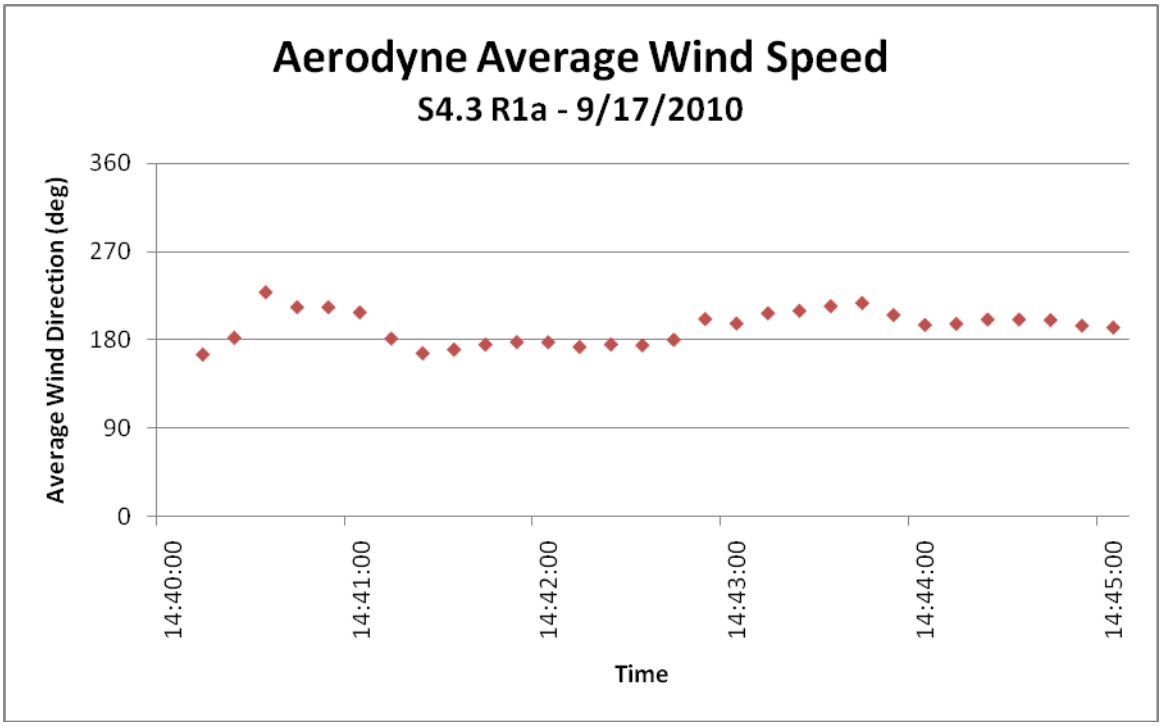


Figure J-13b. Wind Direction vs Time for Steam Flare Test S4.3 R1a

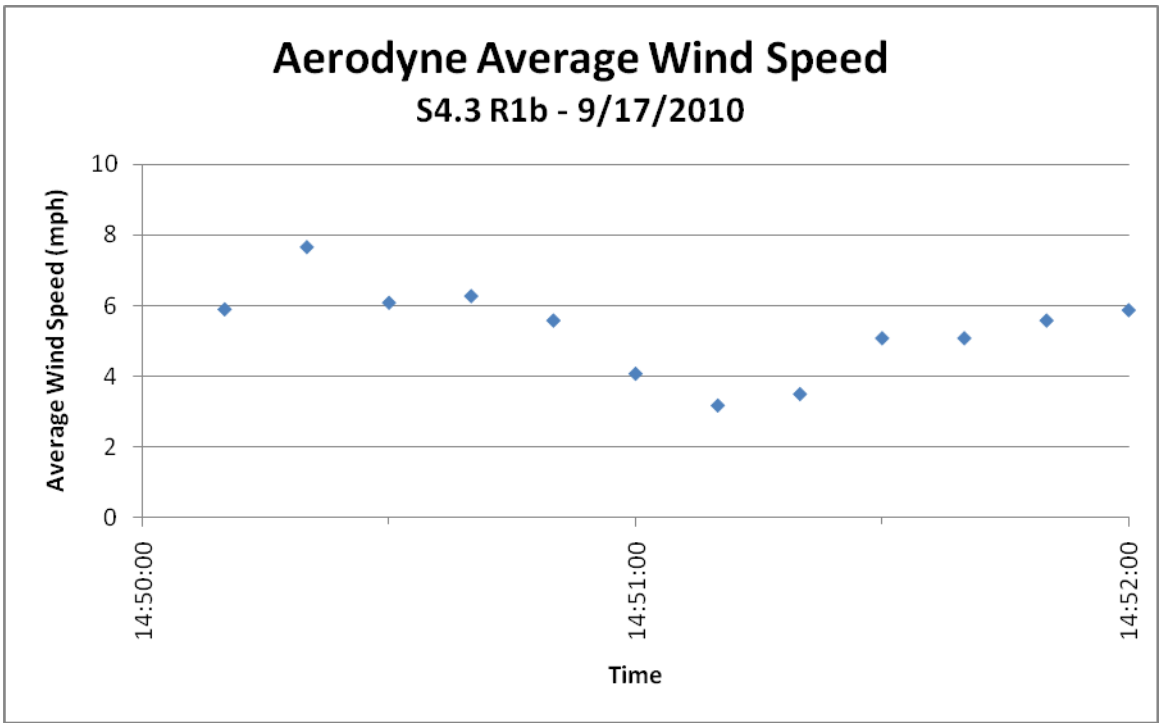


Figure J-14a. Wind Speed vs Time for Steam Flare Test S4.3 R1b

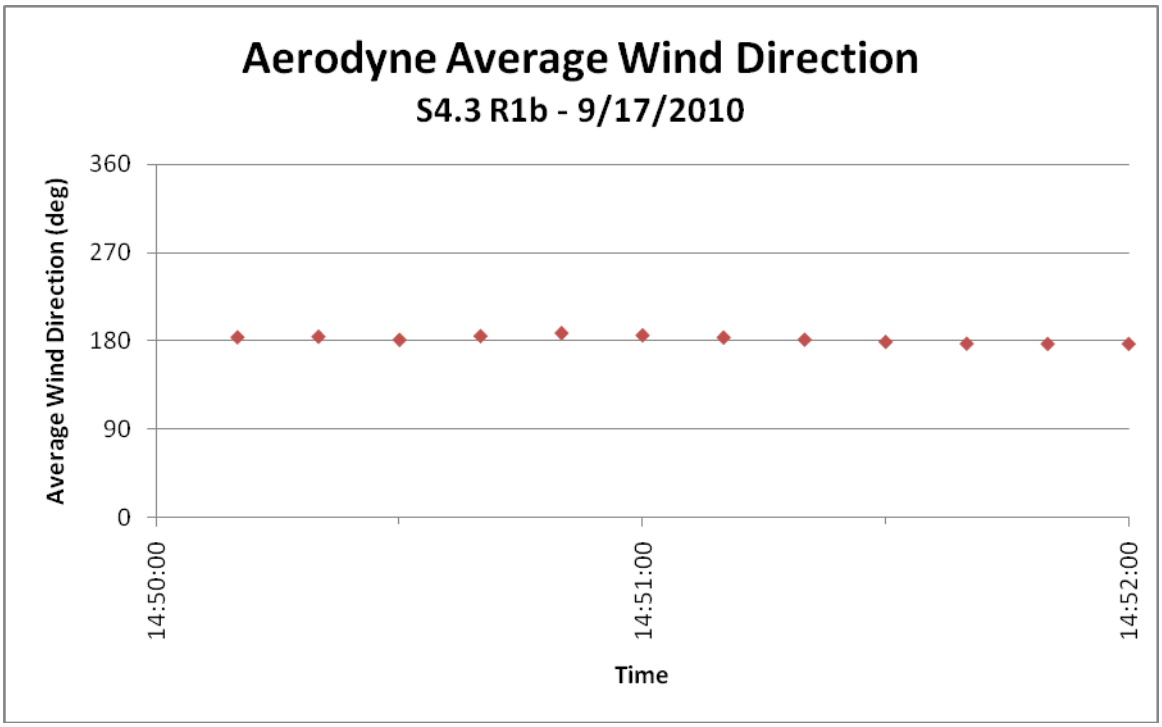


Figure J-14b. Wind Direction vs Time for Steam Flare Test S4.3 R1b

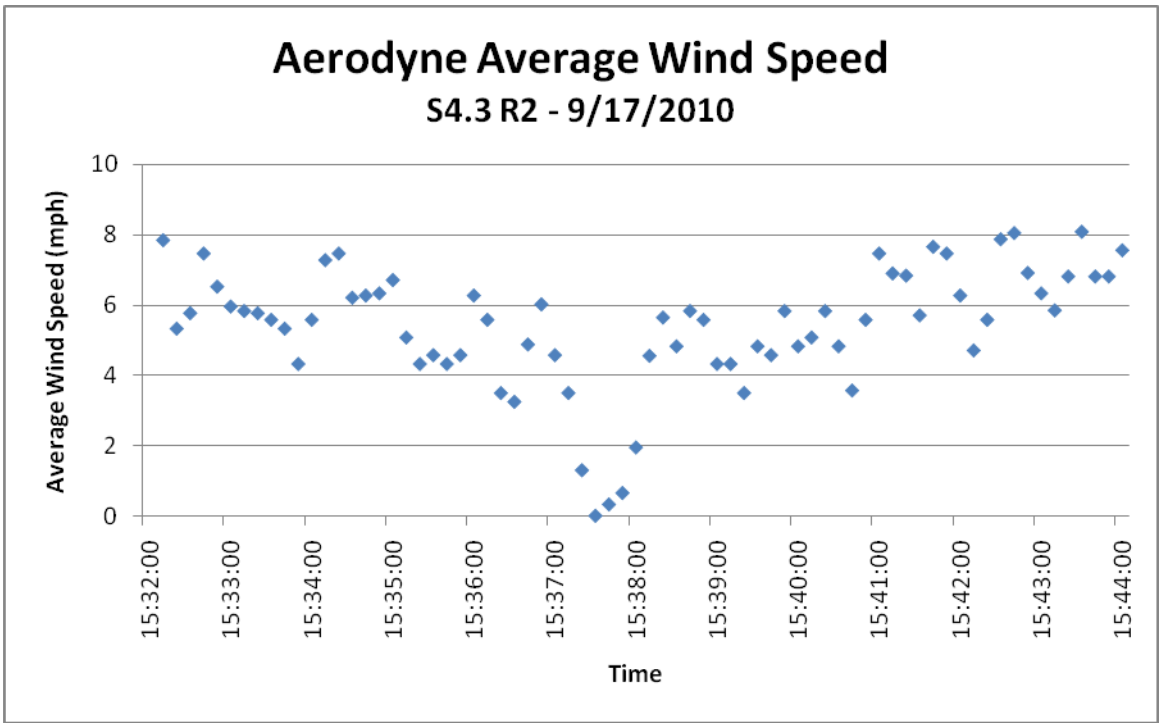


Figure J-15a. Wind Speed vs Time for Steam Flare Test S4.3 R2

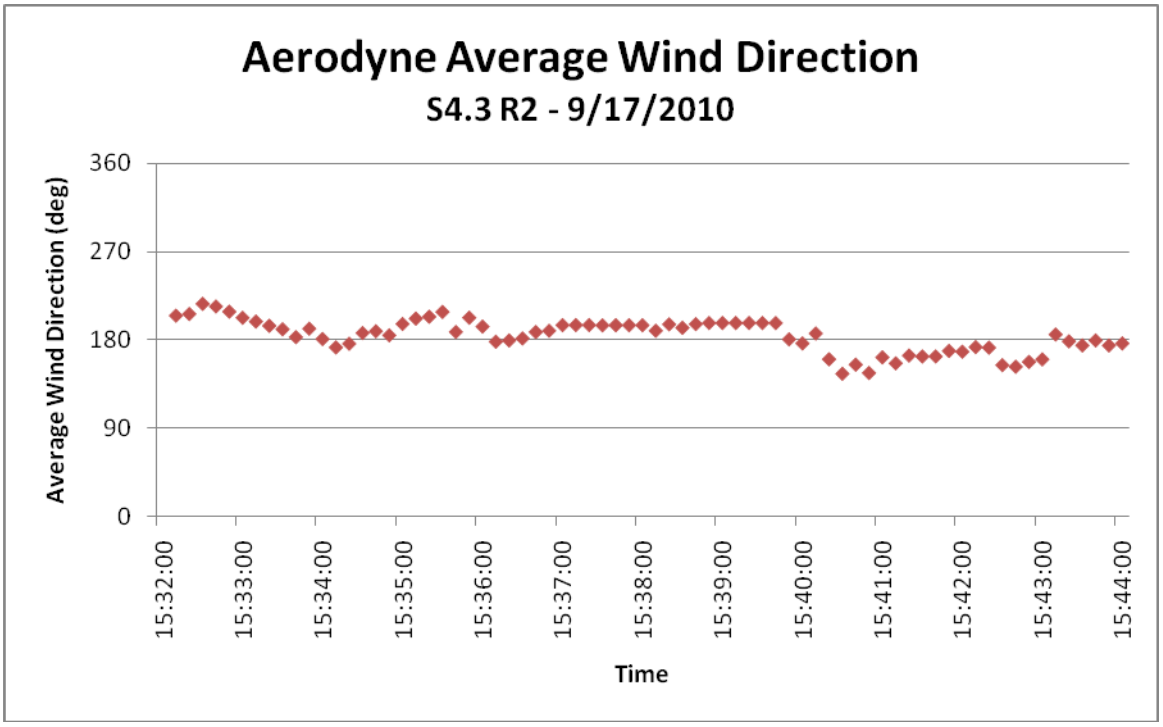


Figure J-15b. Wind Direction vs Time for Steam Flare Test S4.3 R2

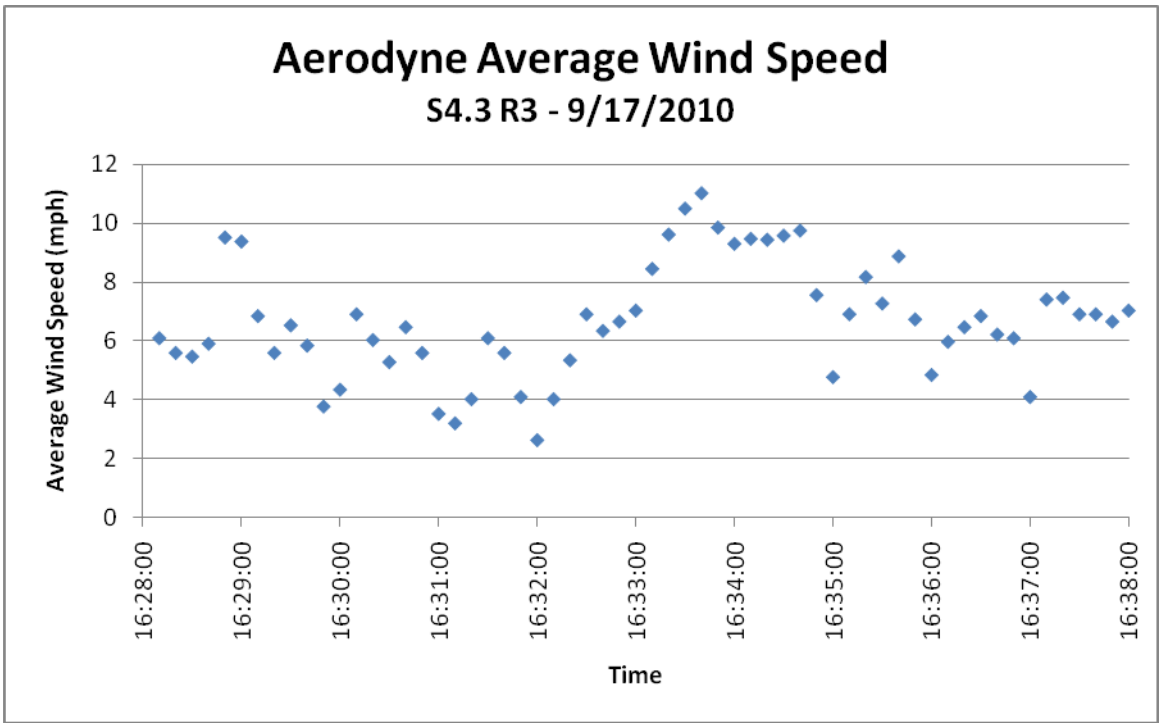


Figure J-16a. Wind Speed vs Time for Steam Flare Test S4.3 R3

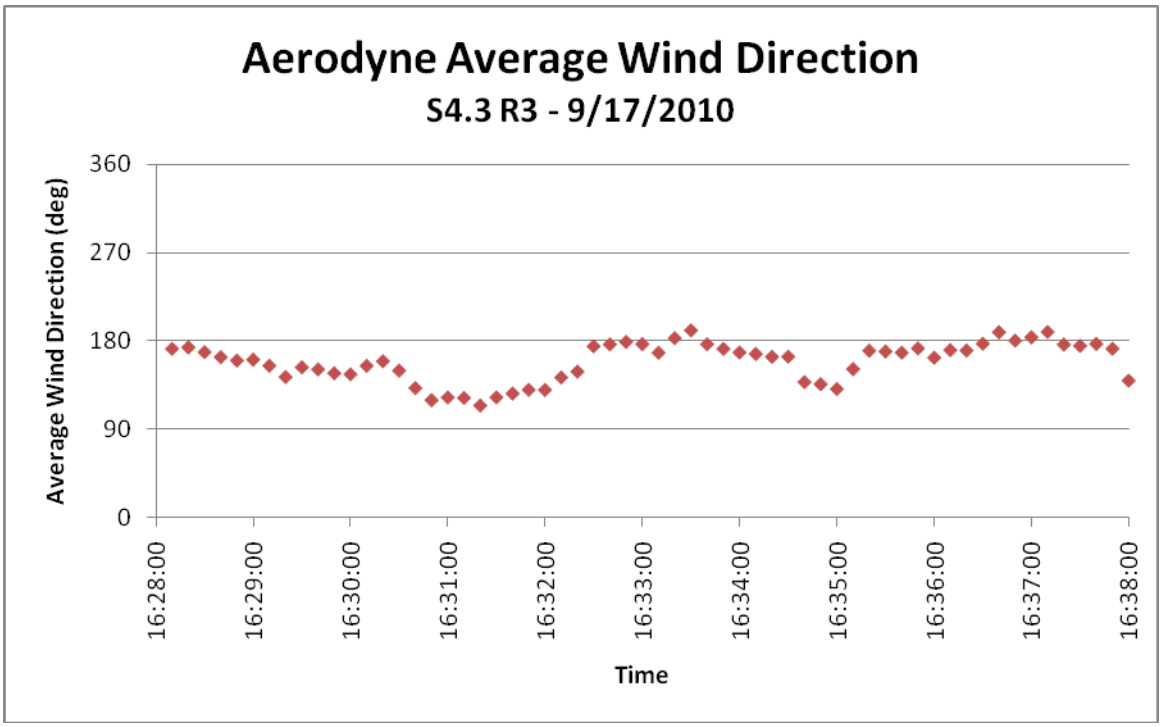


Figure J-16b. Wind Direction vs Time for Steam Flare Test S4.3 R3

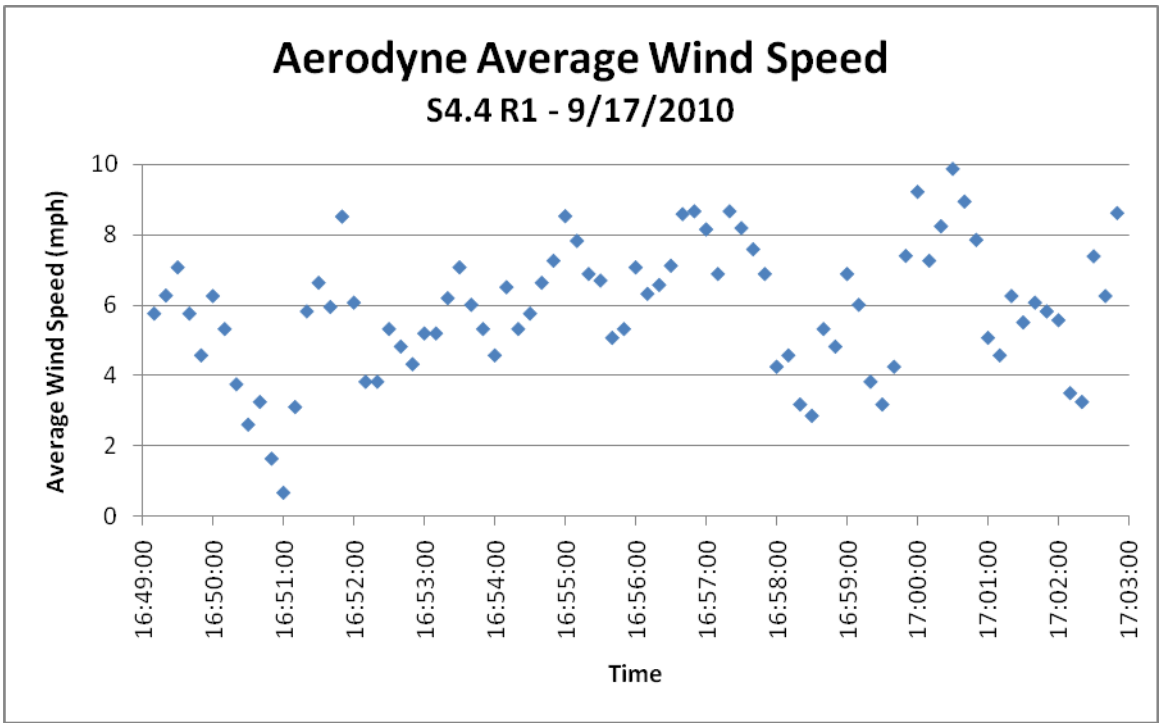


Figure J-17a. Wind Speed vs Time for Steam Flare Test S4.4 R1

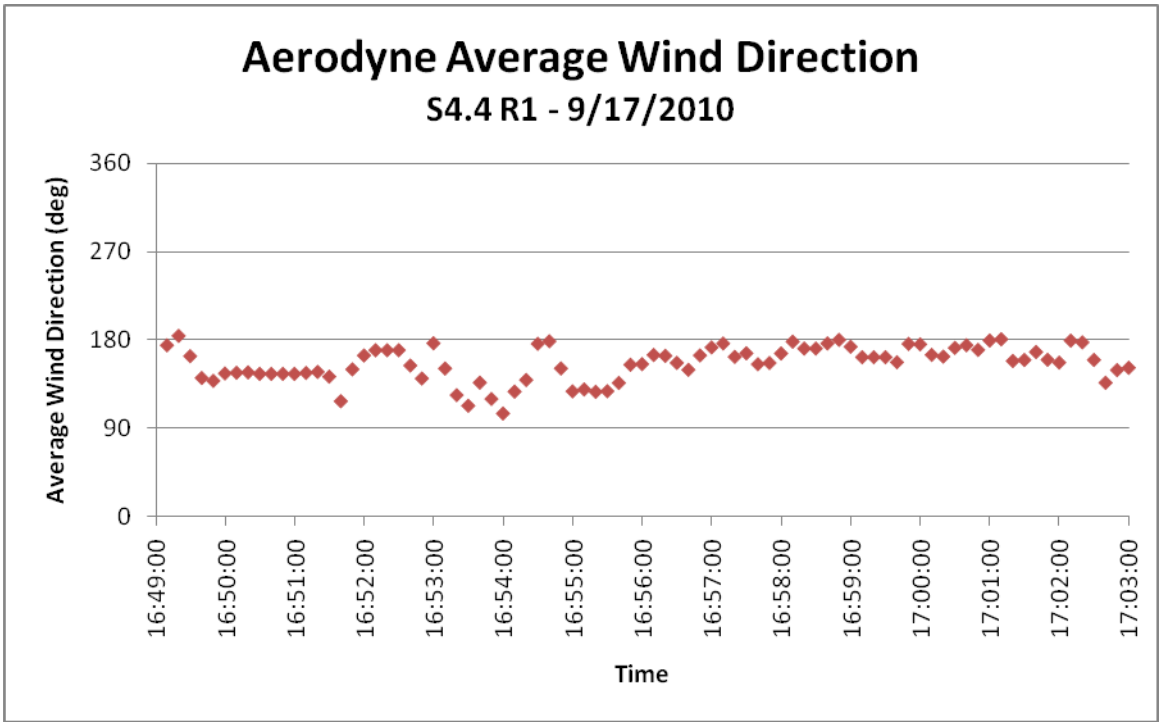


Figure J-17b. Wind Direction vs Time for Steam Flare Test S4.4 R1

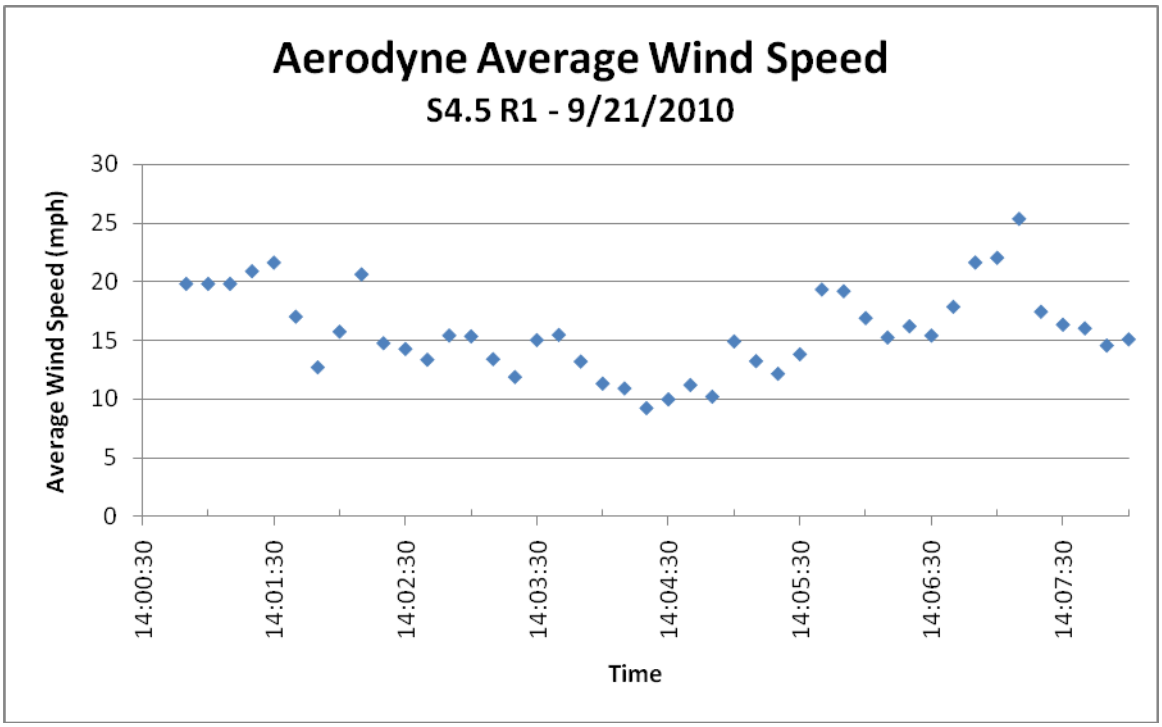


Figure J-18a. Wind Speed vs Time for Steam Flare Test S4.5 R1

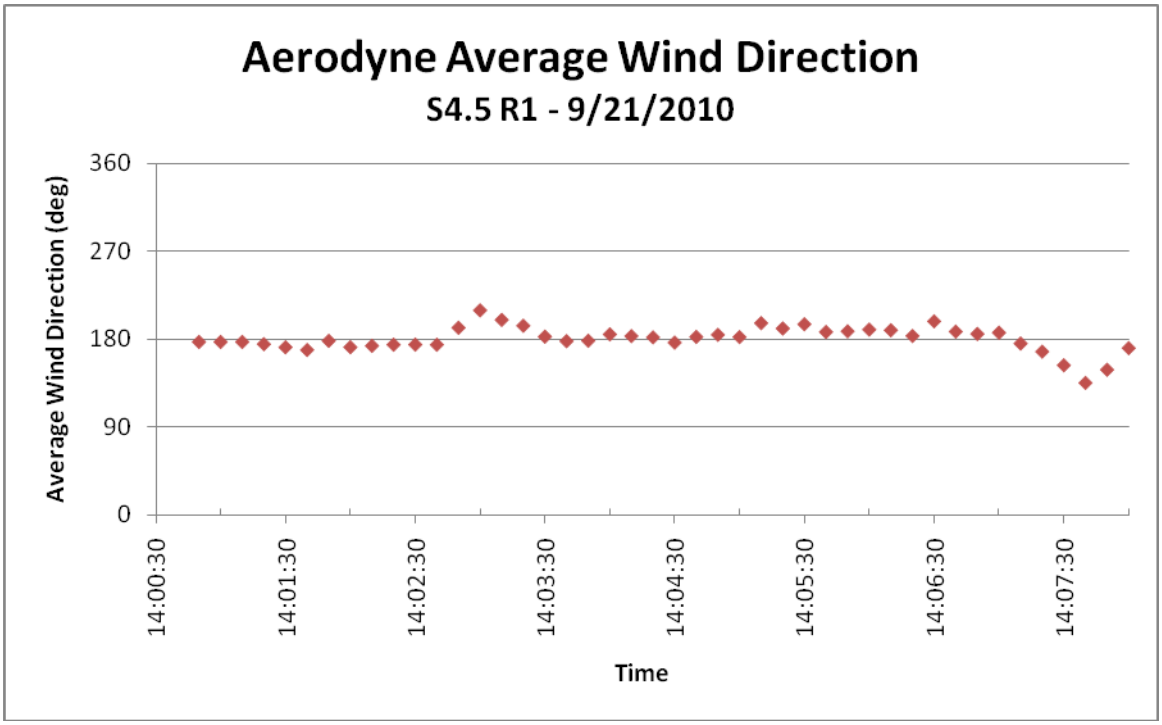


Figure J-18b. Wind Direction vs Time for Steam Flare Test S4.5 R1

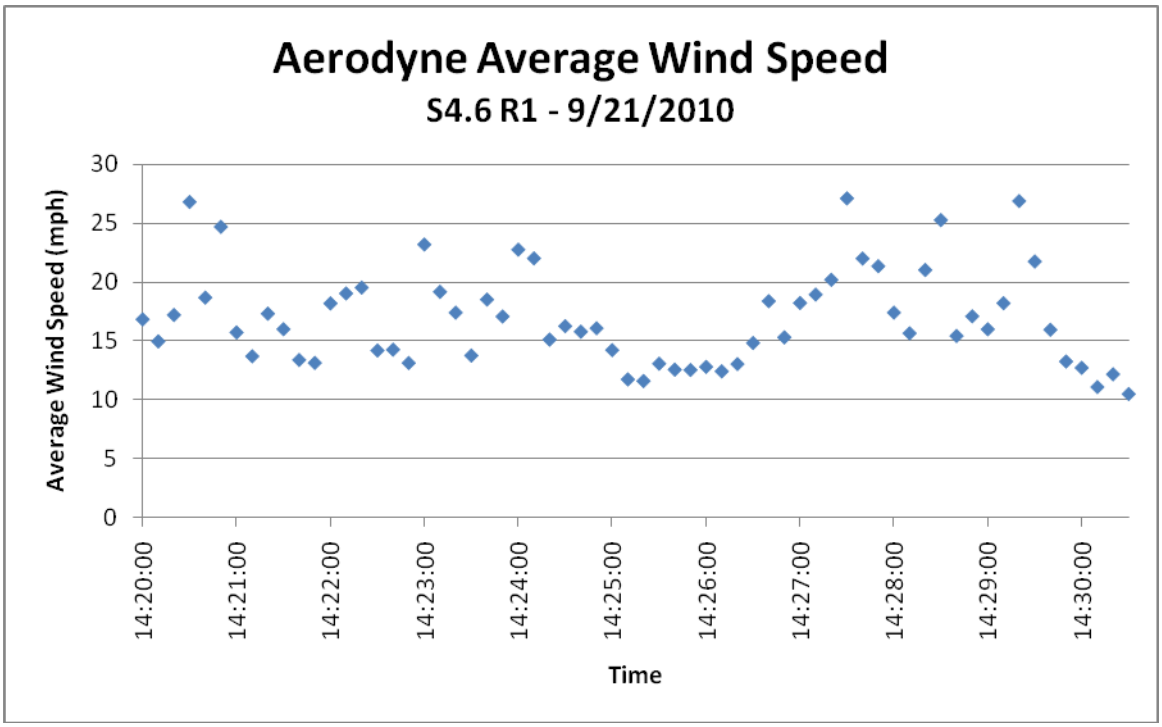


Figure J-19a. Wind Speed vs Time for Steam Flare Test S4.6 R1

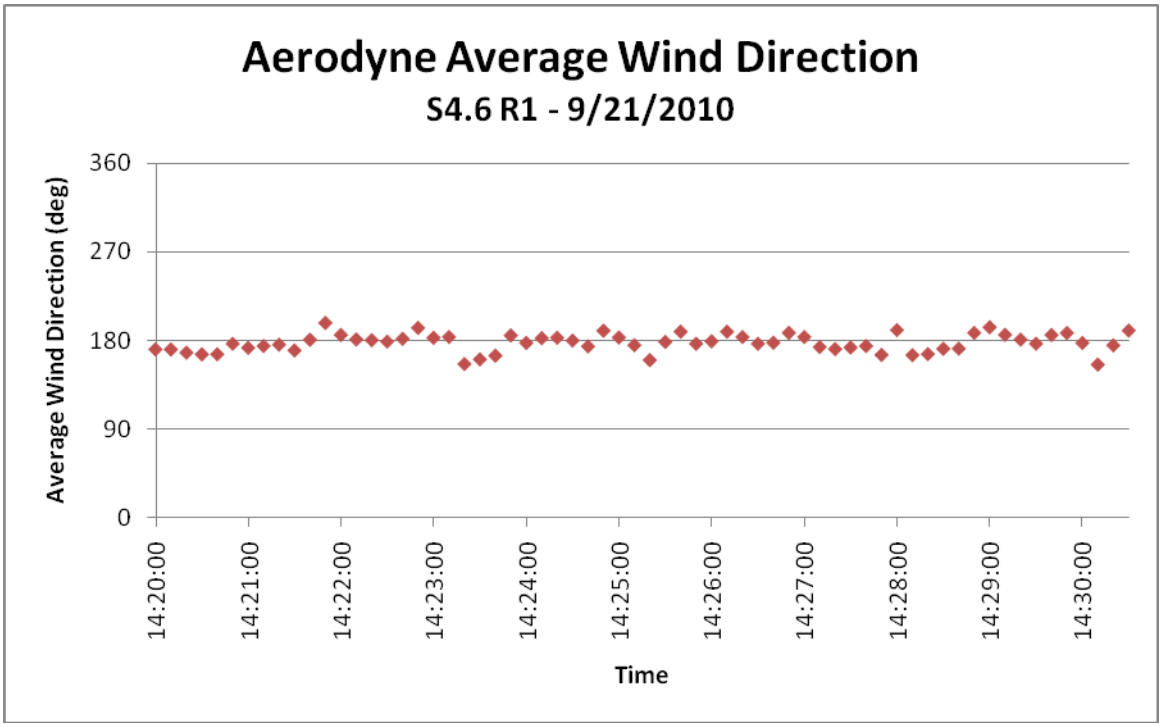


Figure J-19b. Wind Direction vs Time for Steam Flare Test S4.6 R1

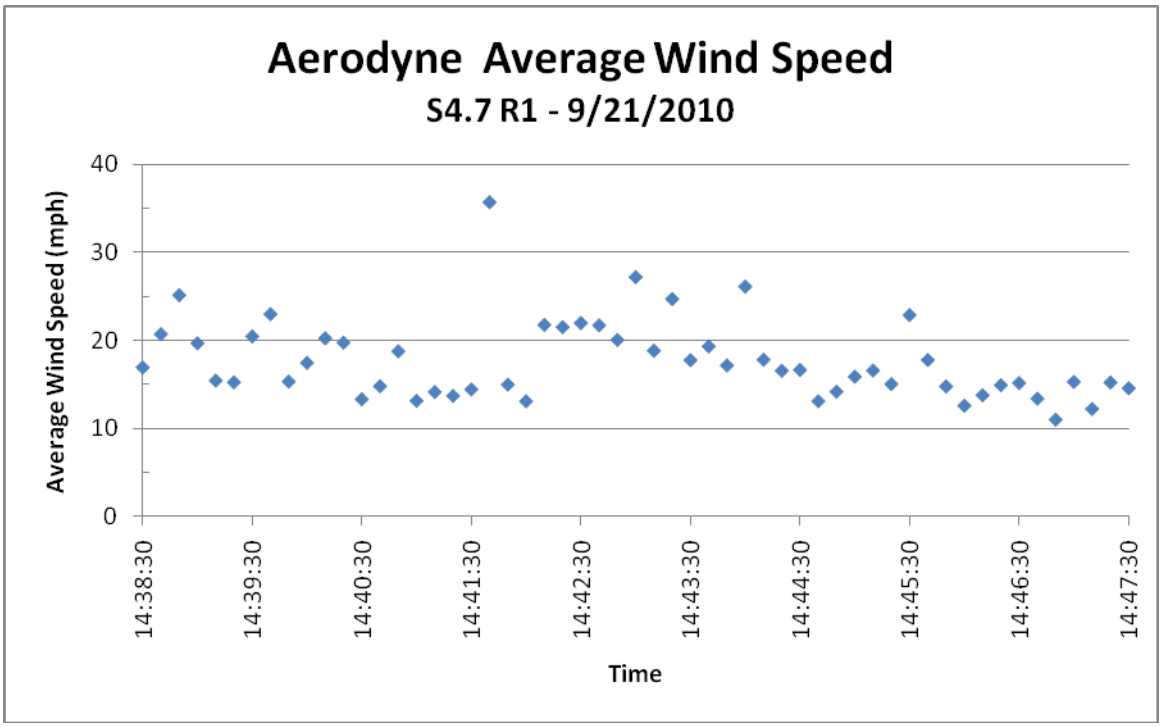


Figure J-20a. Wind Speed vs Time for Steam Flare Test S4.7 R1

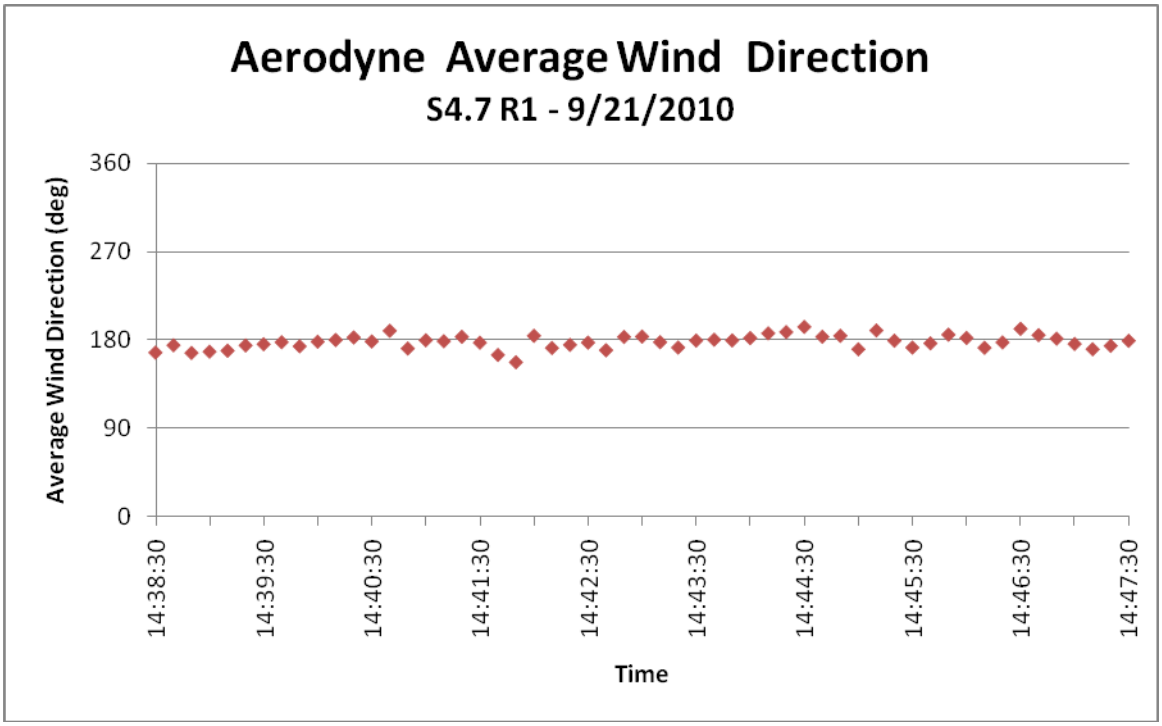


Figure J-20b. Wind Direction vs Time for Steam Flare Test S4.7 R1

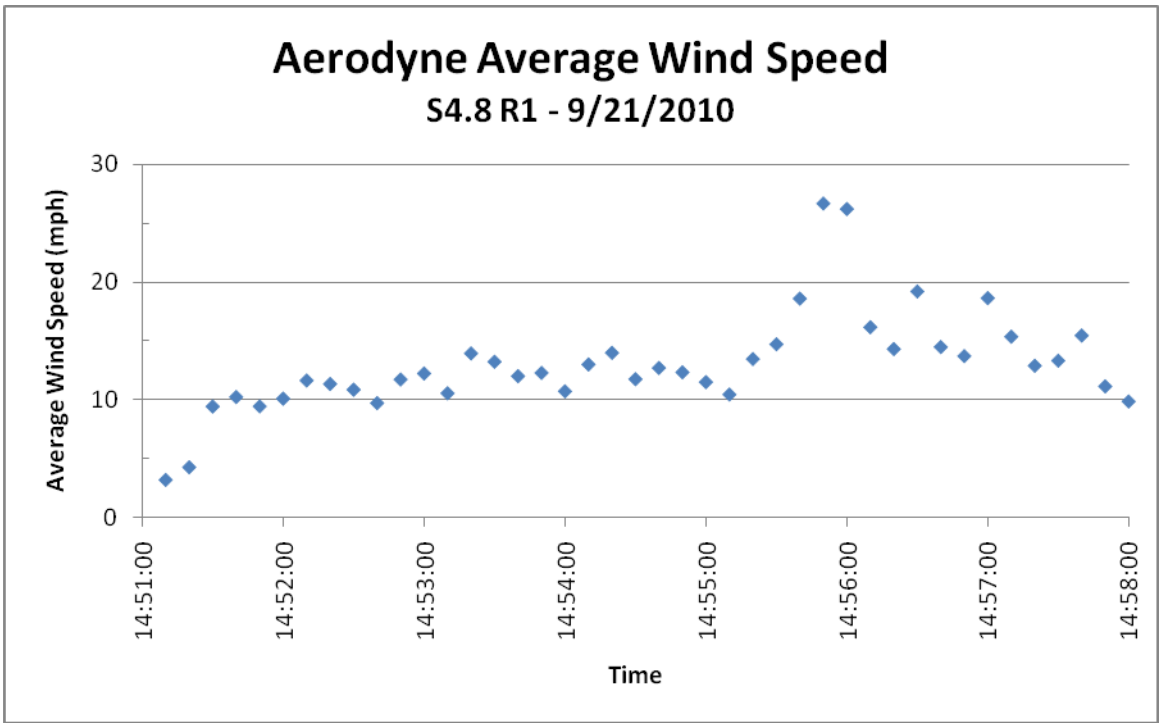


Figure J-21a. Wind Speed vs Time for Steam Flare Test S4.8 R1

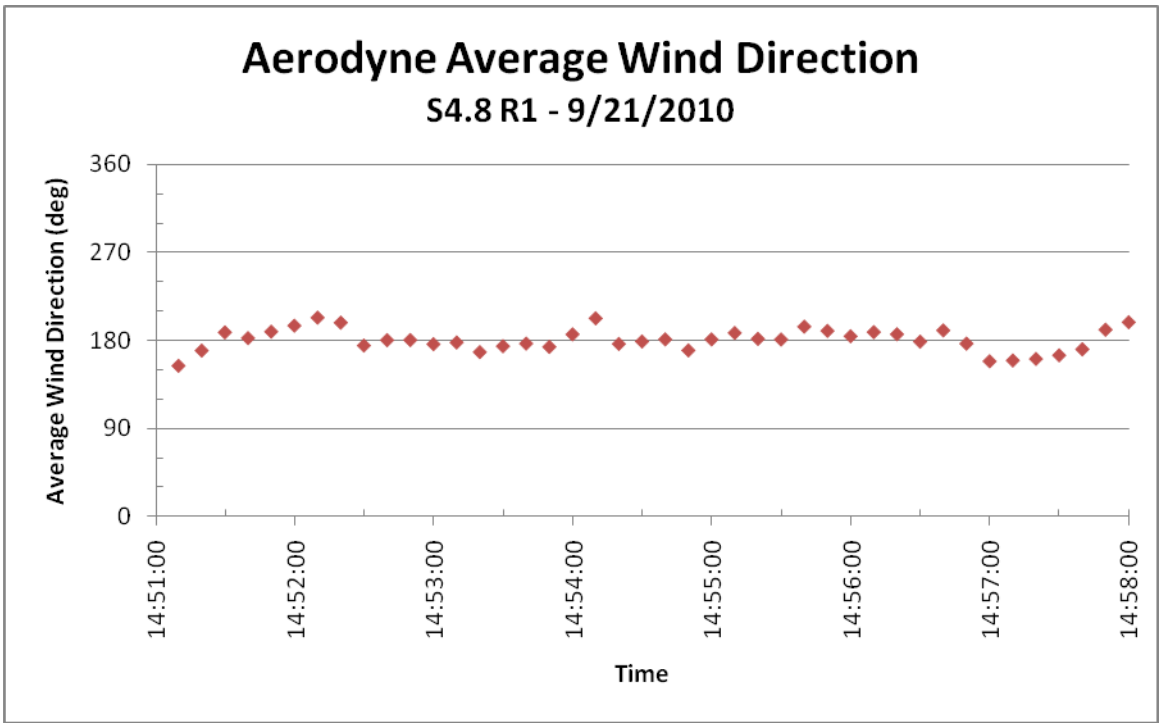


Figure J-21b. Wind Direction vs Time for Steam Flare Test S4.8 R1

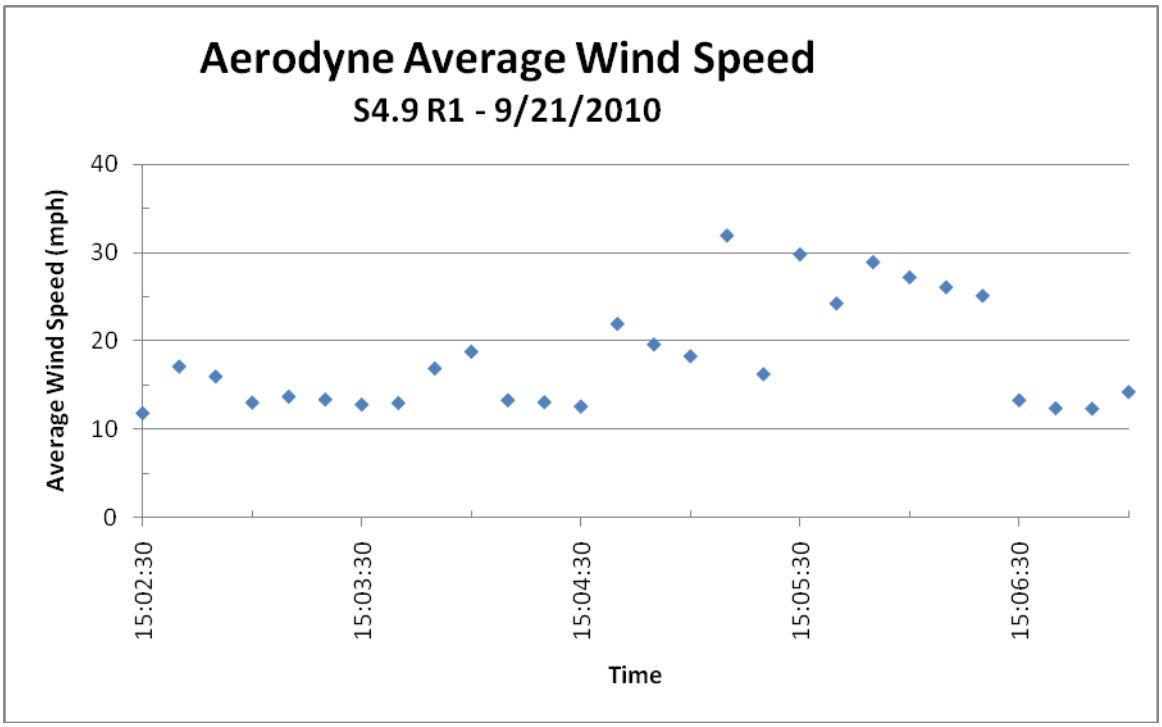


Figure J-22a. Wind Speed vs Time for Steam Flare Test S4.9 R1

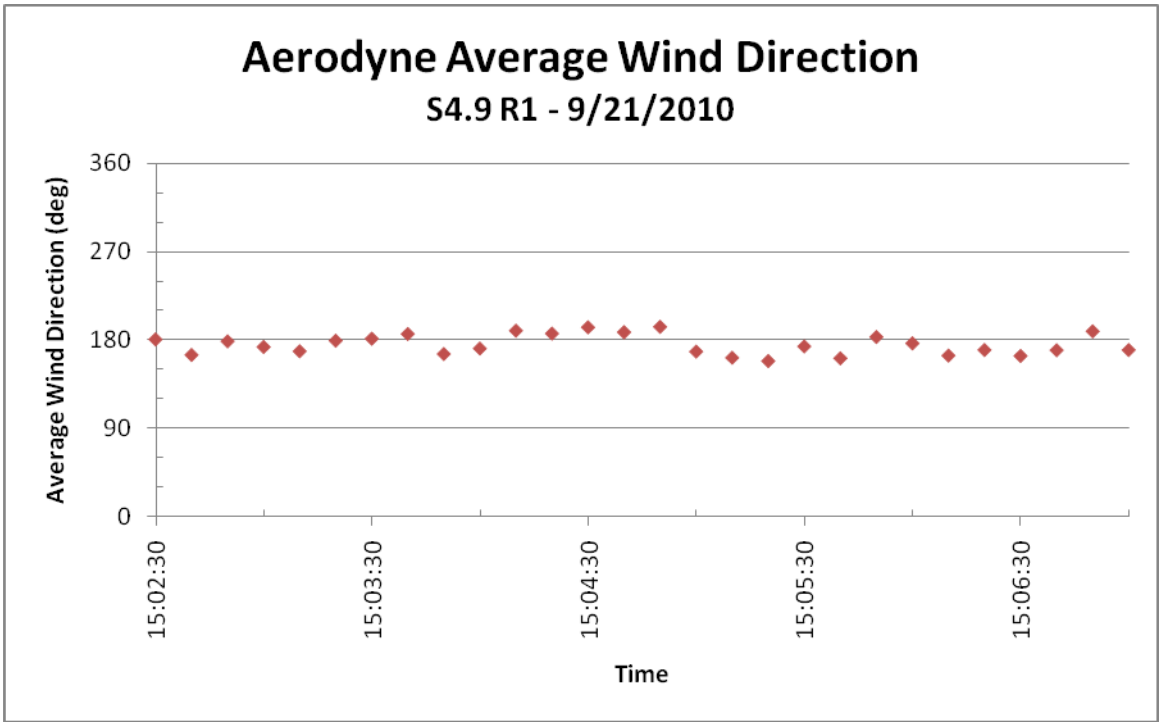


Figure J-22b. Wind Direction vs Time for Steam Flare Test S4.9 R1

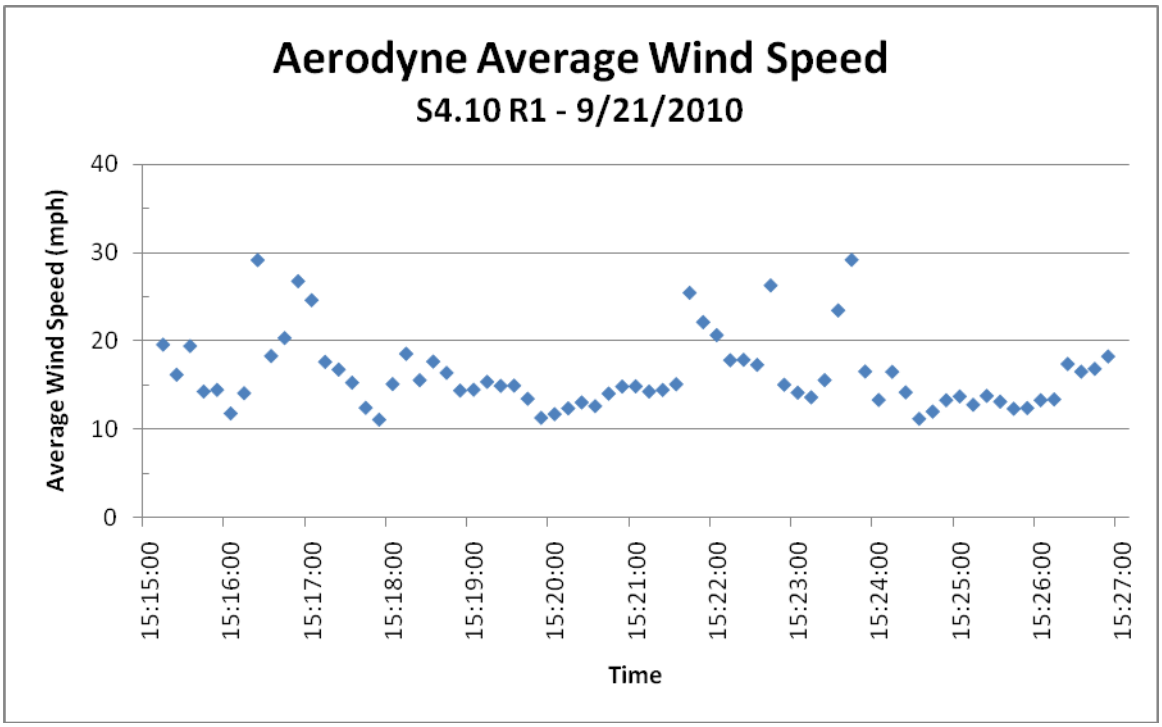


Figure J-23a. Wind Speed vs Time for Steam Flare Test S4.10 R1

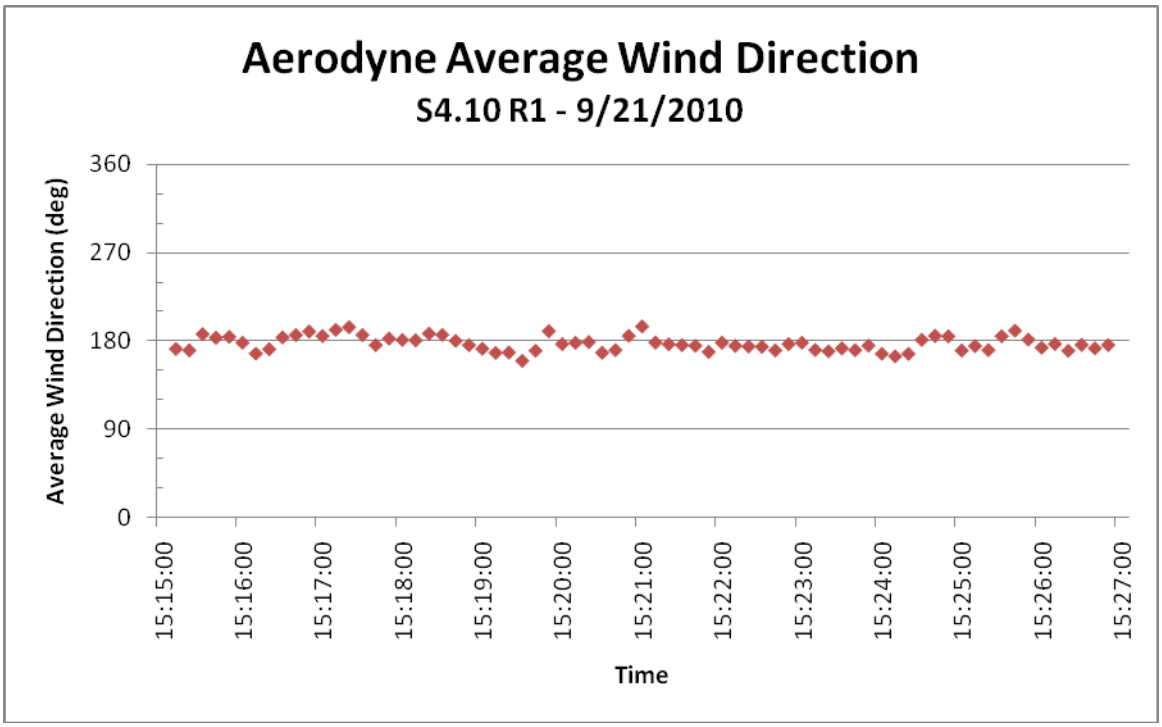


Figure J-23b. Wind Direction vs Time for Steam Flare Test S4.10 R1

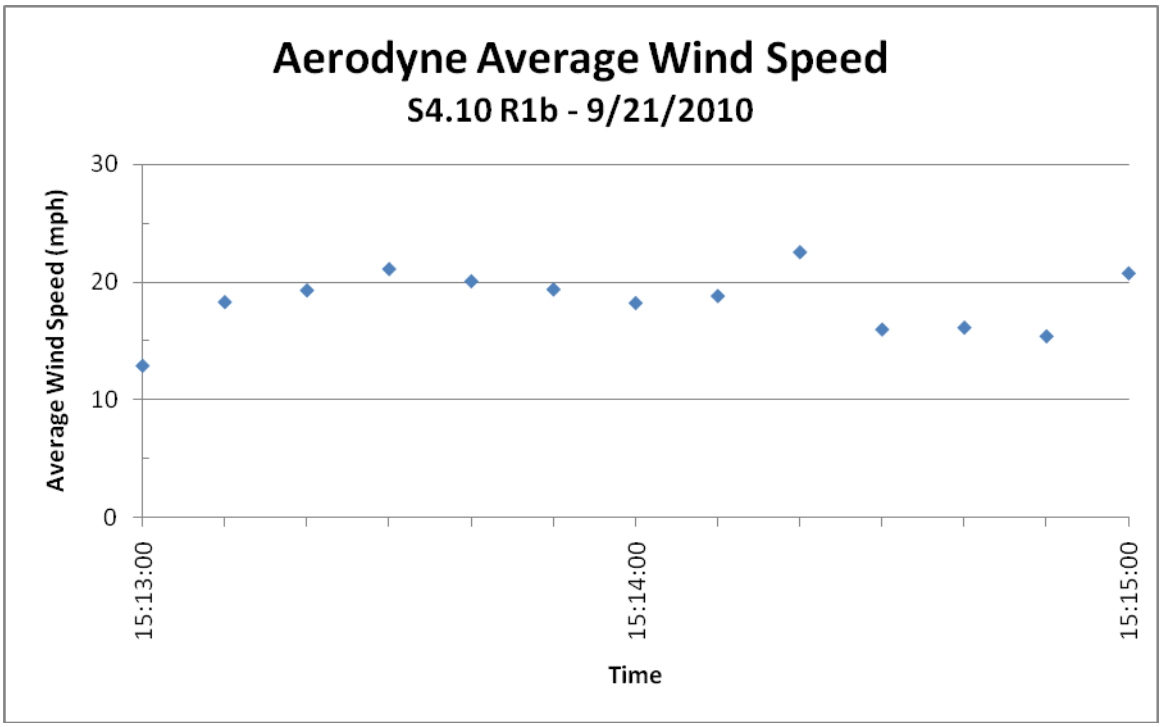


Figure J-24a. Wind Speed vs Time for Steam Flare Test S4.10 R1b

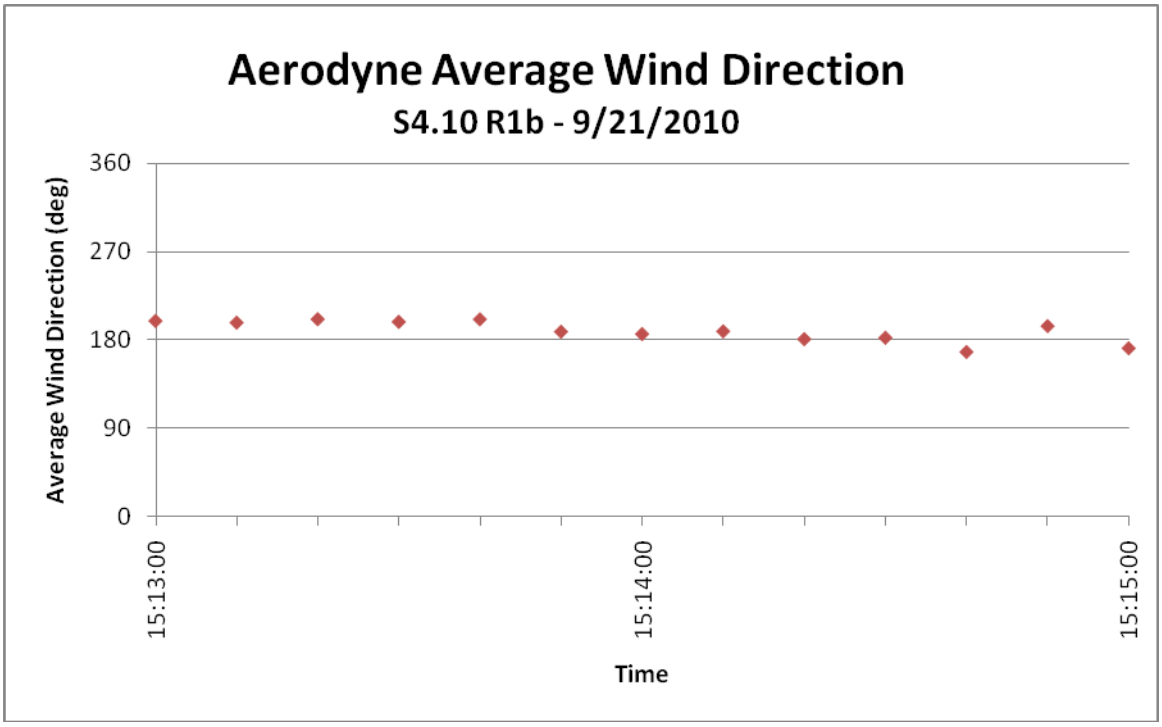


Figure J-24b. Wind Direction vs Time for Steam Flare Test S4.10 R1b

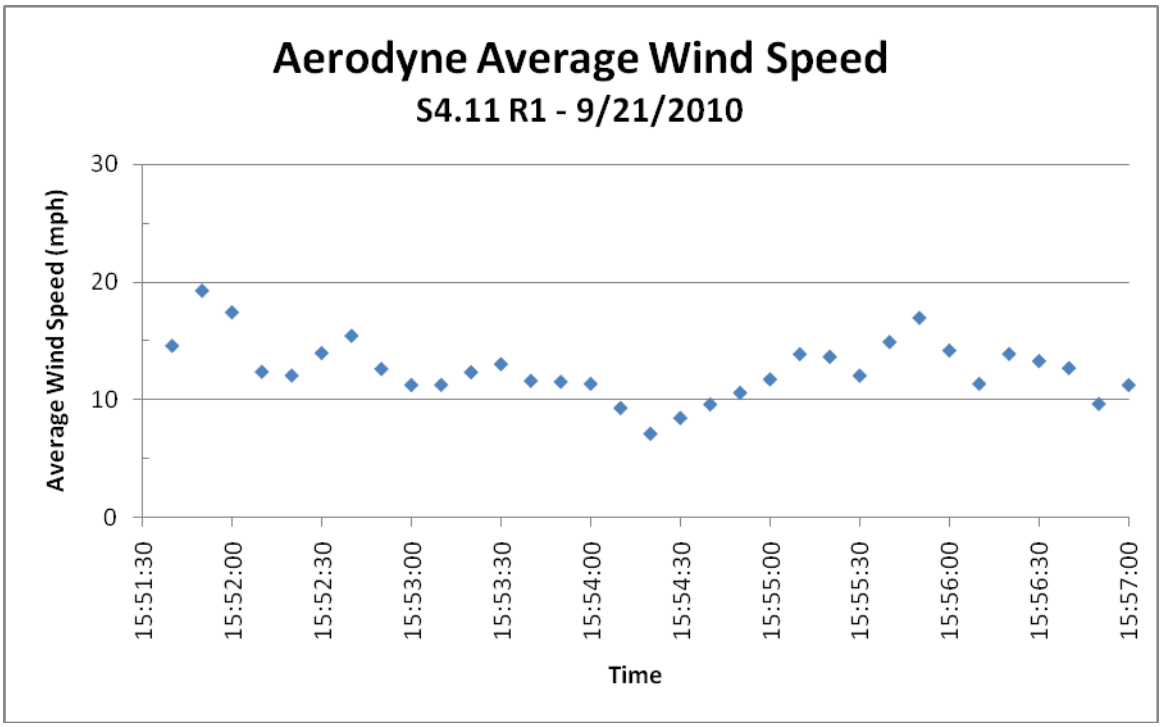


Figure J-25a. Wind Speed vs Time for Steam Flare Test S4.11 R1

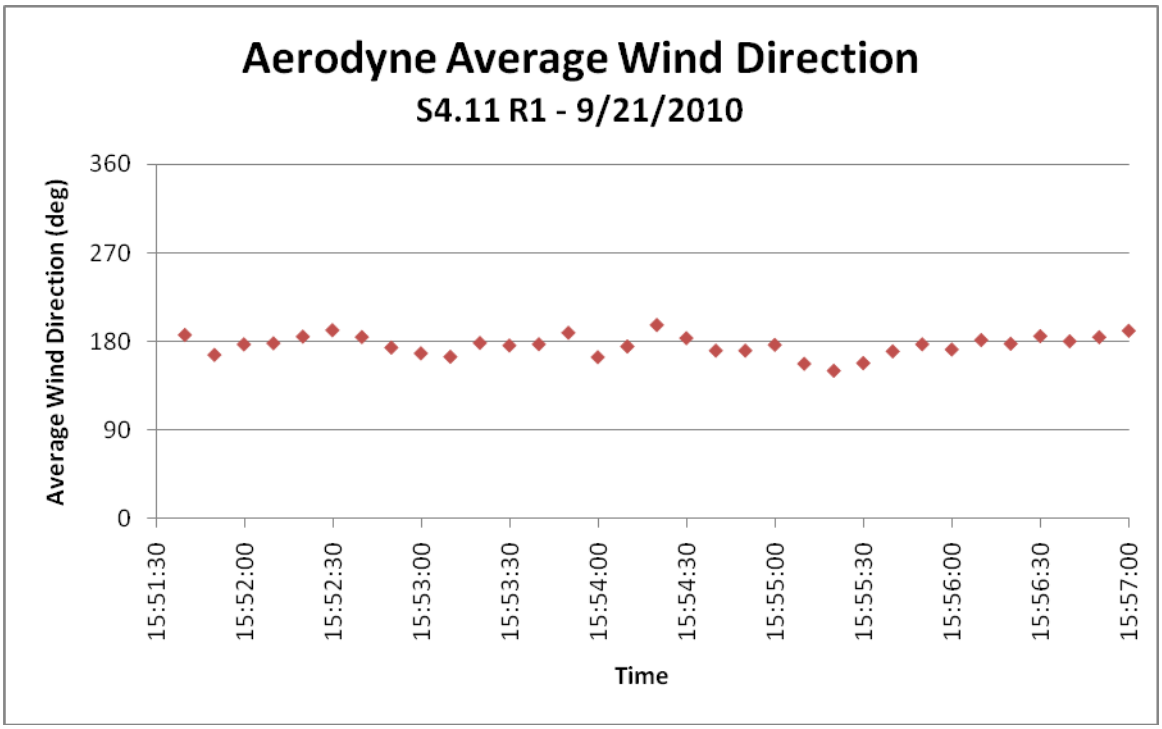


Figure J-25b. Wind Direction vs Time for Steam Flare Test S4.11 R1

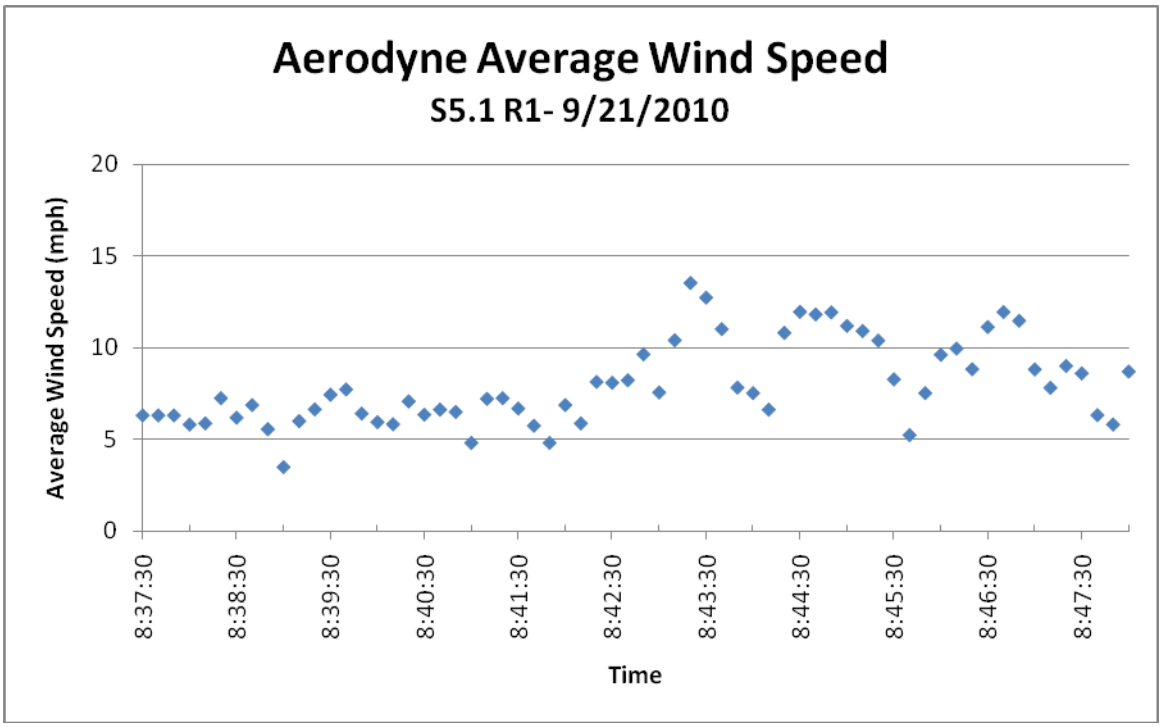


Figure J-26a. Wind Speed vs Time for Steam Flare Test S5.1 R1

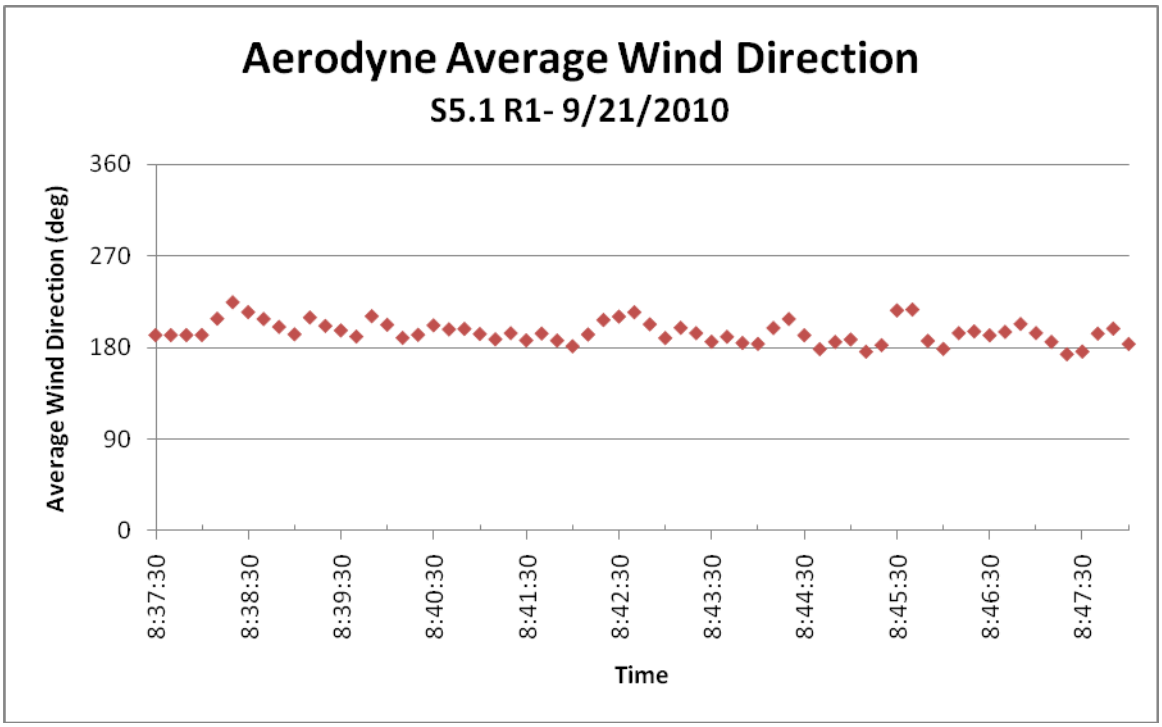


Figure J-26b. Wind Direction vs Time for Steam Flare Test S5.1 R1

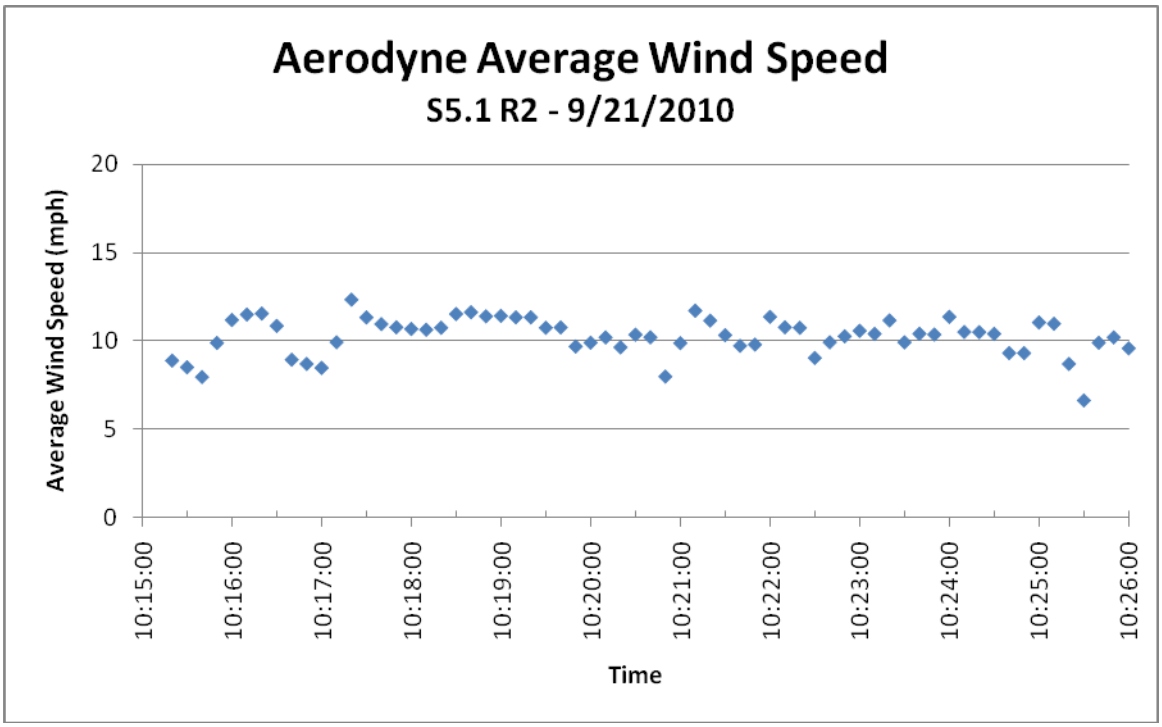


Figure J-27a. Wind Speed vs Time for Steam Flare Test S5.1 R2

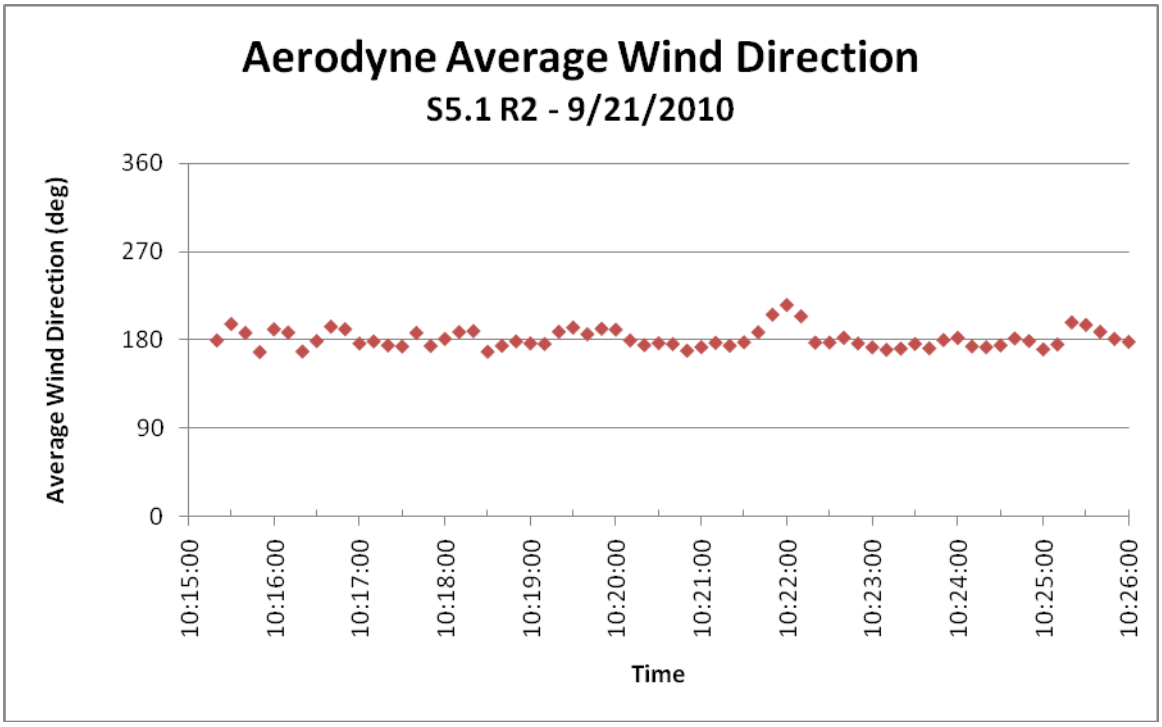


Figure J-27b. Wind Direction vs Time for Steam Flare Test S5.1 R2

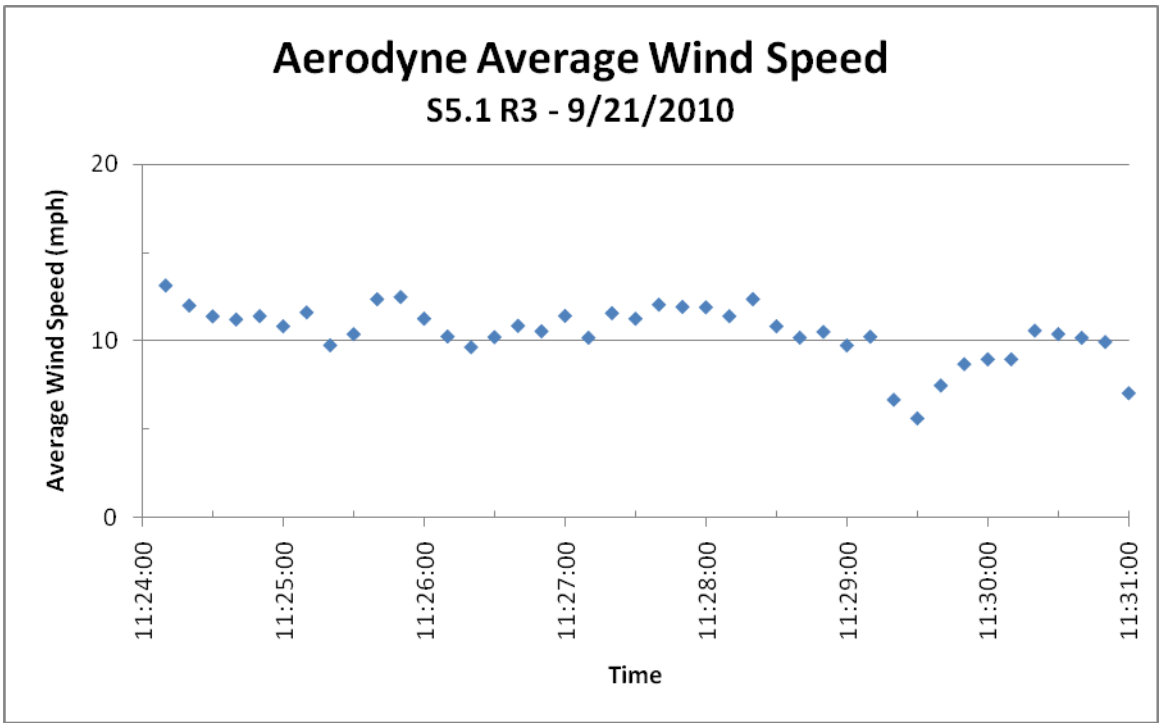


Figure J-28a. Wind Speed vs Time for Steam Flare Test S5.1 R3

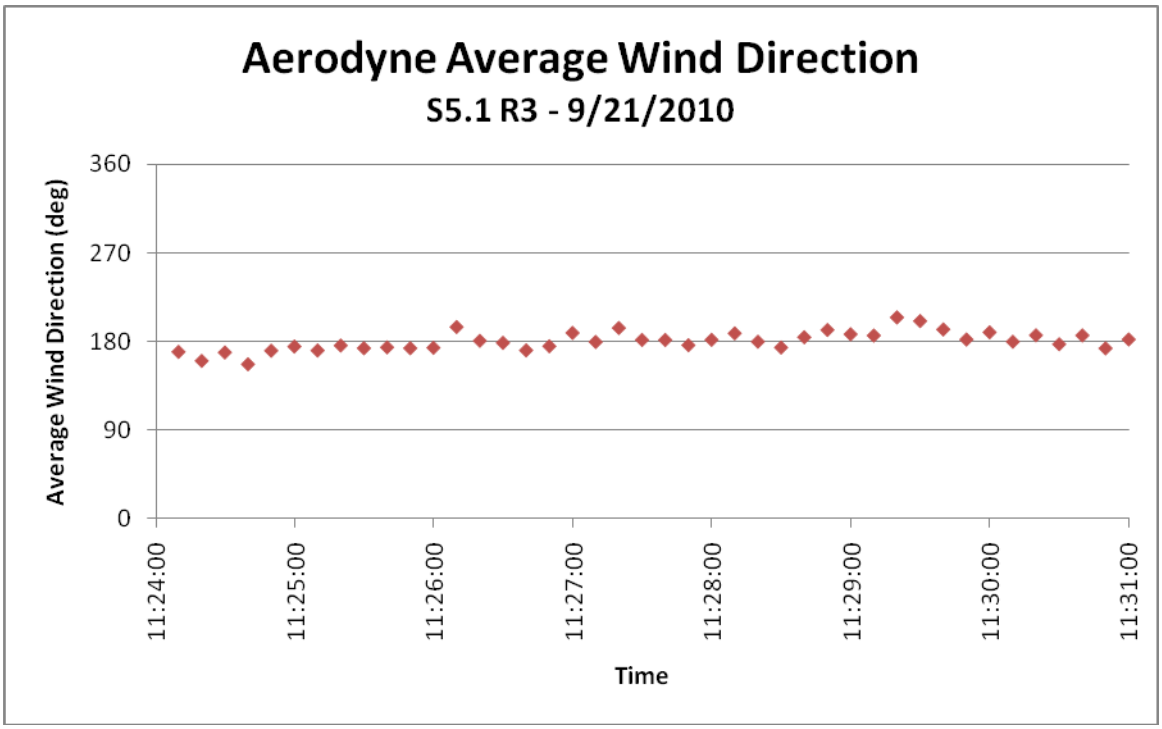


Figure J-28b. Wind Direction vs Time for Steam Flare Test S5.1 R3

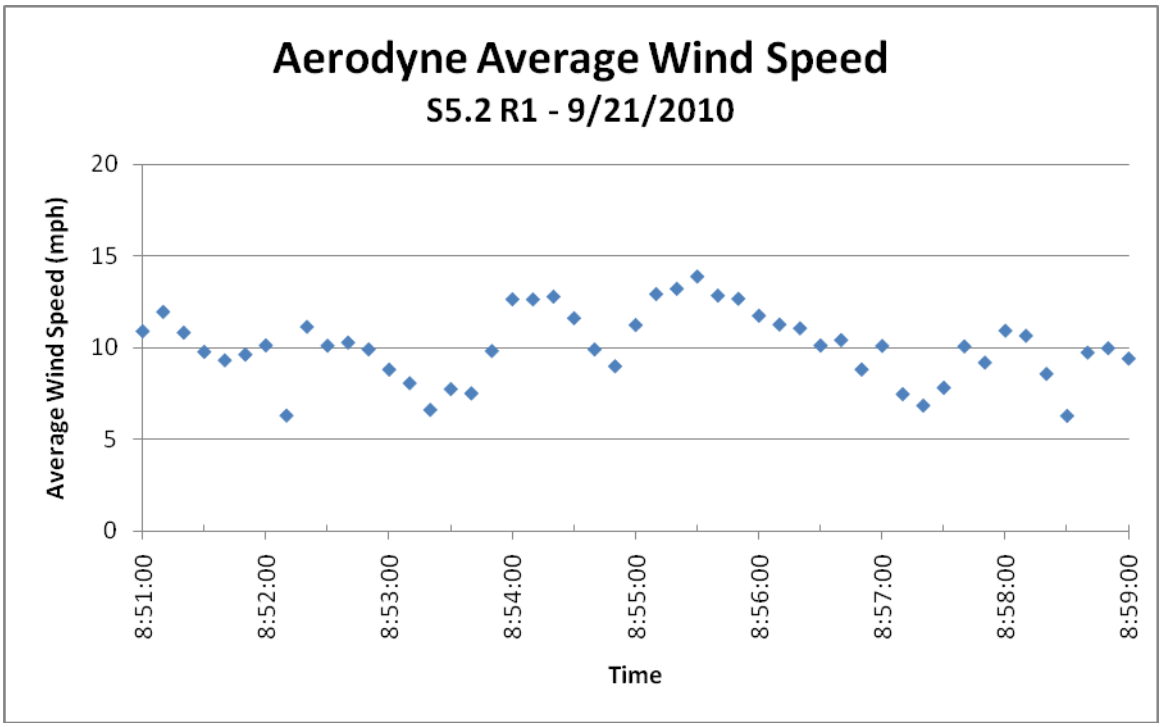


Figure J-29a. Wind Speed vs Time for Steam Flare Test S5.2 R1

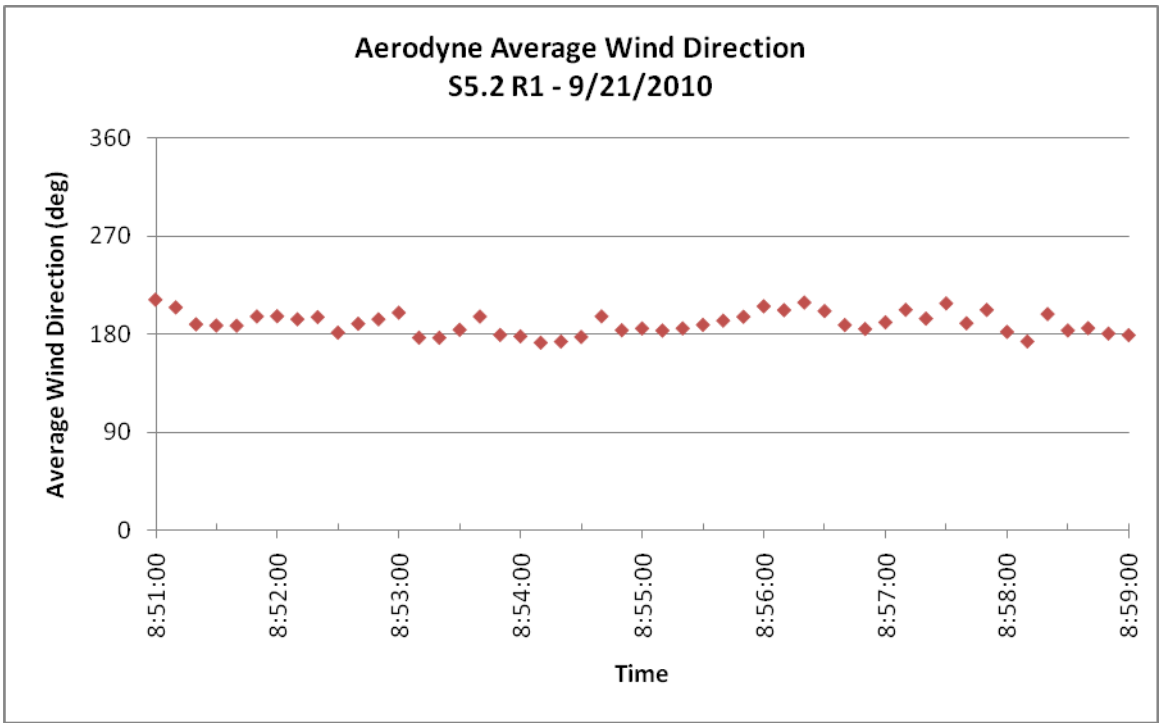


Figure J-29b. Wind Direction vs Time for Steam Flare Test S5.2 R1

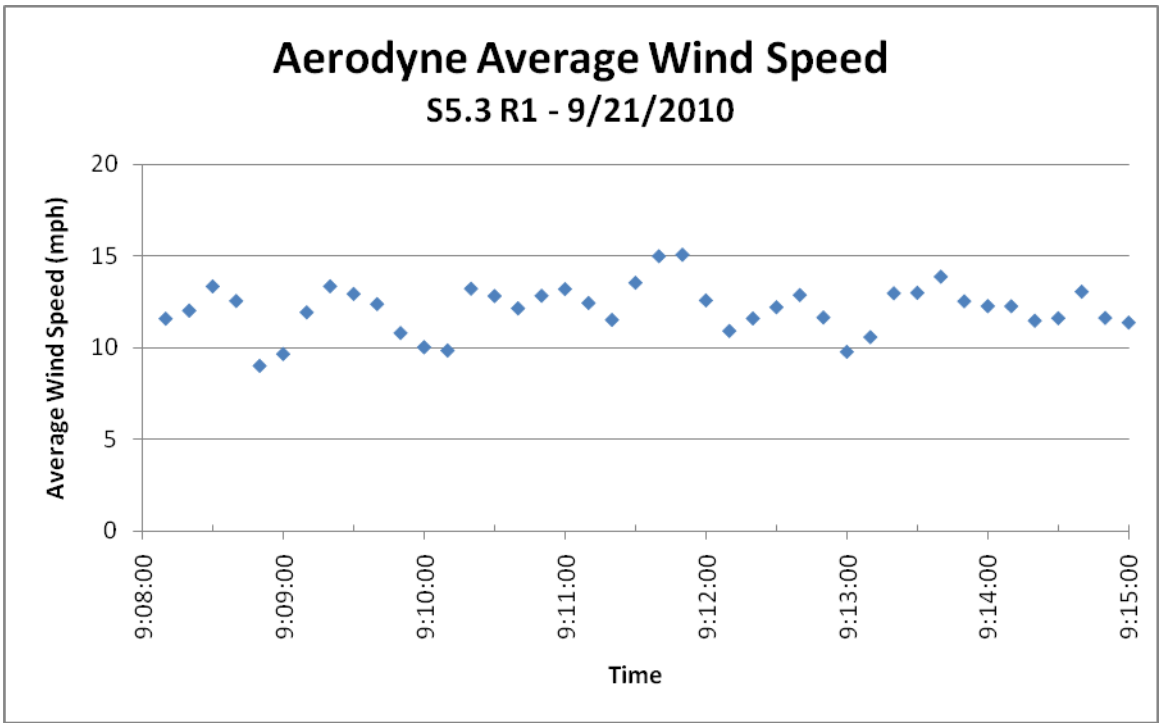


Figure J-30a. Wind Speed vs Time for Steam Flare Test S5.3 R1

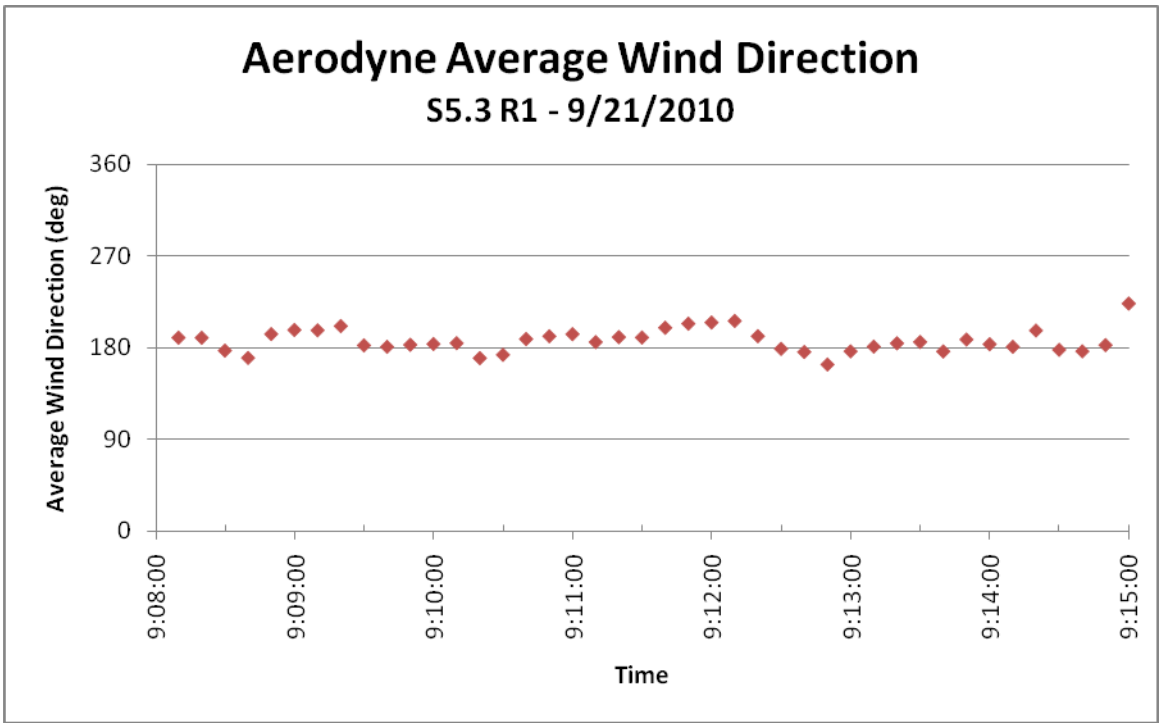


Figure J-30b. Wind Direction vs Time for Steam Flare Test S5.3 R1

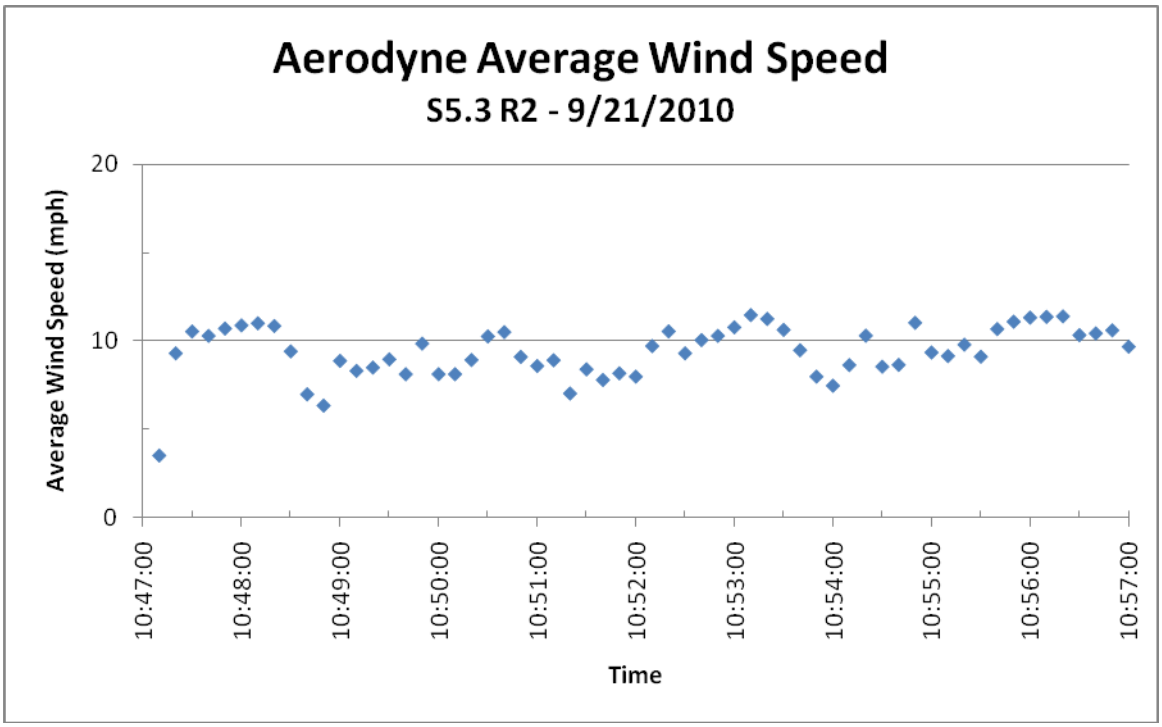


Figure J-31a. Wind Speed vs Time for Steam Flare Test S5.3 R2

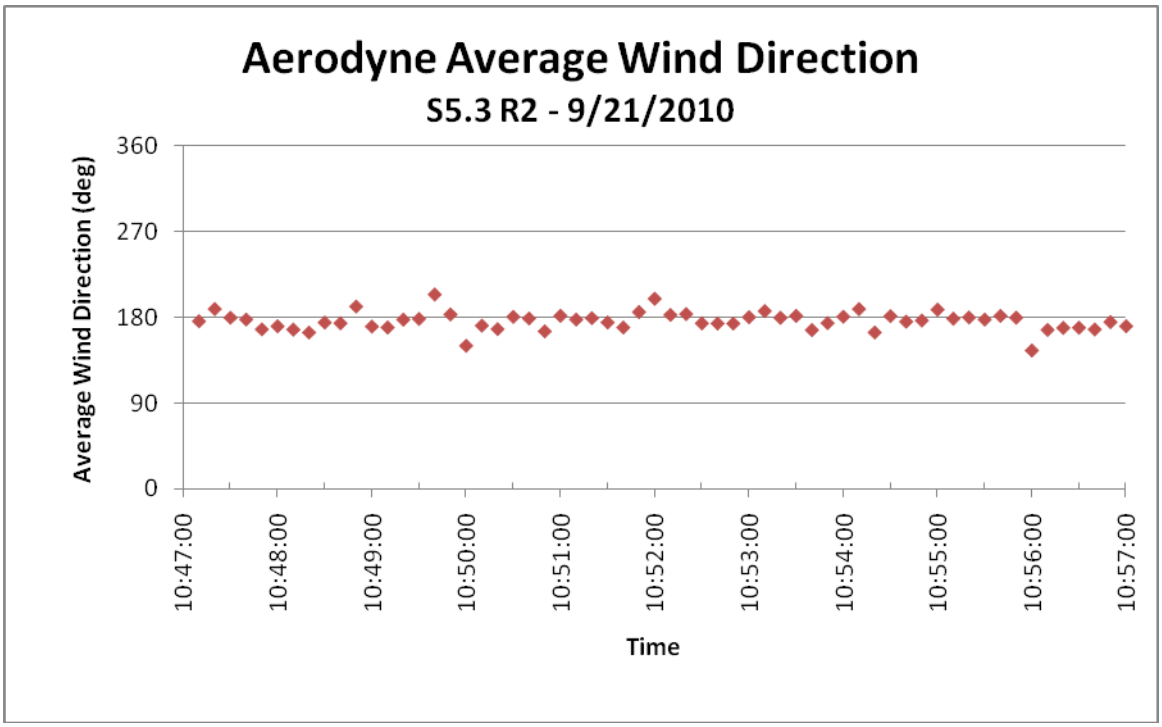


Figure J-31b. Wind Direction vs Time for Steam Flare Test S5.3 R2

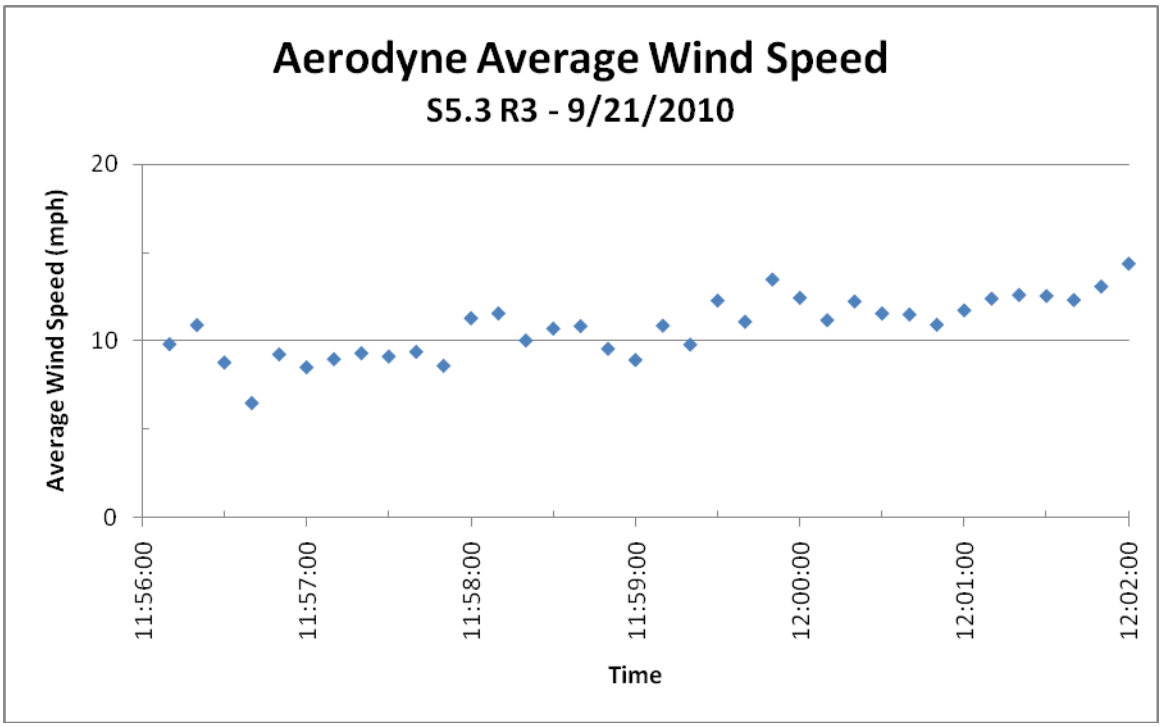


Figure J-32a. Wind Speed vs Time for Steam Flare Test S5.3 R3

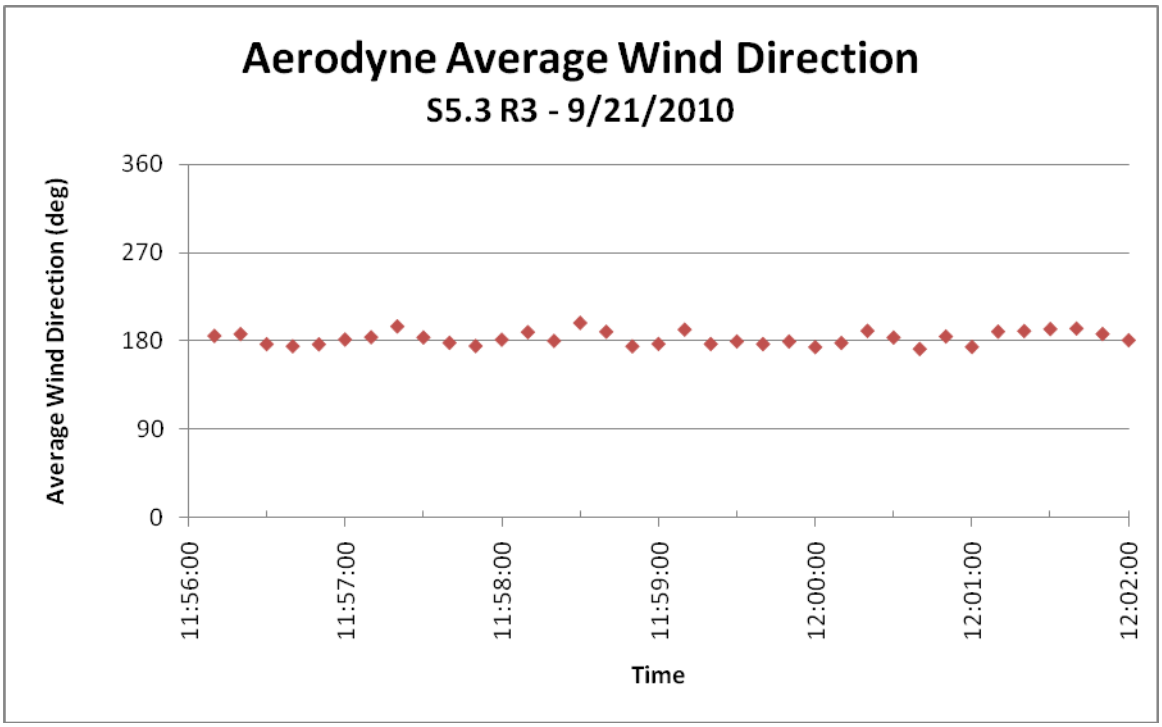


Figure J-32b. Wind Direction vs Time for Steam Flare Test S5.3 R3

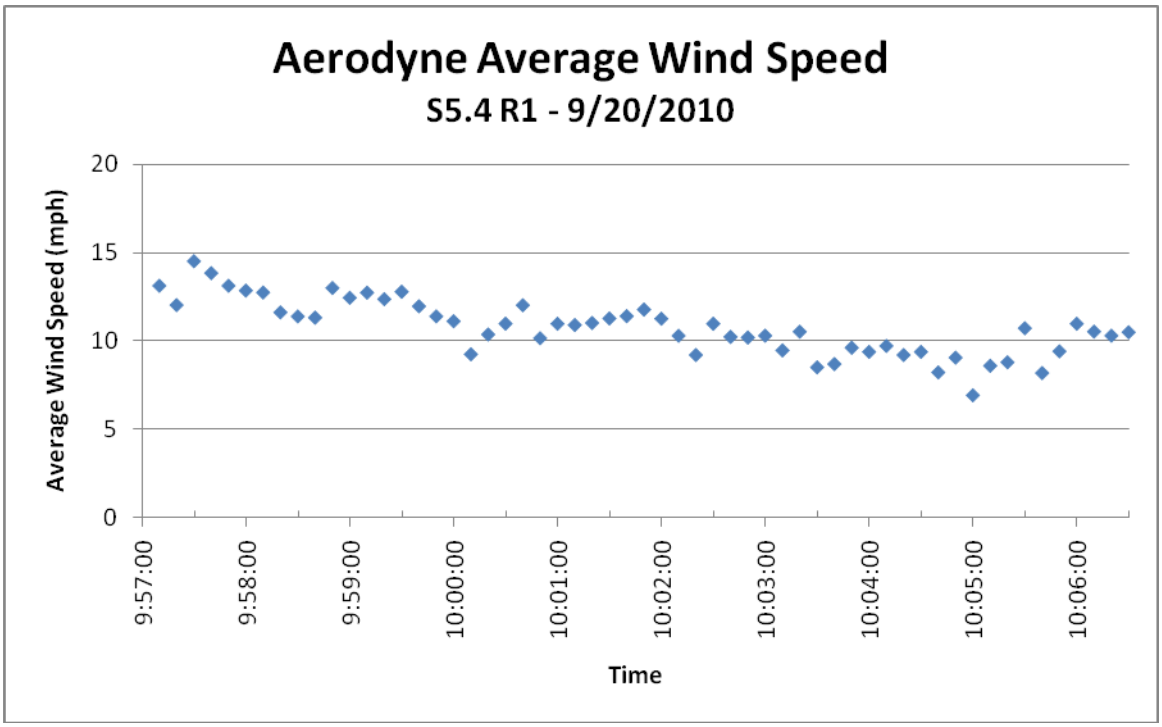


Figure J-33a. Wind Speed vs Time for Steam Flare Test S5.4 R1

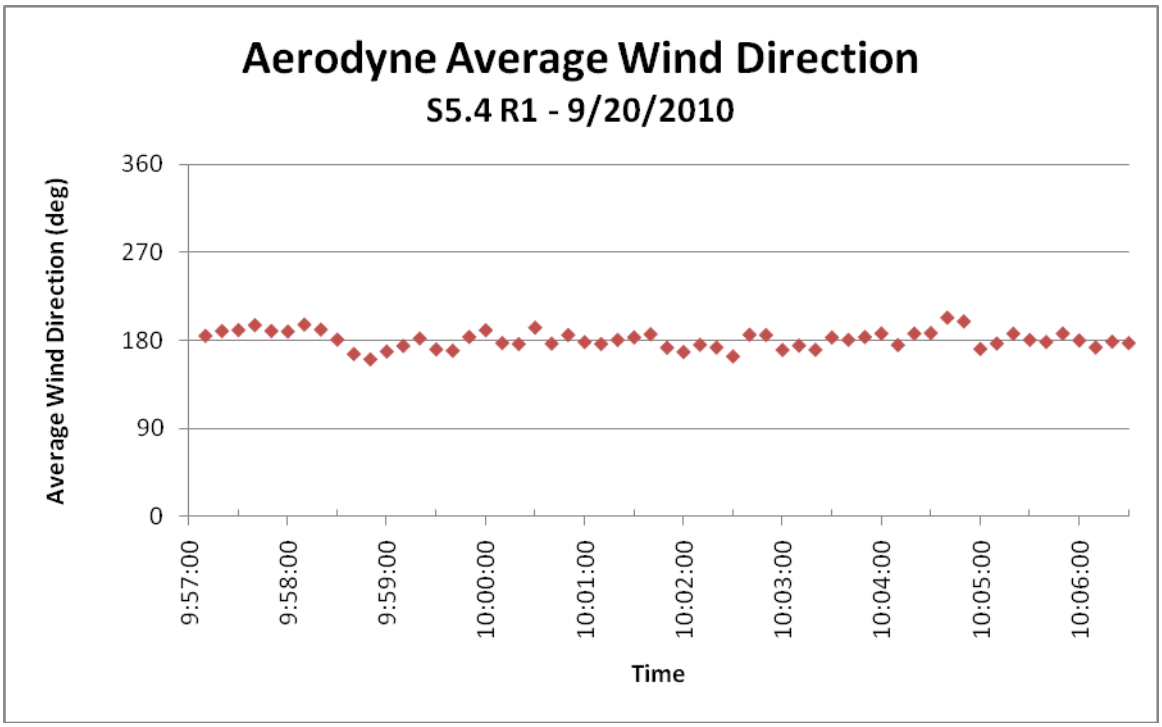


Figure J-33b. Wind Direction vs Time for Steam Flare Test S5.4 R1

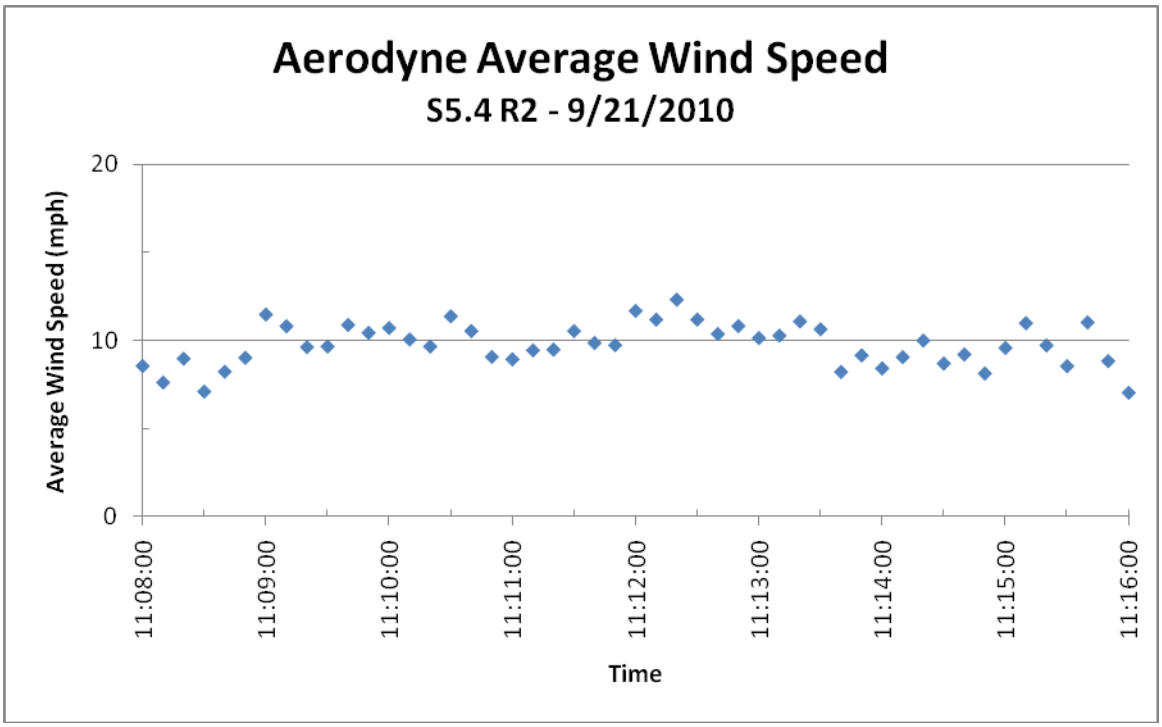


Figure J-34a. Wind Speed vs Time for Steam Flare Test S5.4 R2

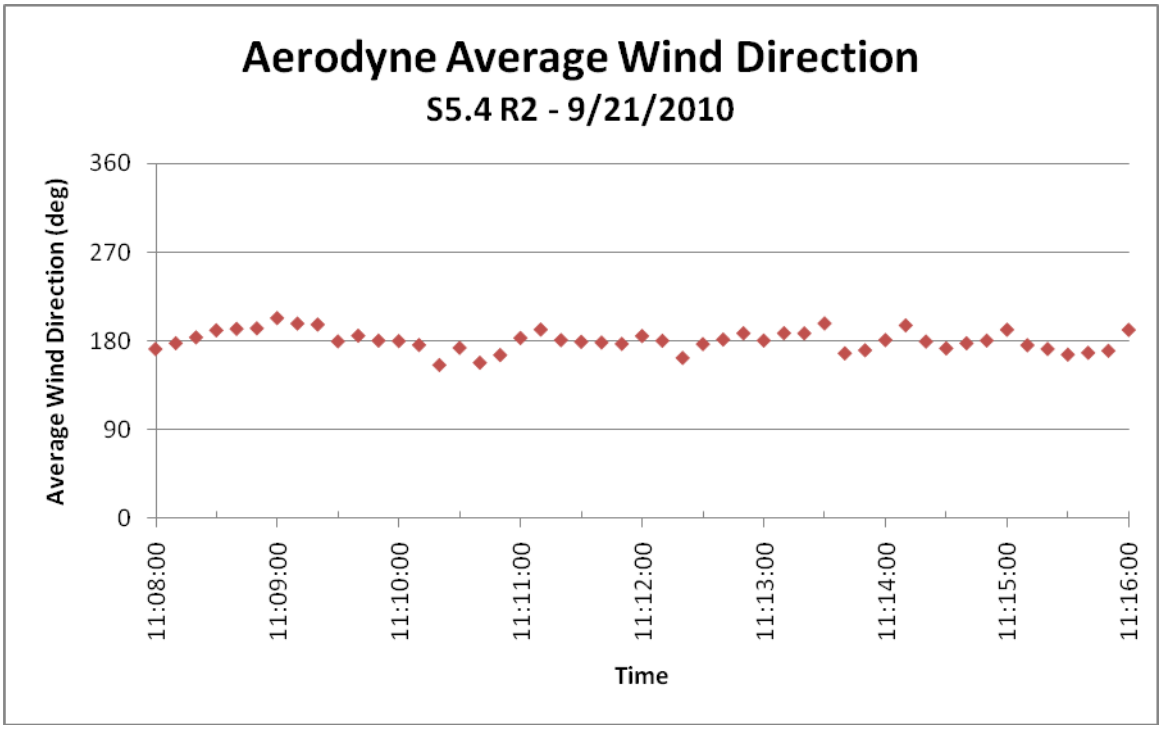


Figure J-34b. Wind Direction vs Time for Steam Flare Test S5.4 R2

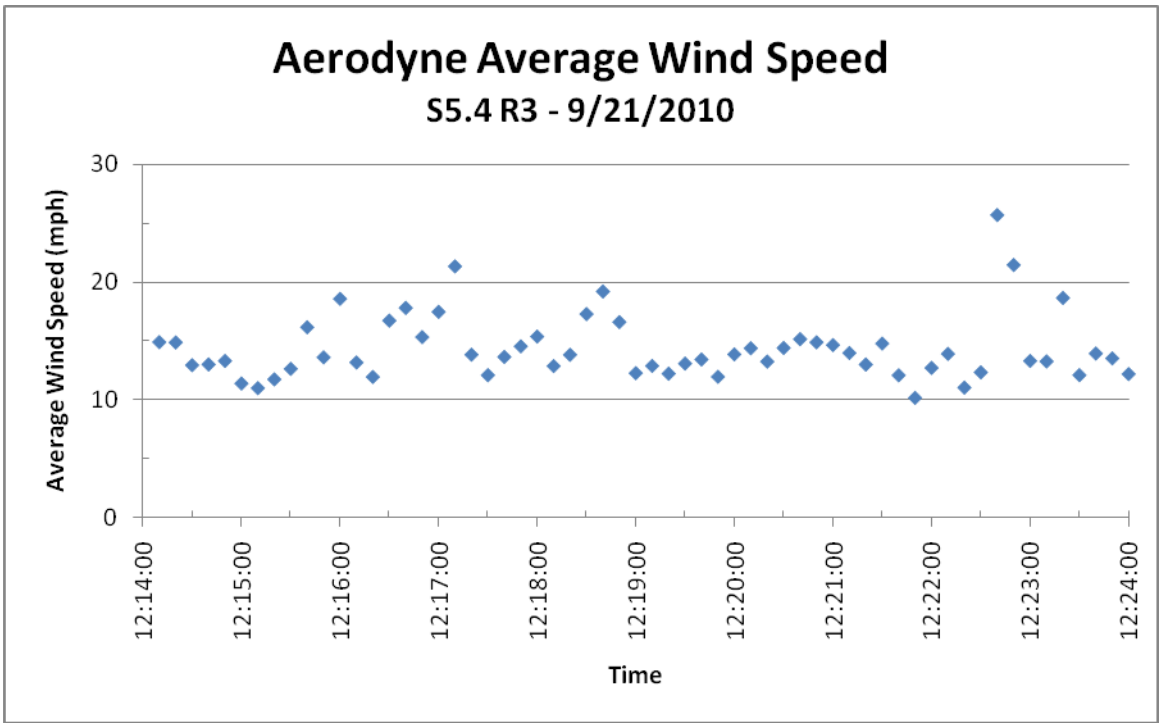


Figure J-35a. Wind Speed vs Time for Steam Flare Test S5.4 R3

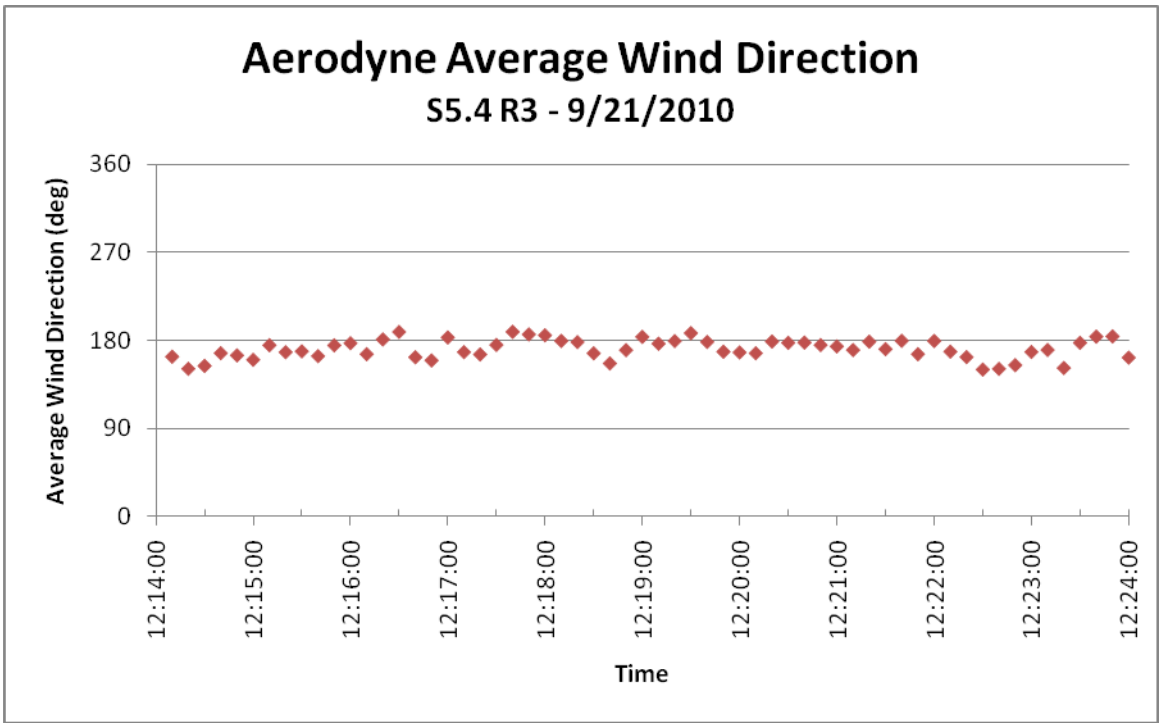


Figure J-35b. Wind Direction vs Time for Steam Flare Test S5.4 R3

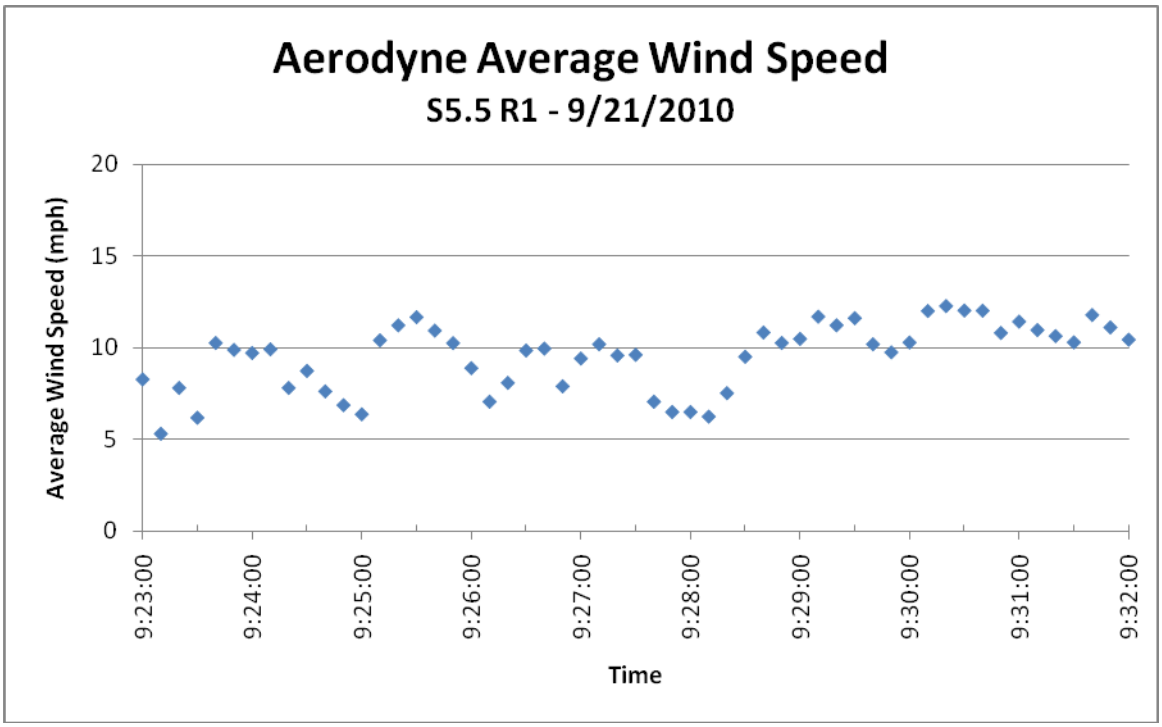


Figure J-36a. Wind Speed vs Time for Steam Flare Test S5.5 R1

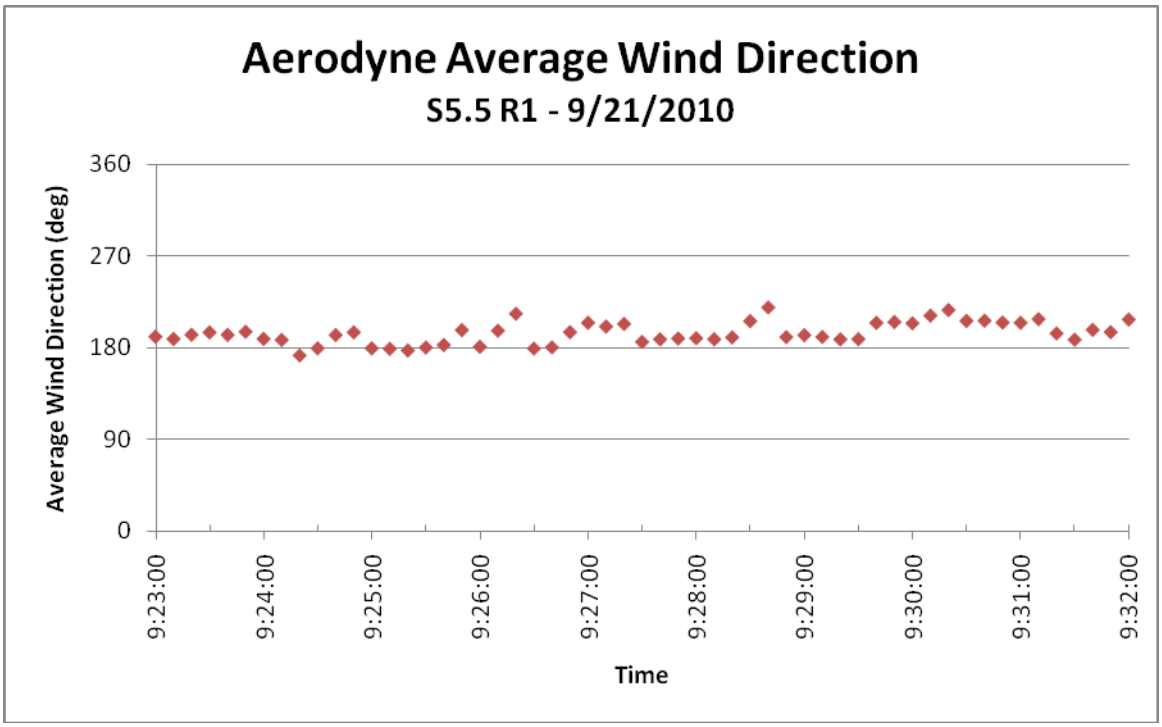


Figure J-36b. Wind Direction vs Time for Steam Flare Test S5.5 R1

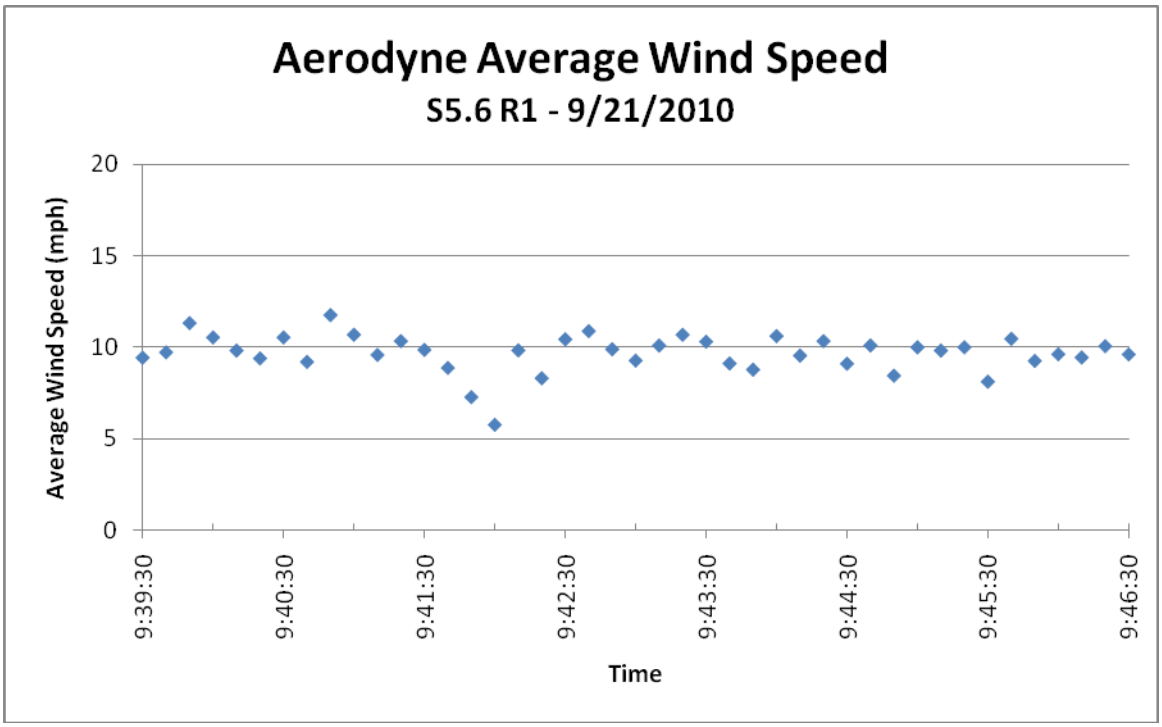


Figure J-37a. Wind Speed vs Time for Steam Flare Test S5.6 R1

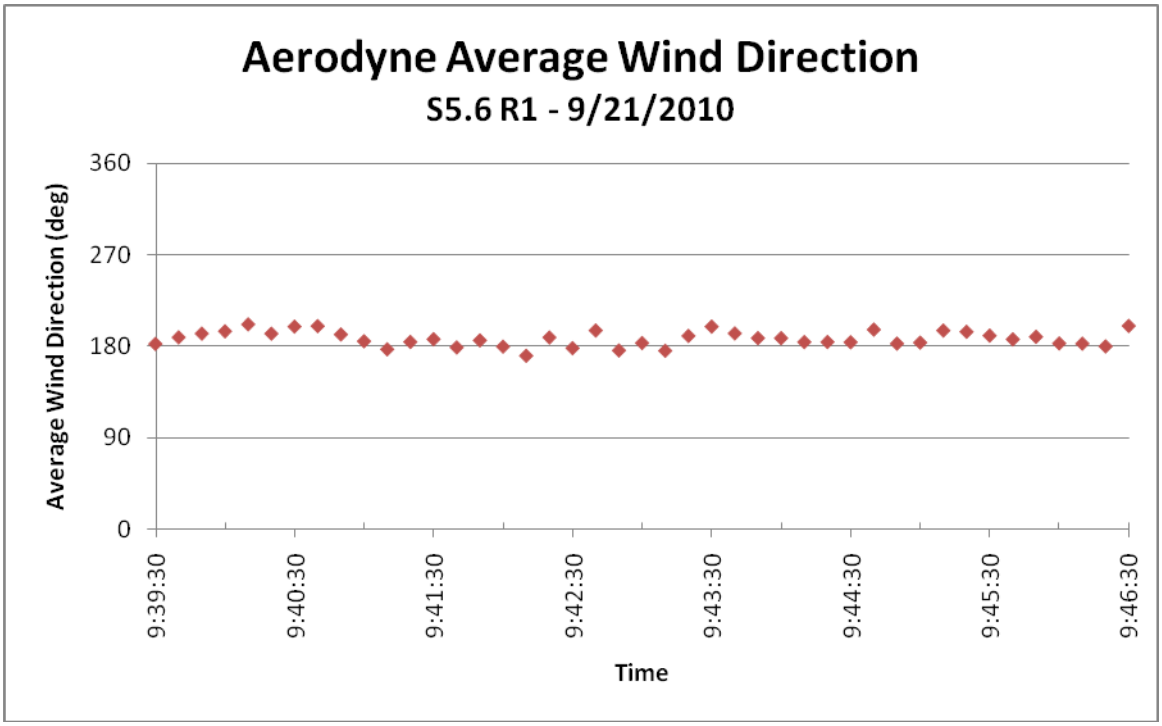


Figure J-37b. Wind Direction vs Time for Steam Flare Test S5.6 R1

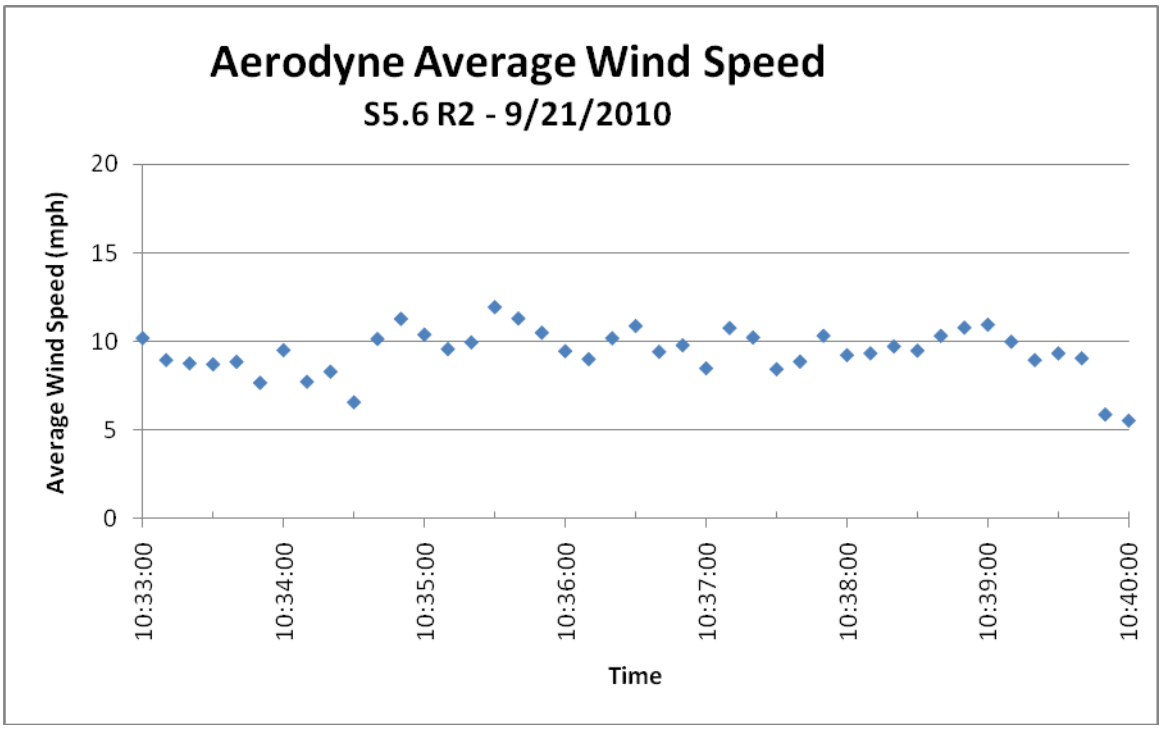


Figure J-38a. Wind Speed vs Time for Steam Flare Test S5.6 R2

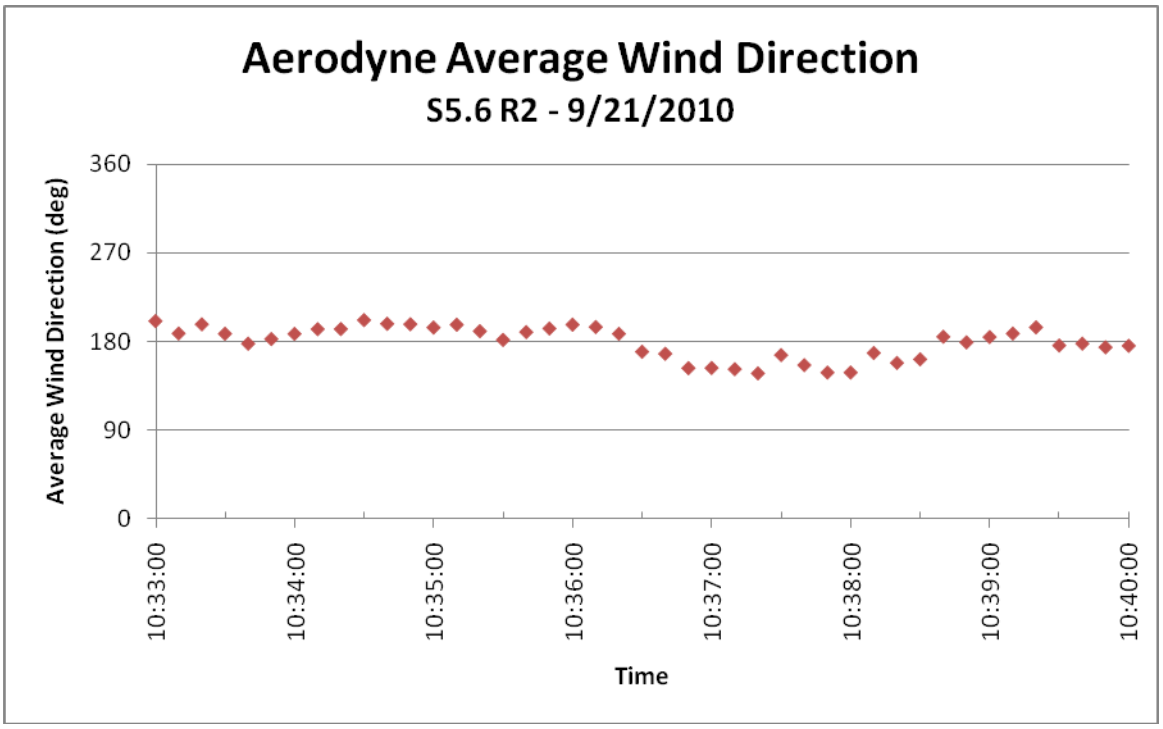


Figure J-38b. Wind Direction vs Time for Steam Flare Test S5.6 R2

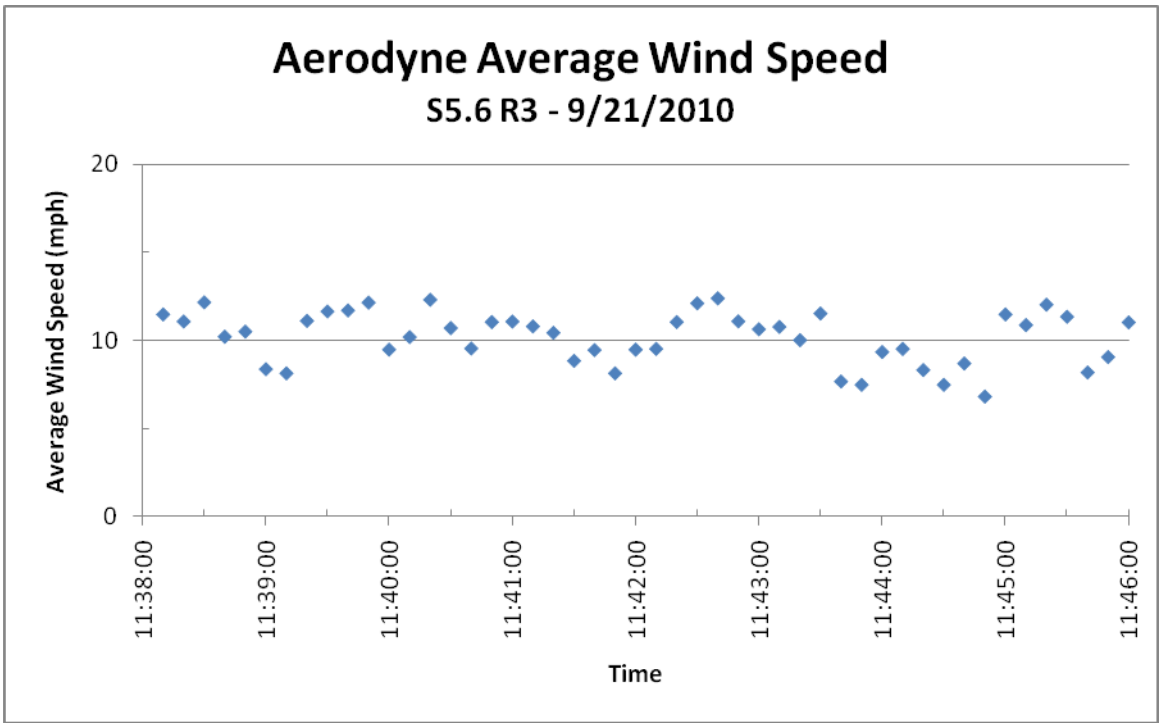


Figure J-39a. Wind Speed vs Time for Steam Flare Test S5.6 R3

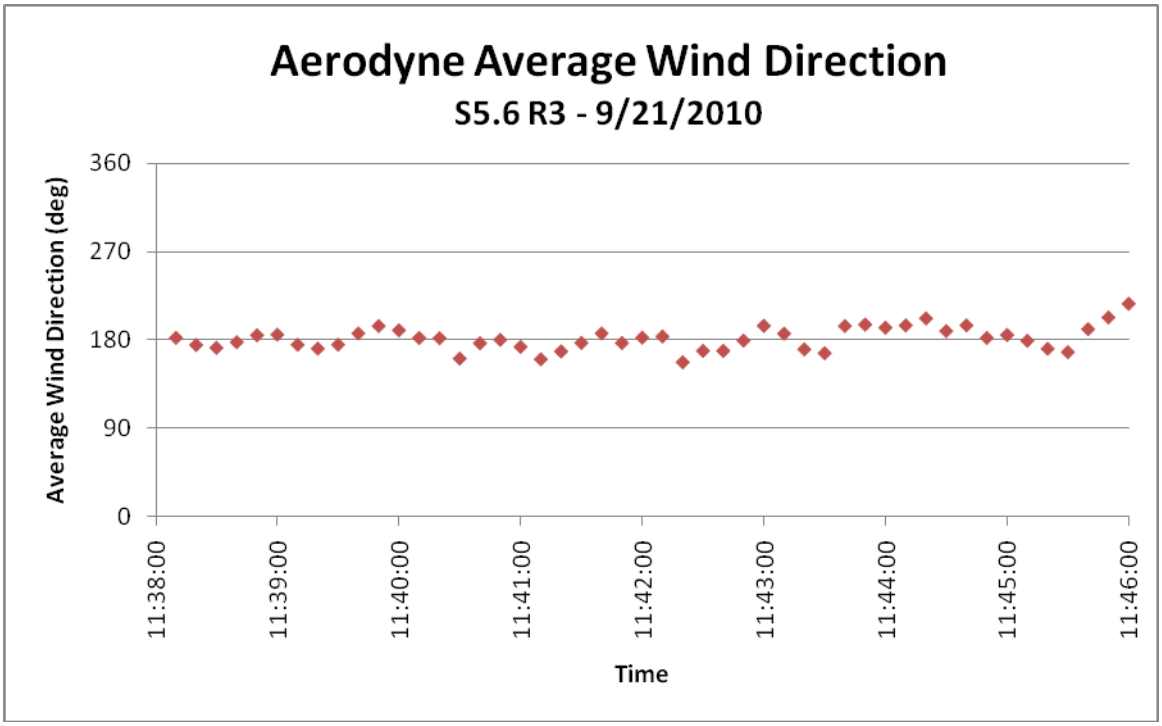


Figure J-39b. Wind Direction vs Time for Steam Flare Test S5.6 R3

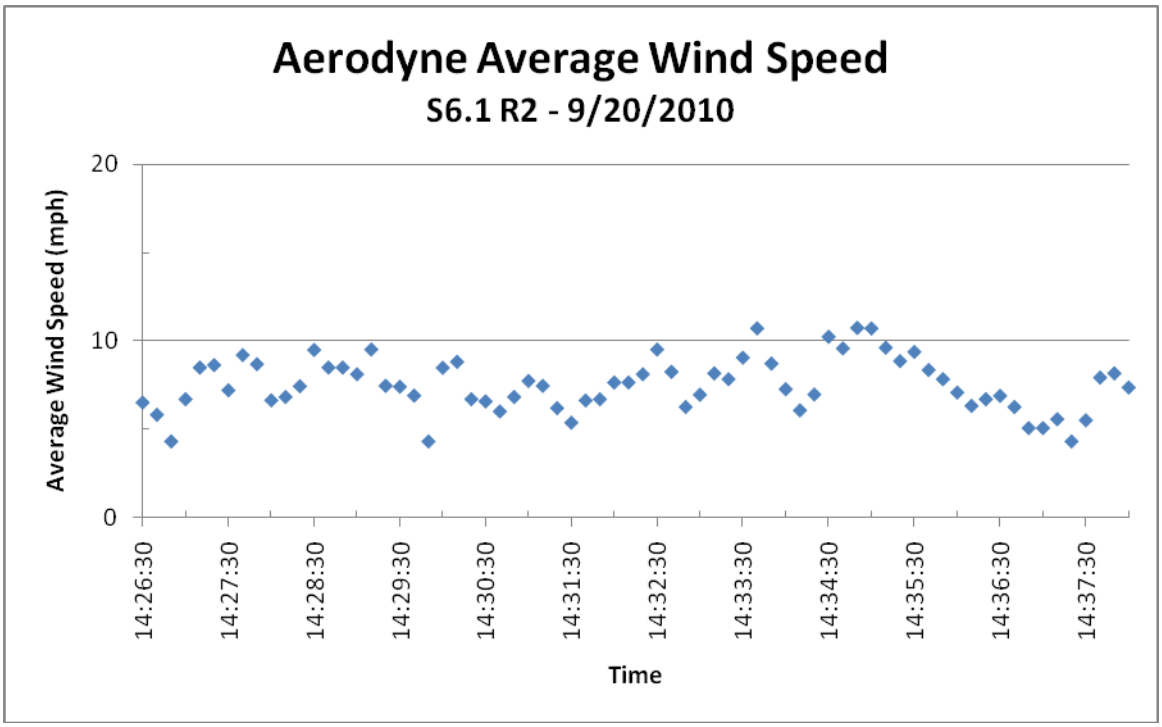


Figure J-40a. Wind Speed vs Time for Steam Flare Test S6.1 R2

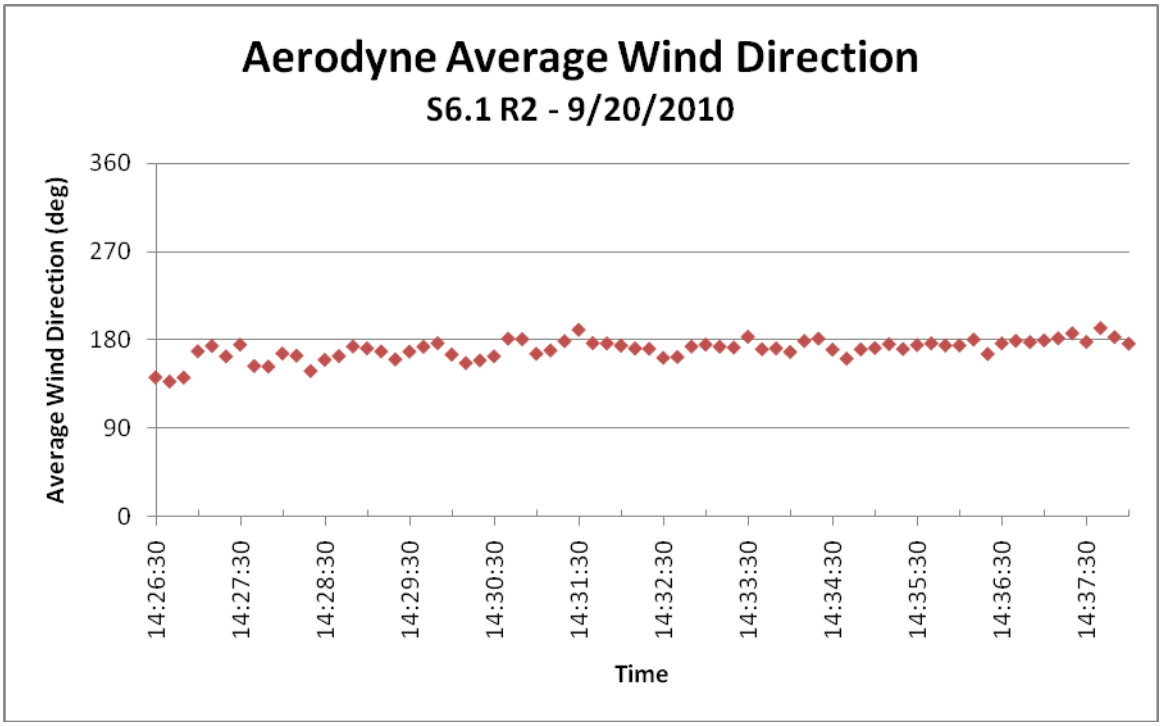


Figure J-40b. Wind Direction vs Time for Steam Flare Test S6.1 R2

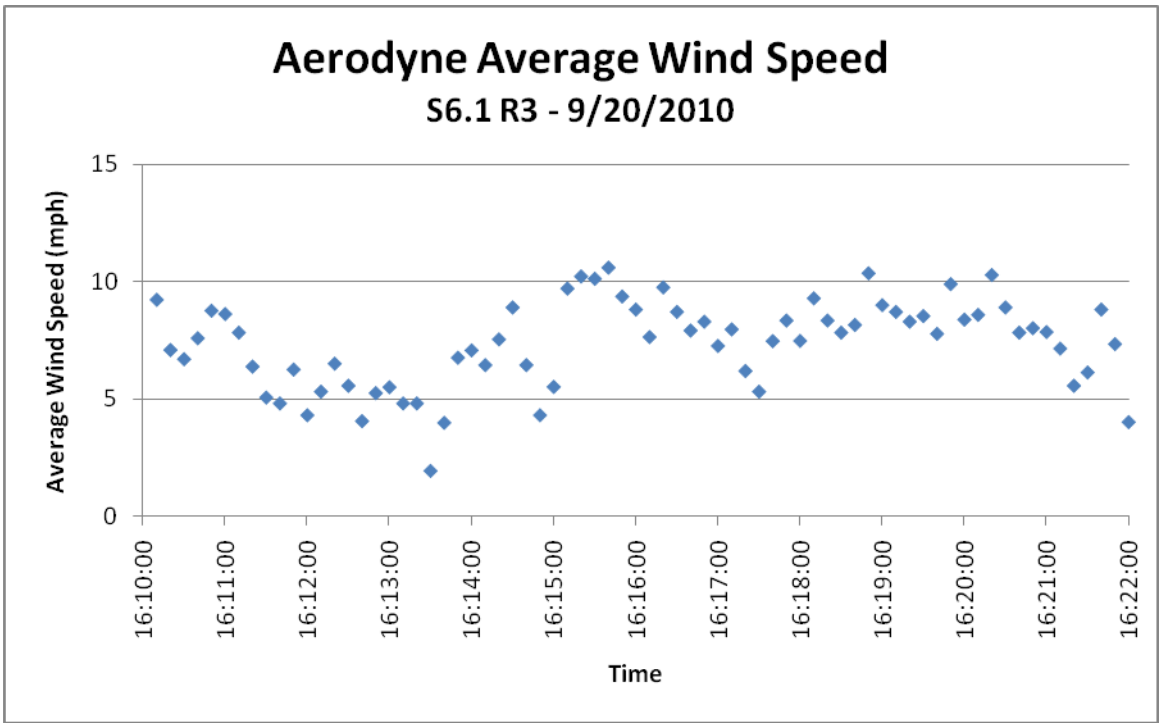


Figure J-41a. Wind Speed vs Time for Steam Flare Test S6.1 R3

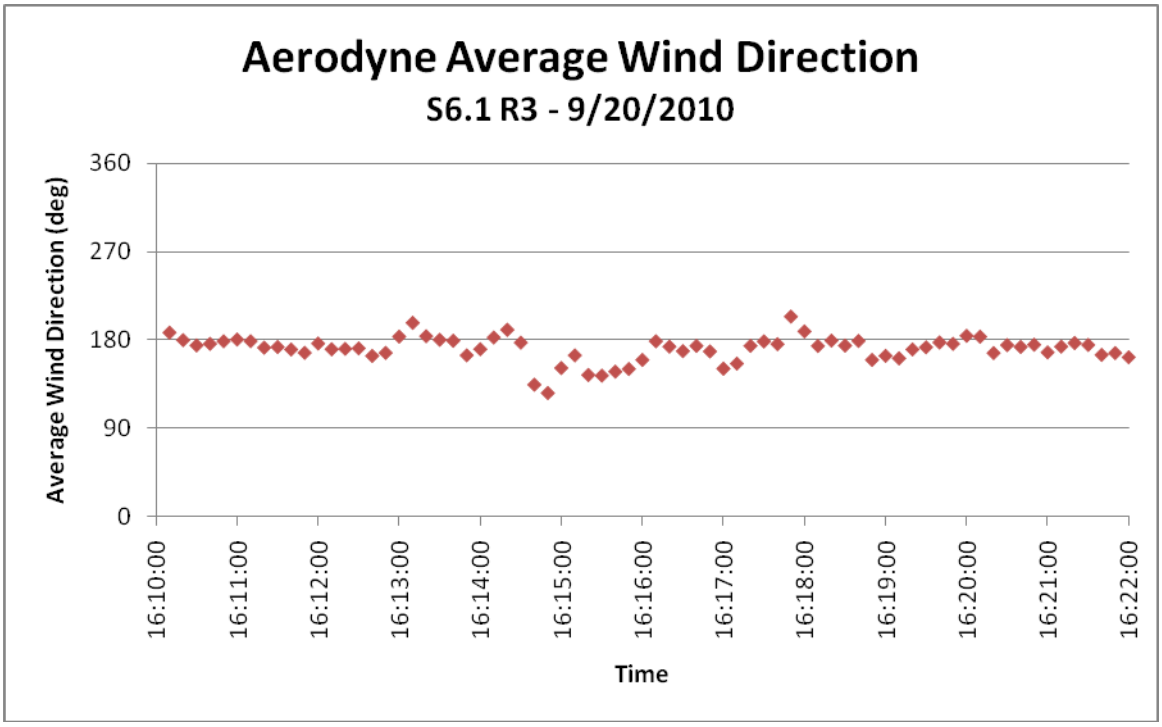


Figure J-41b. Wind Direction vs Time for Steam Flare Test S6.1 R3

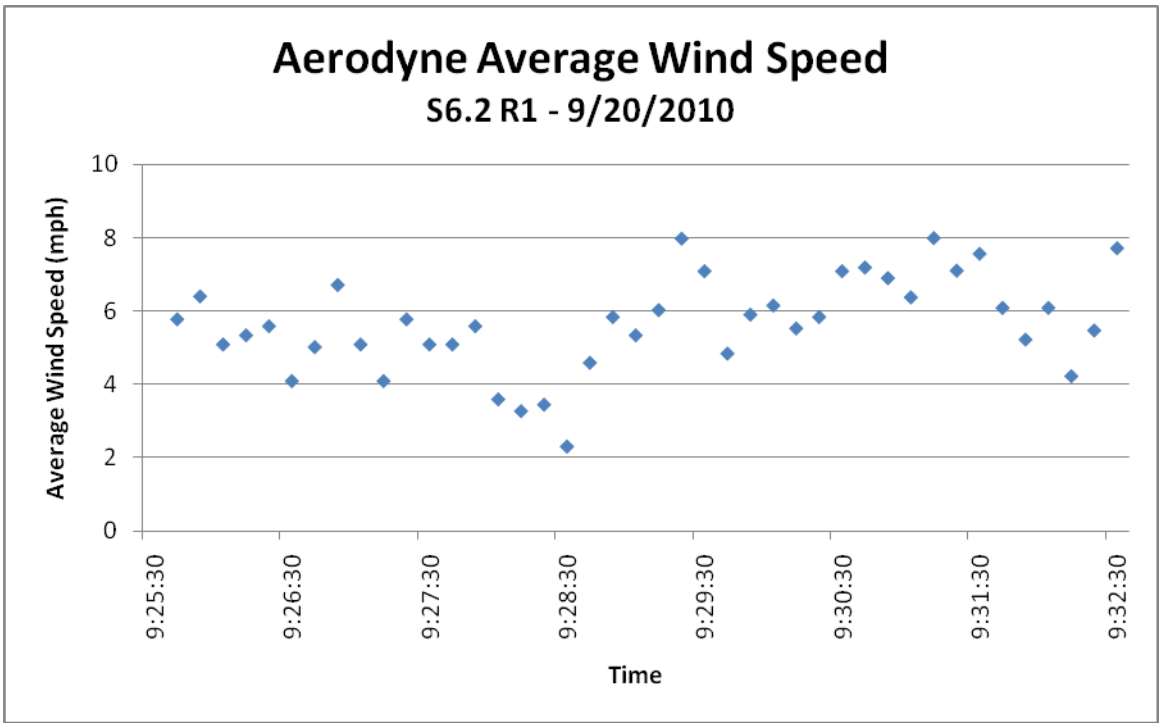


Figure J-42a. Wind Speed vs Time for Steam Flare Test S6.2 R1

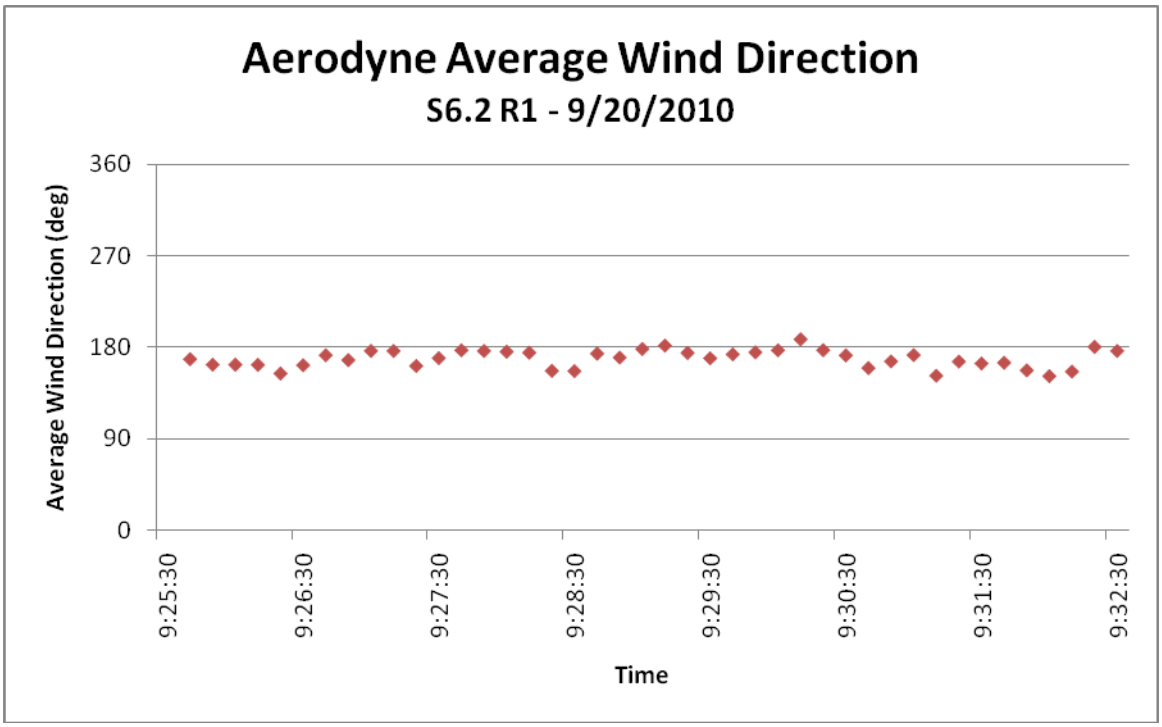


Figure J-42b. Wind Direction vs Time for Steam Flare Test S6.2 R1

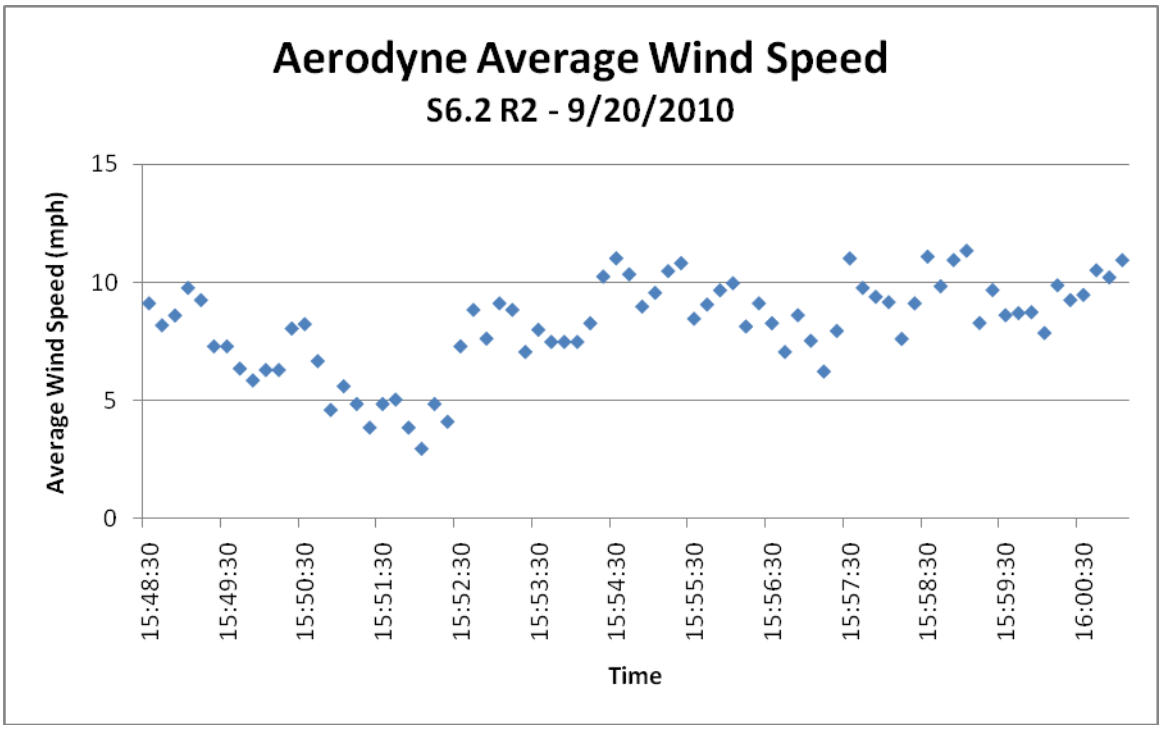


Figure J-43a. Wind Speed vs Time for Steam Flare Test S6.2 R2

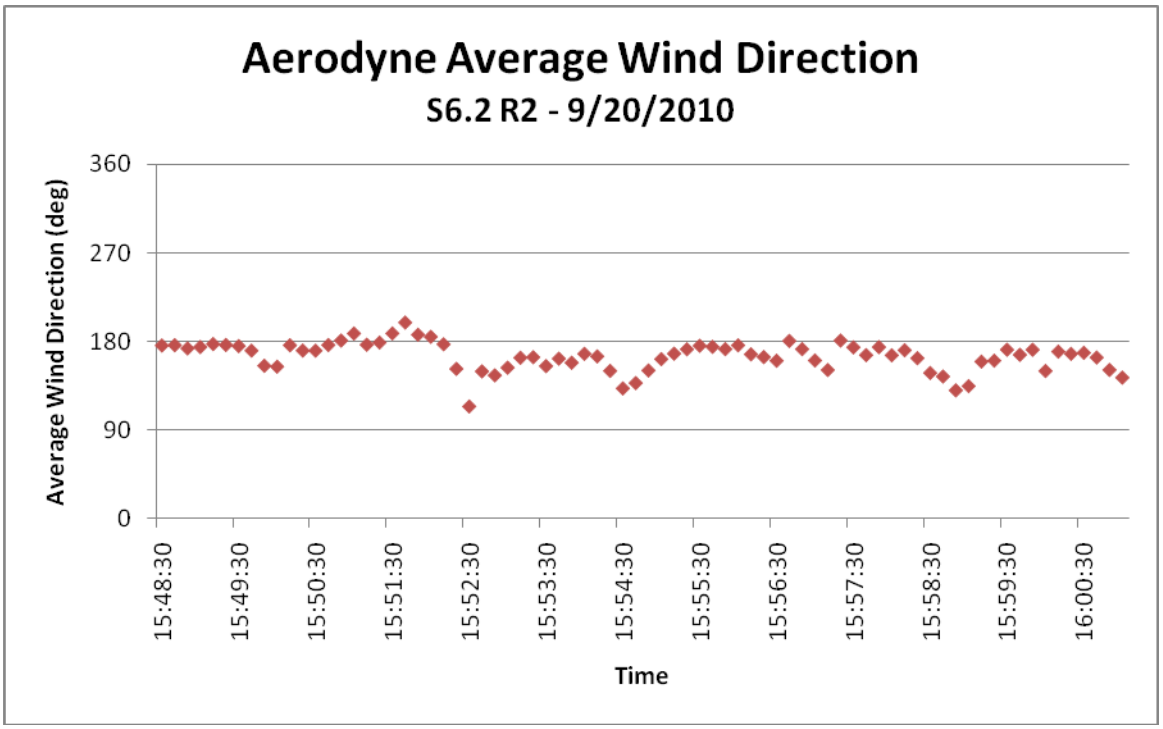


Figure J-43b. Wind Direction vs Time for Steam Flare Test S6.2 R2

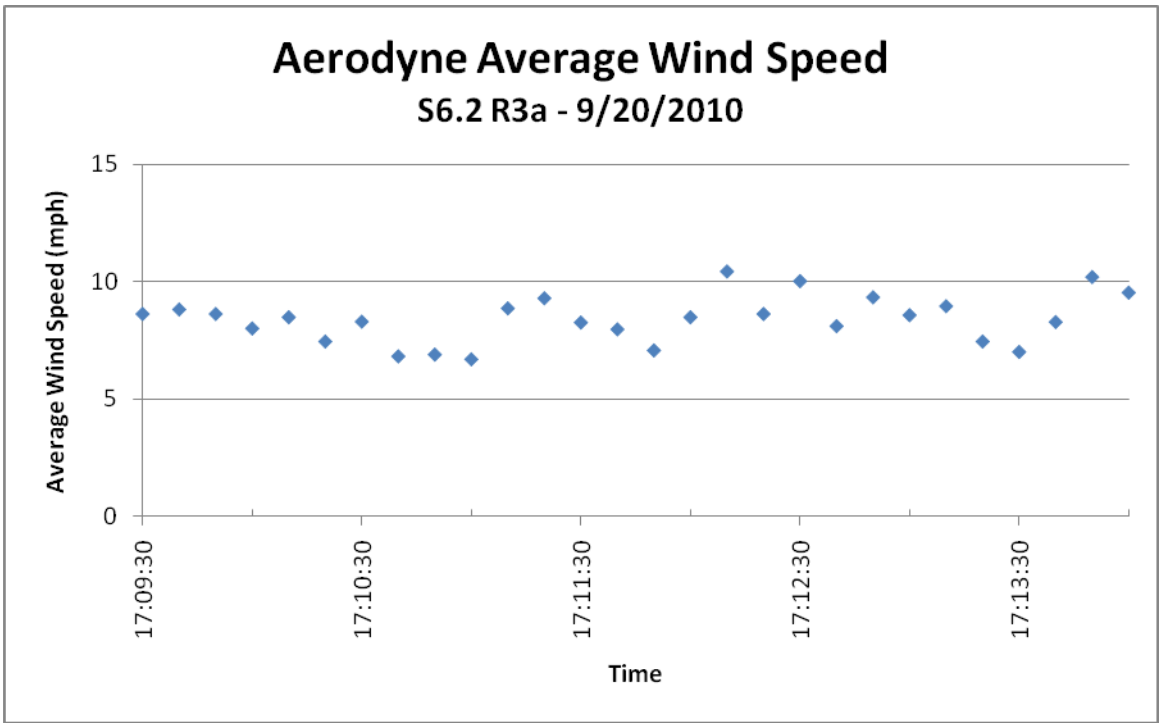


Figure J-44a. Wind Speed vs Time for Steam Flare Test S6.2 R3a

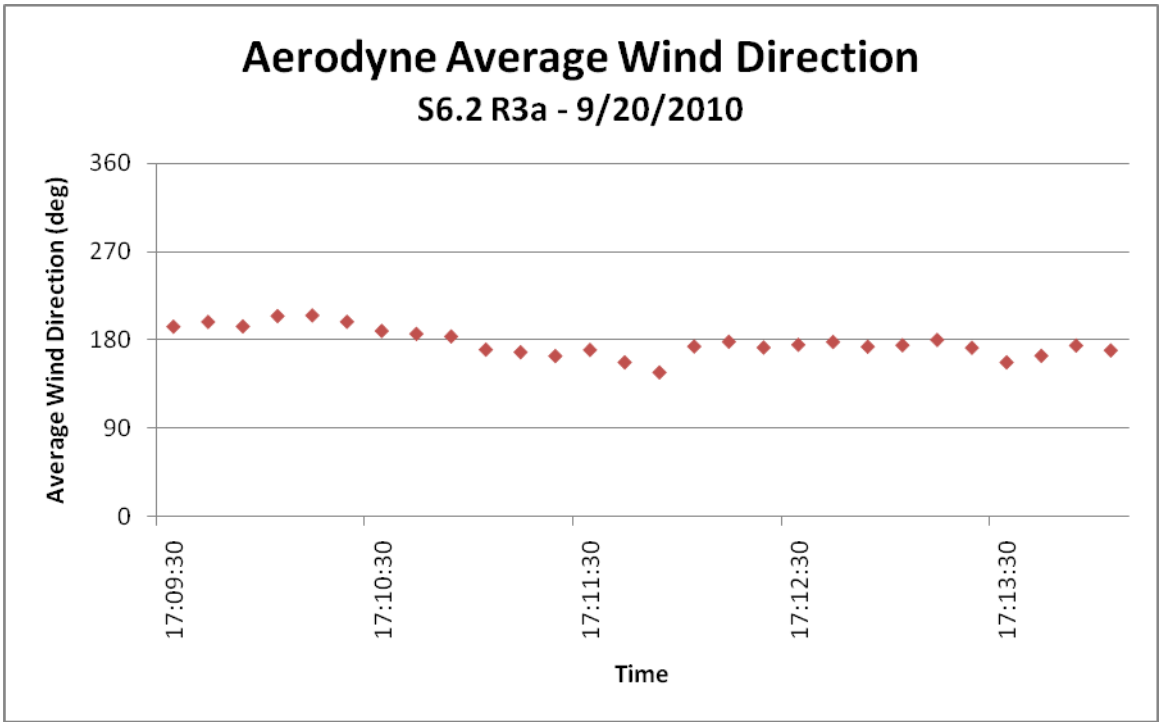


Figure J-44b. Wind Direction vs Time for Steam Flare Test S6.2 R3a

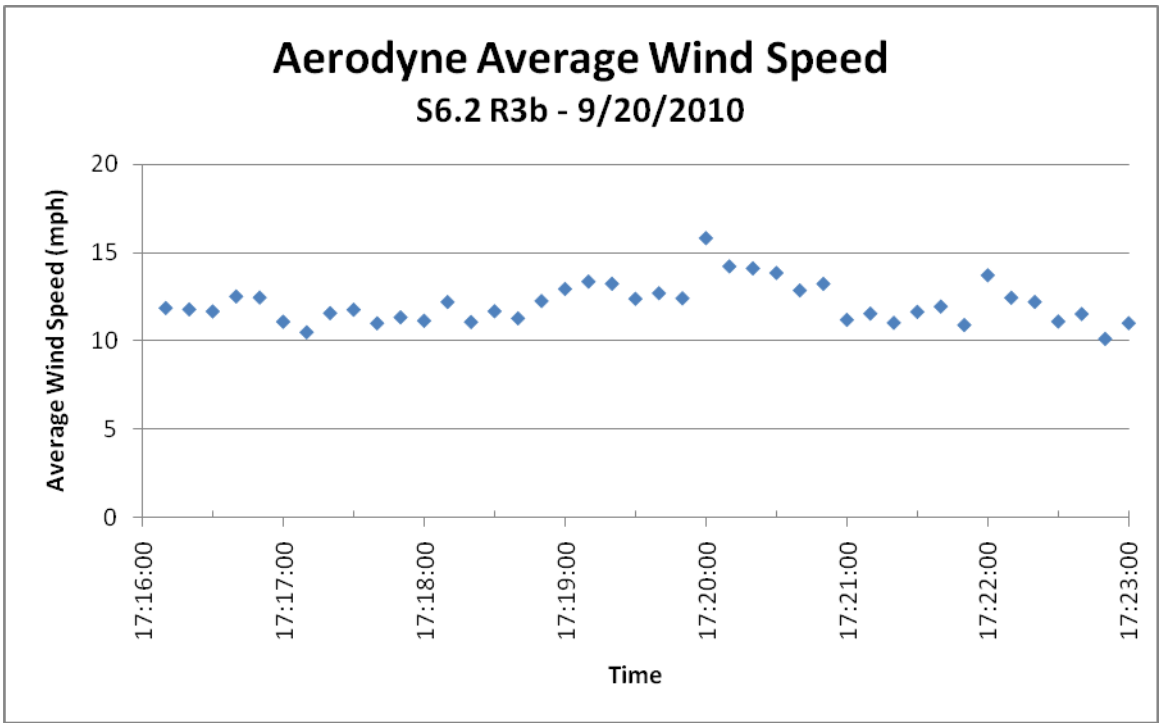


Figure J-45a. Wind Speed vs Time for Steam Flare Test S6.2 R3b

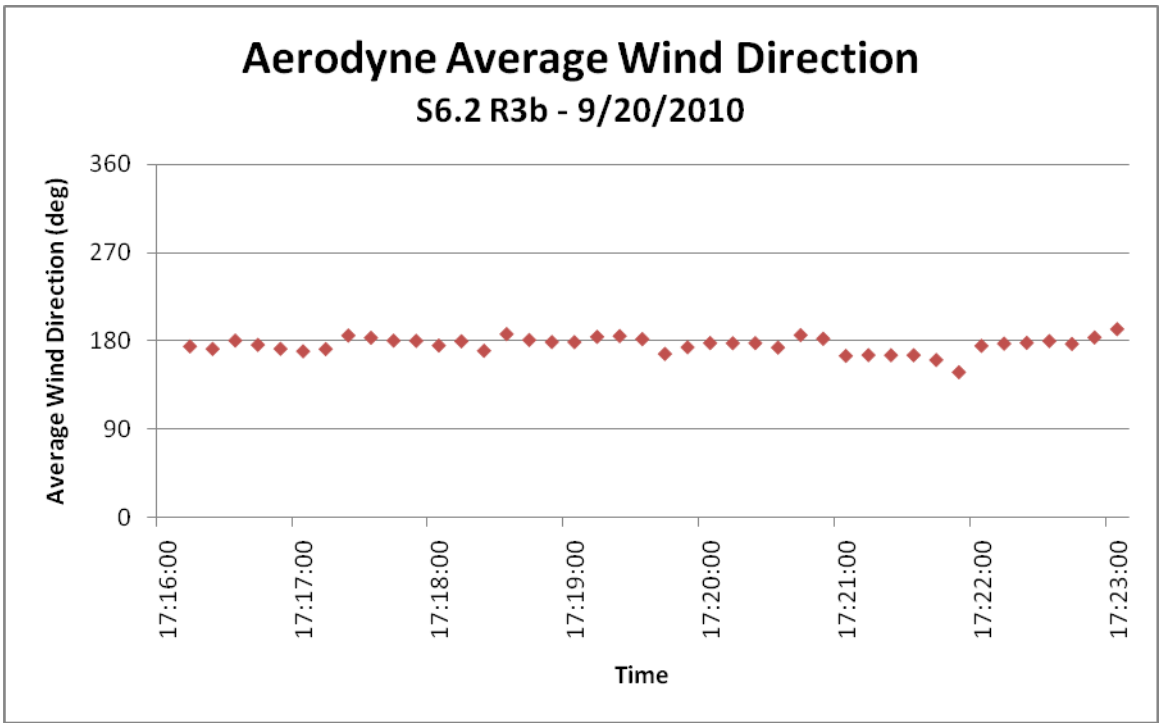


Figure J-45b. Wind Direction vs Time for Steam Flare Test S6.2 R3b

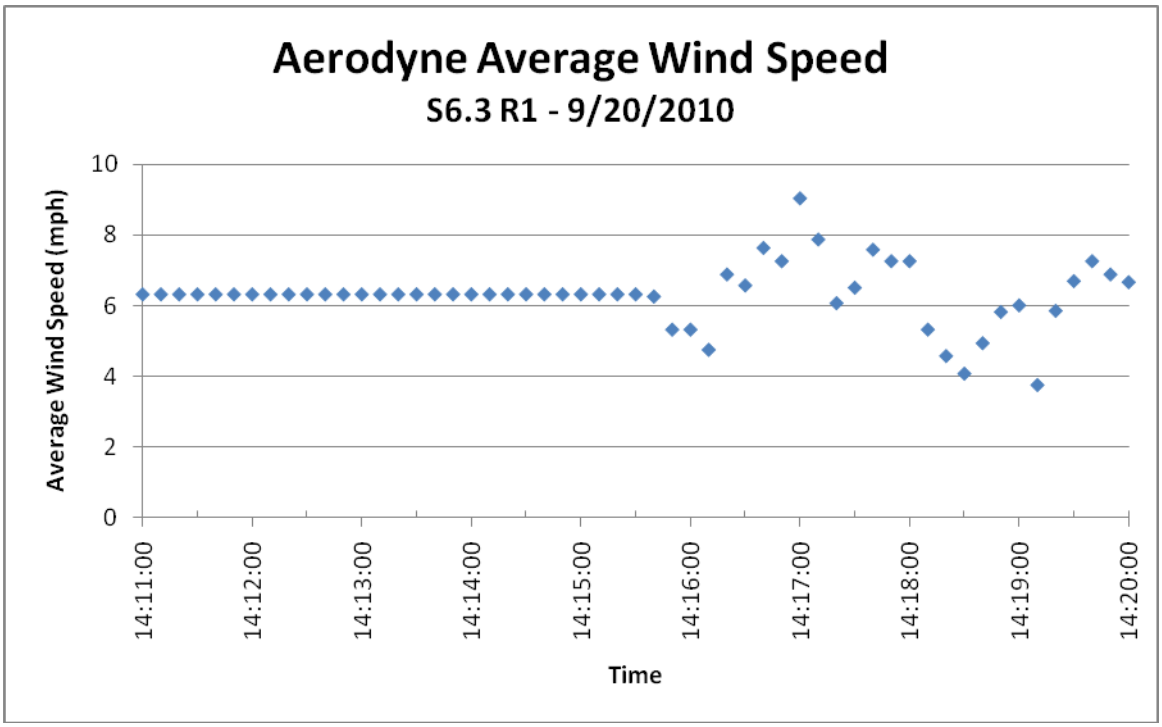


Figure J-46a. Wind Speed vs Time for Steam Flare Test S6.3 R1

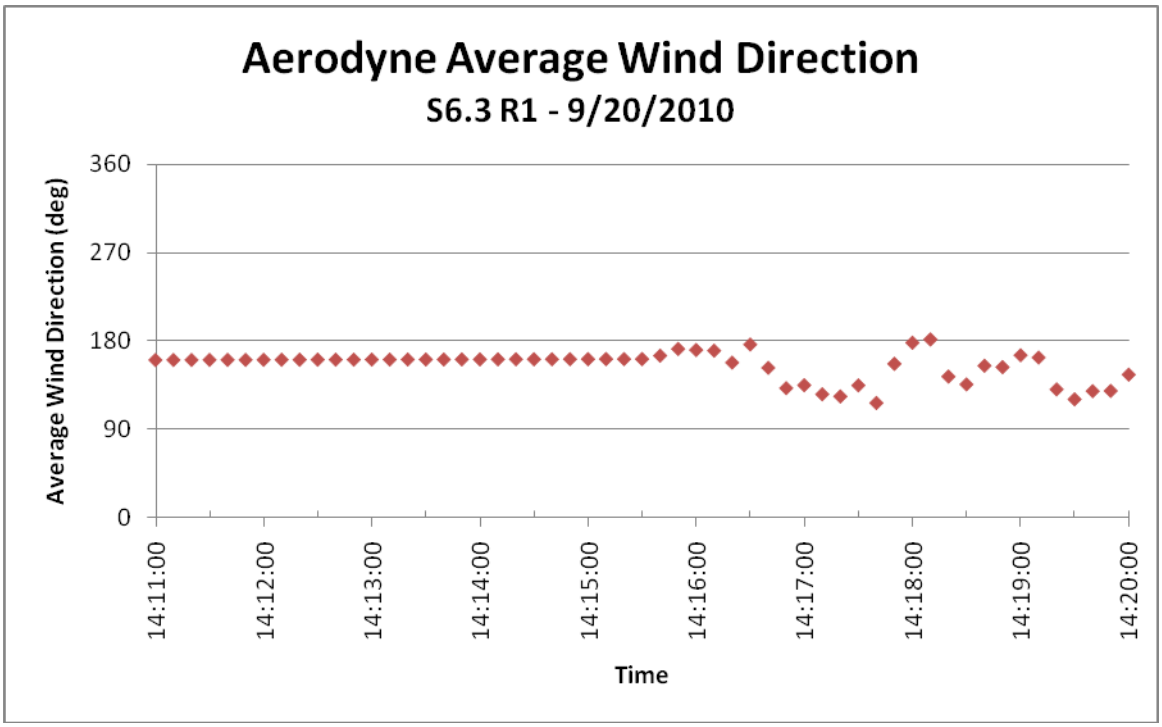


Figure J-46b. Wind Direction vs Time for Steam Flare Test S6.3 R1

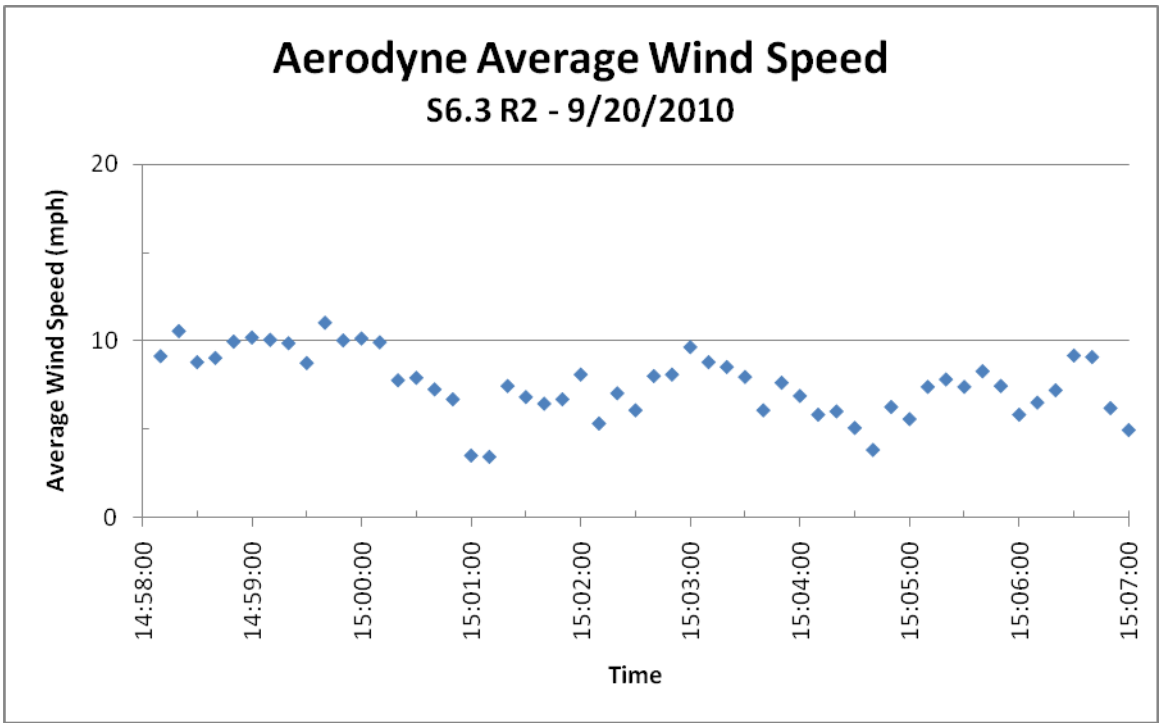


Figure J-47a. Wind Speed vs Time for Steam Flare Test S6.3 R2

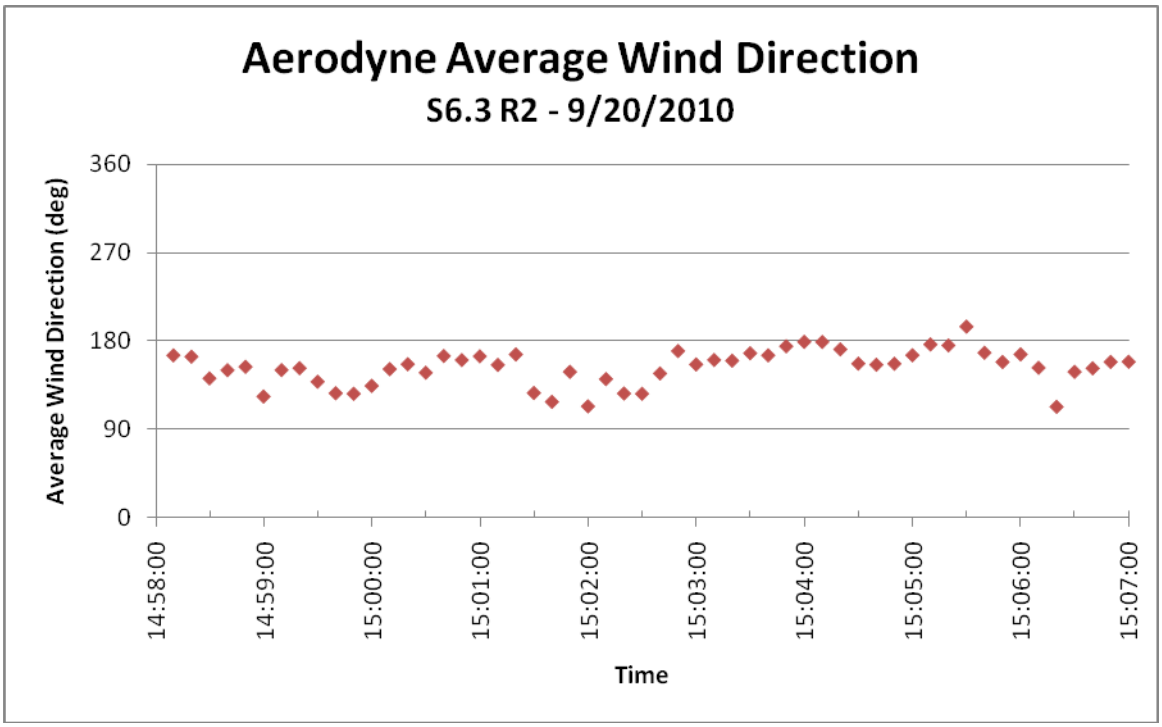


Figure J-47b. Wind Direction vs Time for Steam Flare Test S6.3 R2

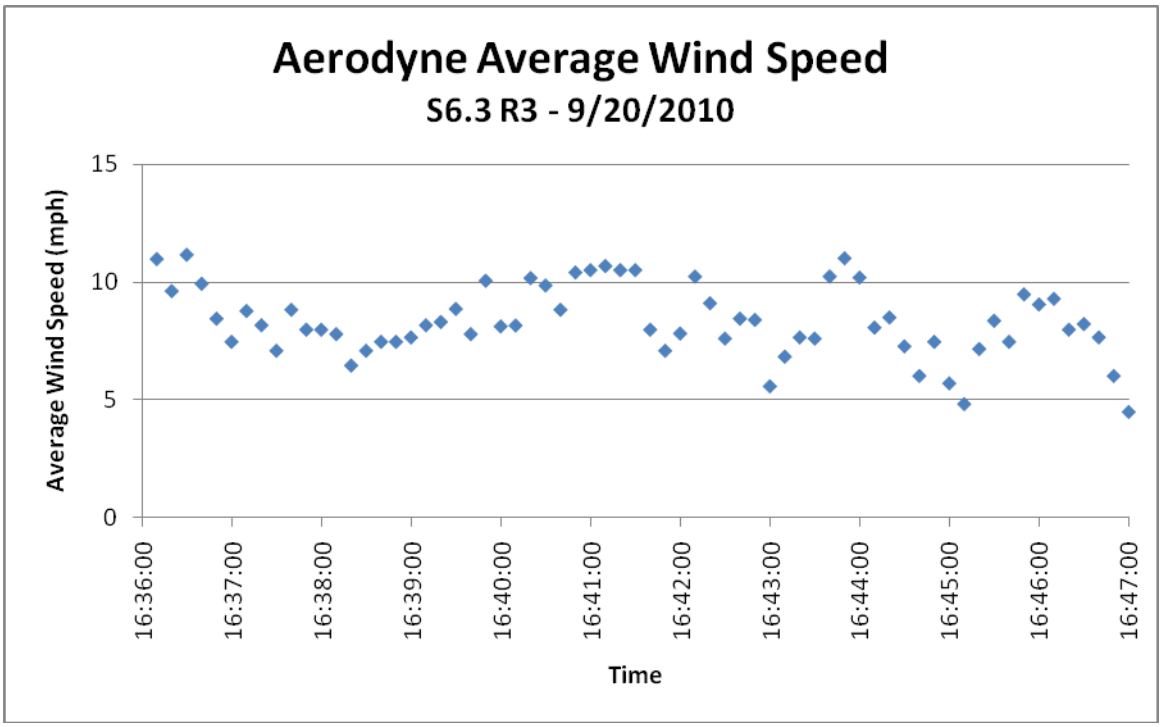


Figure J-48a. Wind Speed vs Time for Steam Flare Test S6.3 R3

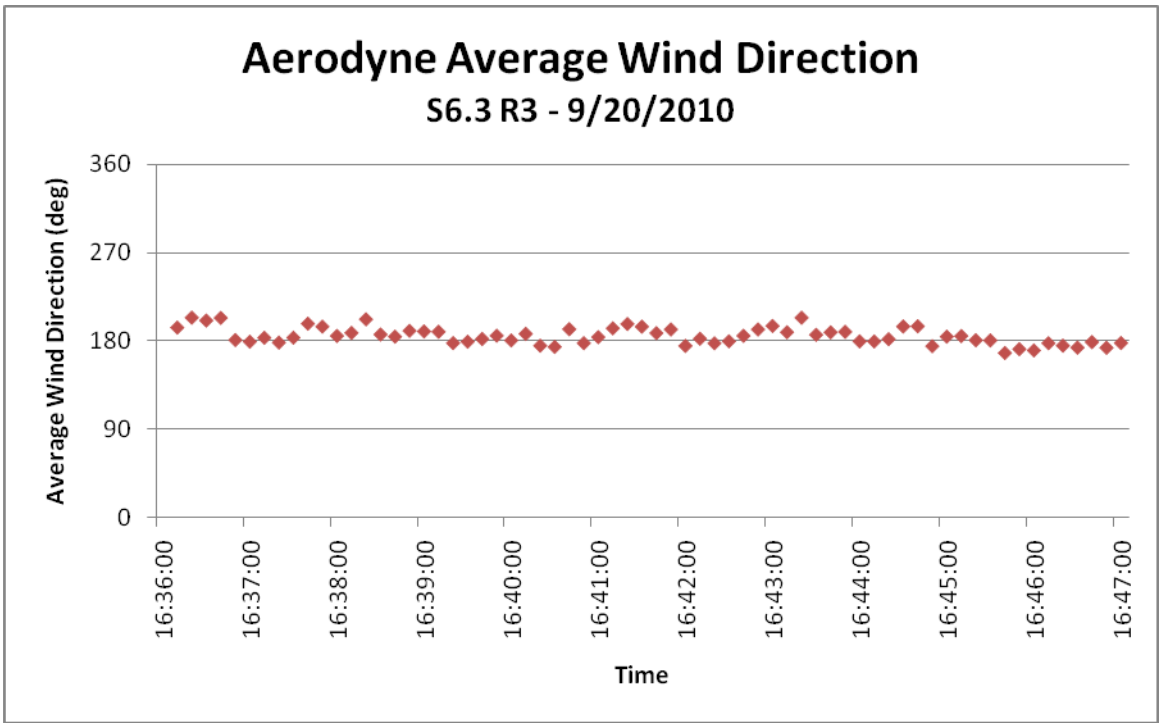


Figure J-48b. Wind Direction vs Time for Steam Flare Test S6.3 R3

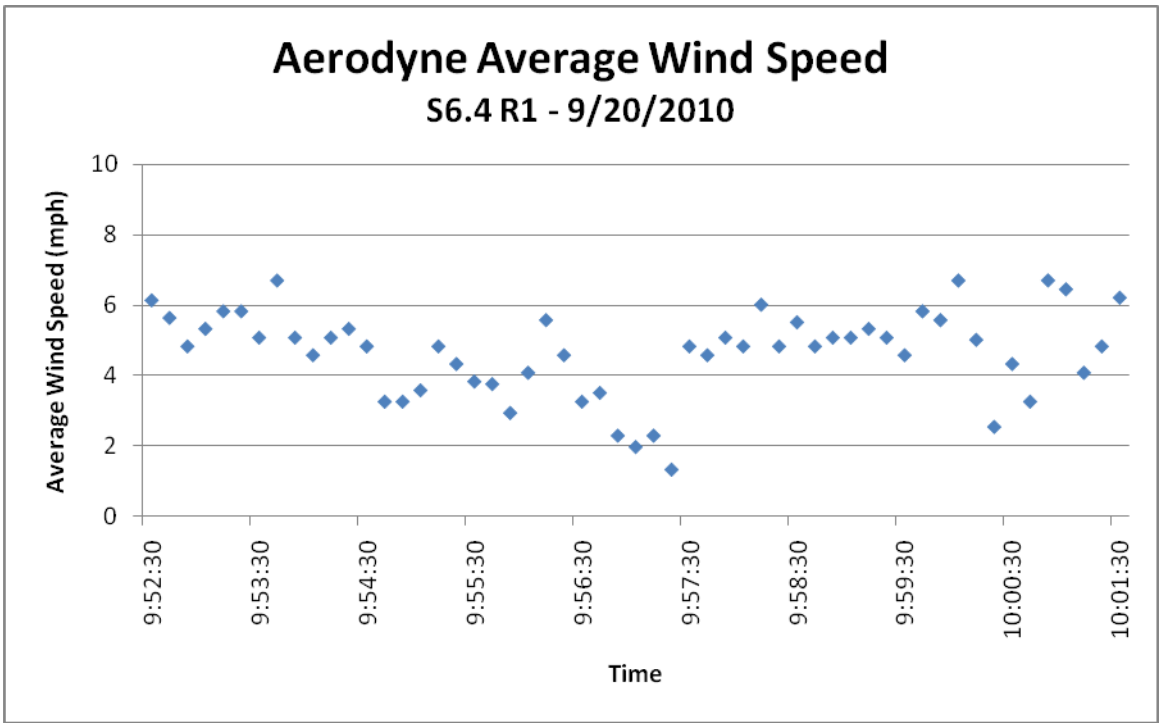


Figure J-49a. Wind Speed vs Time for Steam Flare Test S6.4 R1

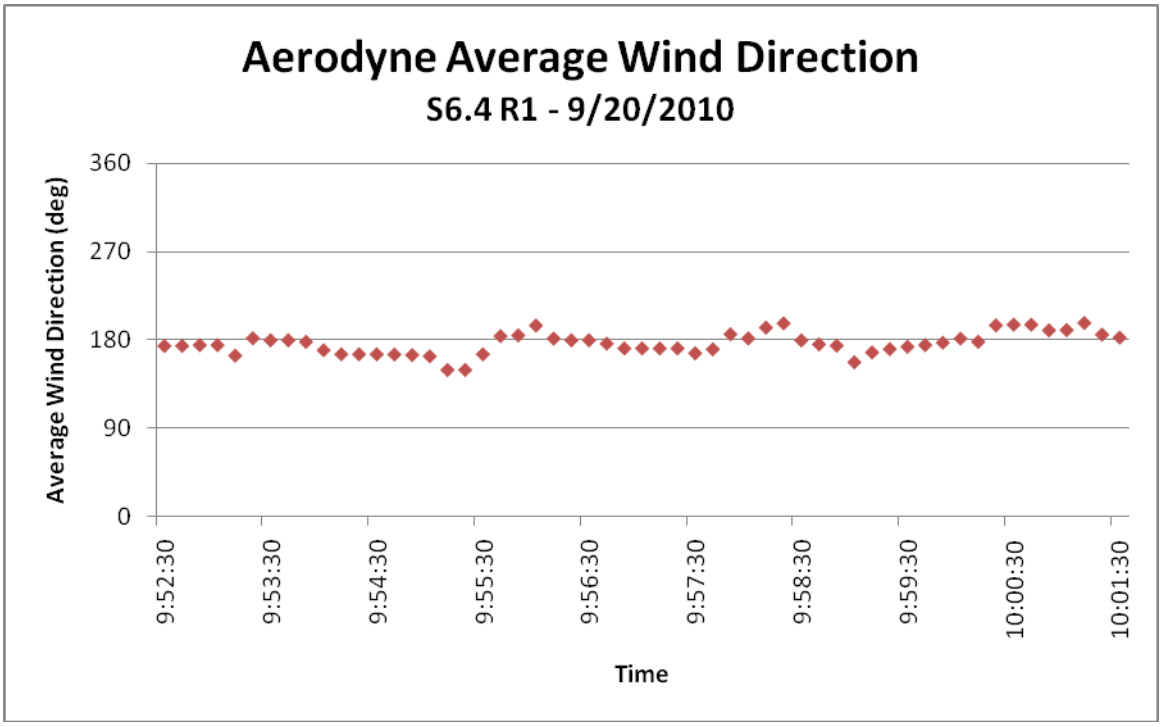


Figure J-49b. Wind Direction vs Time for Steam Flare Test S6.4 R1

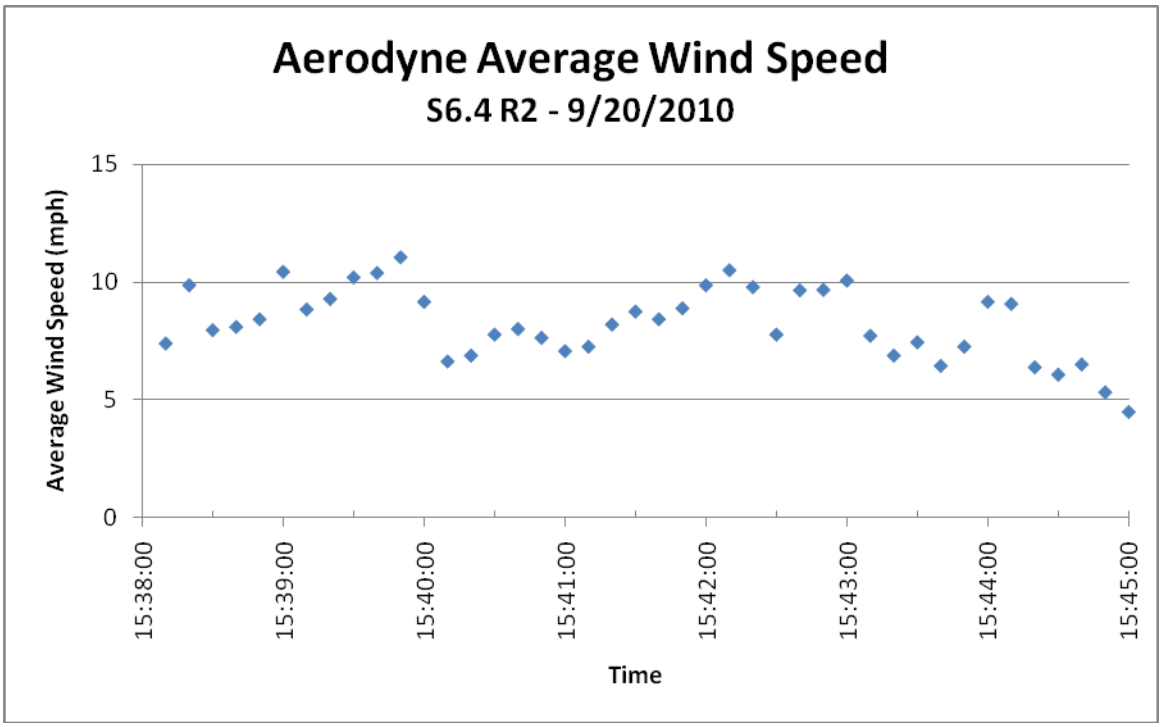


Figure J-50a. Wind Speed vs Time for Steam Flare Test S6.4 R2

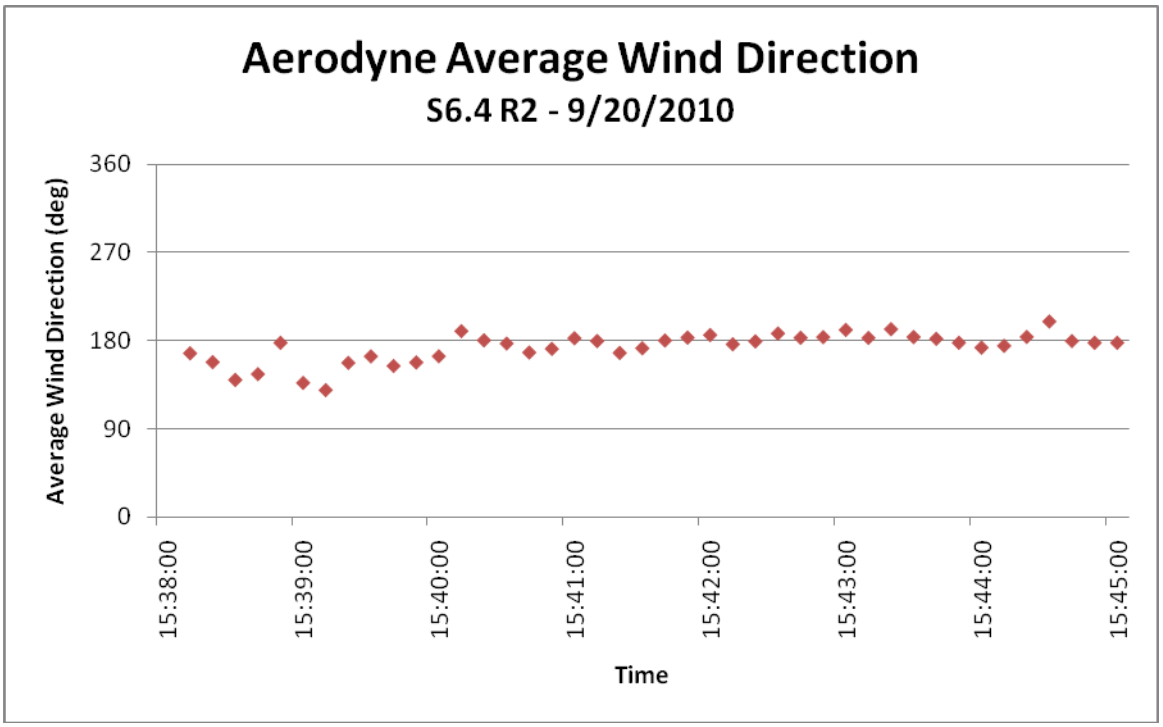


Figure J-50b. Wind Direction vs Time for Steam Flare Test S6.4 R2

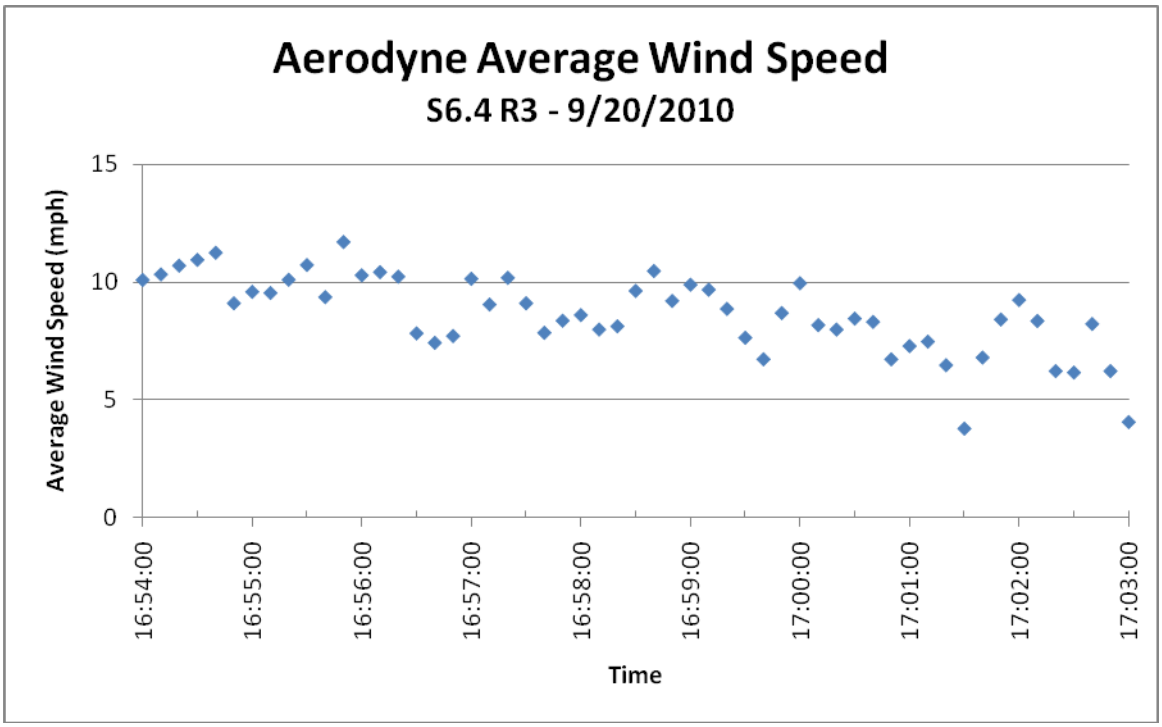


Figure J-51a. Wind Speed vs Time for Steam Flare Test S6.4 R3

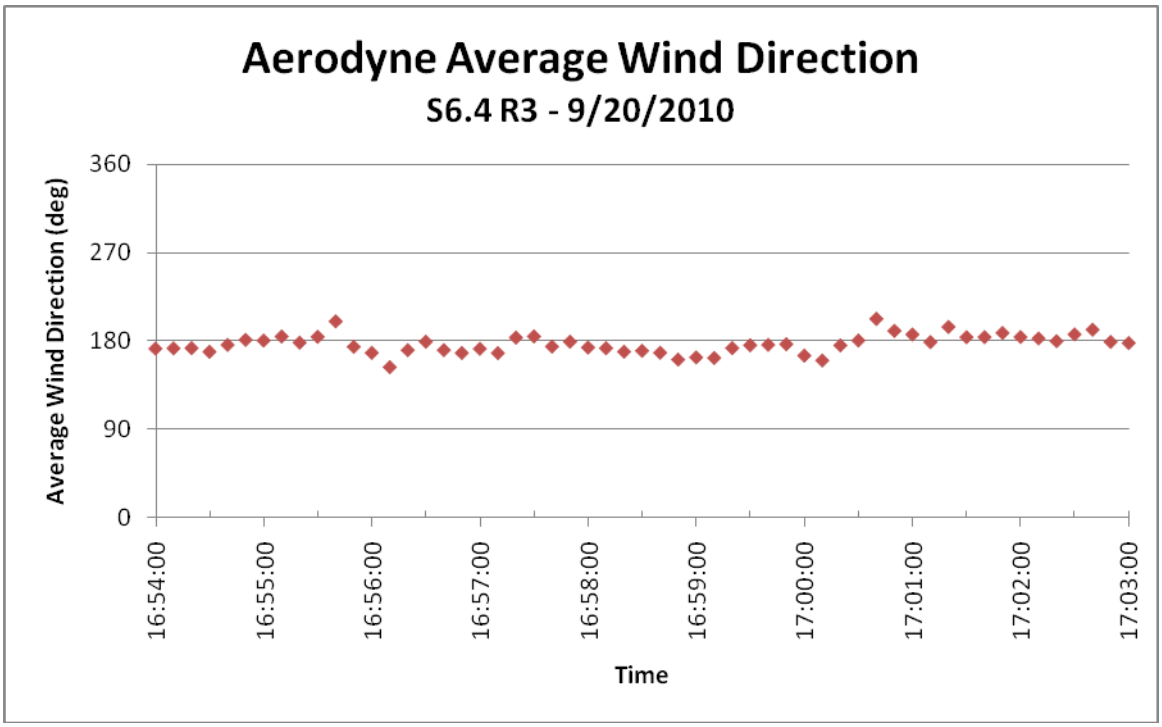


Figure J-51b. Wind Direction vs Time for Steam Flare Test S6.4 R3

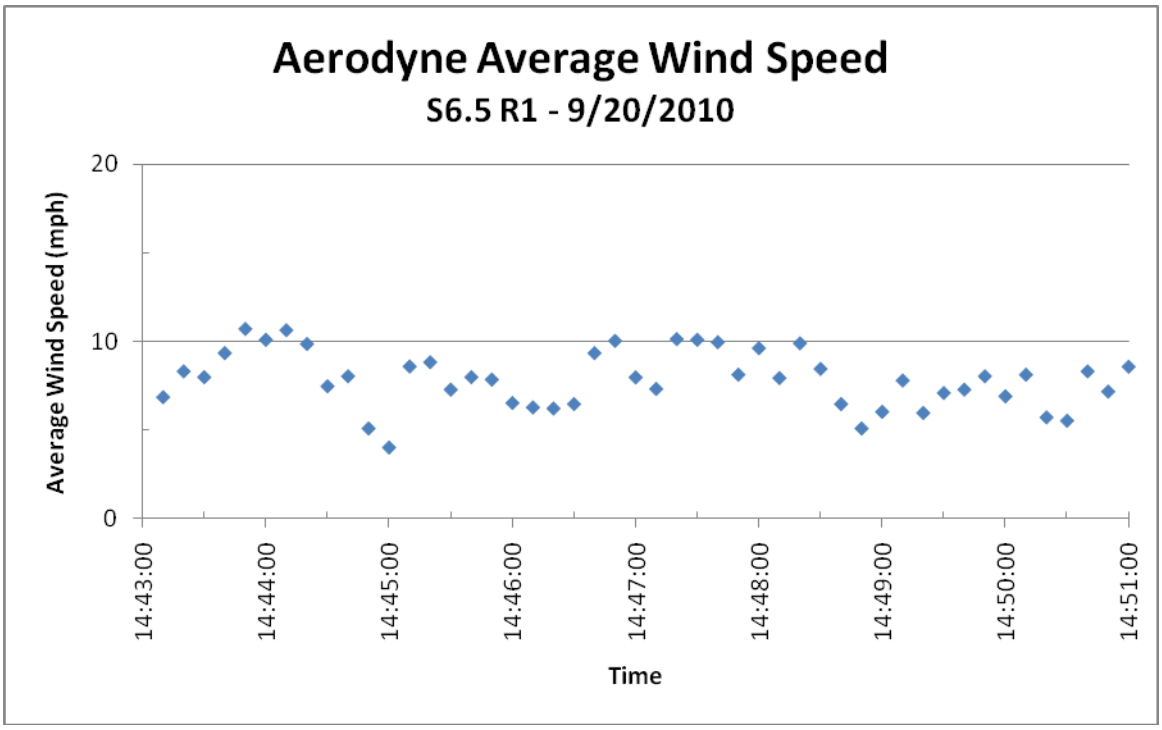


Figure J-52a. Wind Speed vs Time for Steam Flare Test S6.5 R1

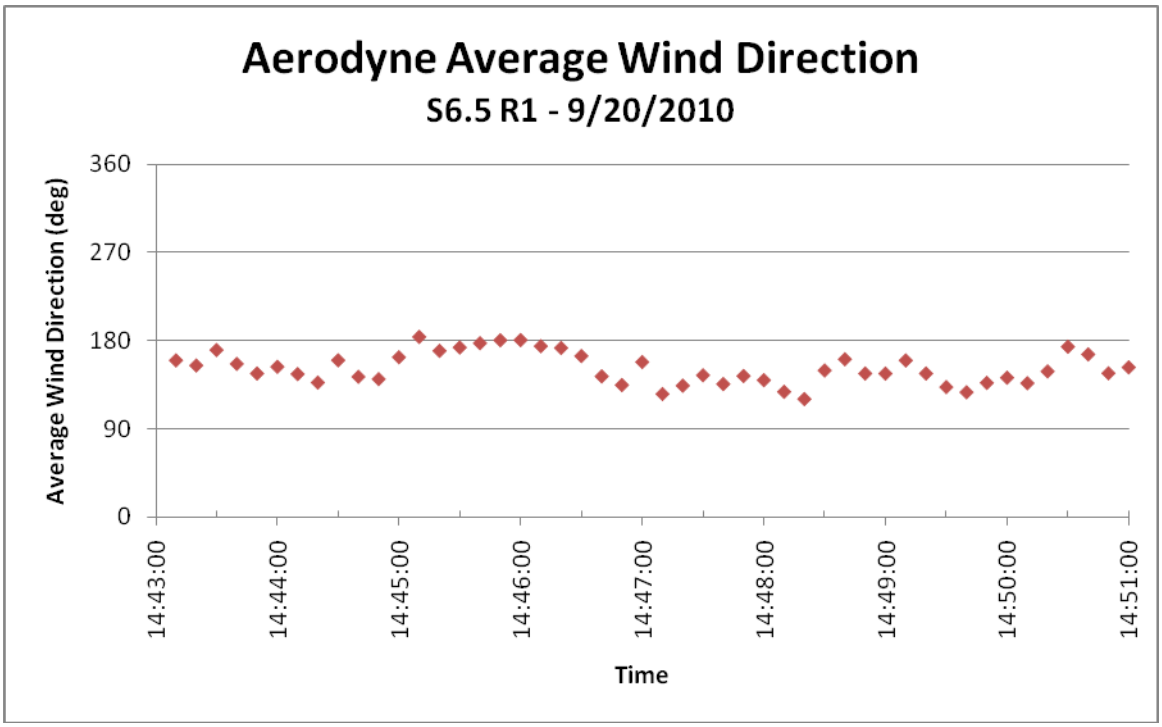


Figure J-52b. Wind Direction vs Time for Steam Flare Test S6.5 R1

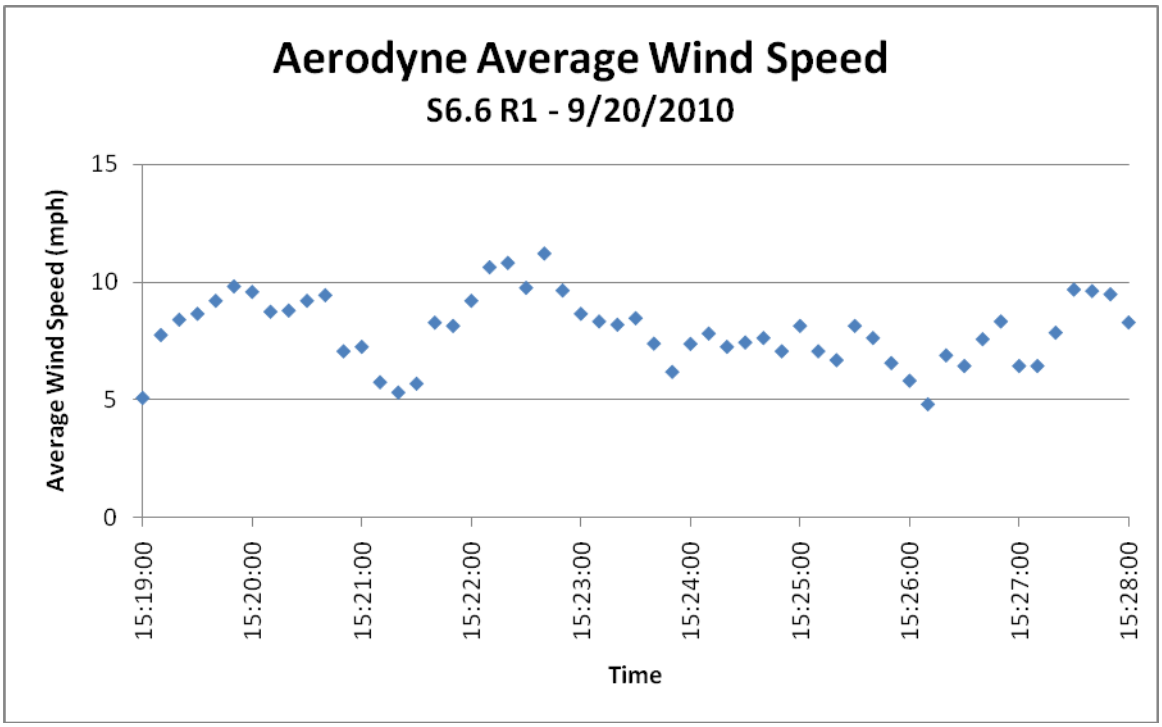


Figure J-53a. Wind Speed vs Time for Steam Flare Test S6.6 R1

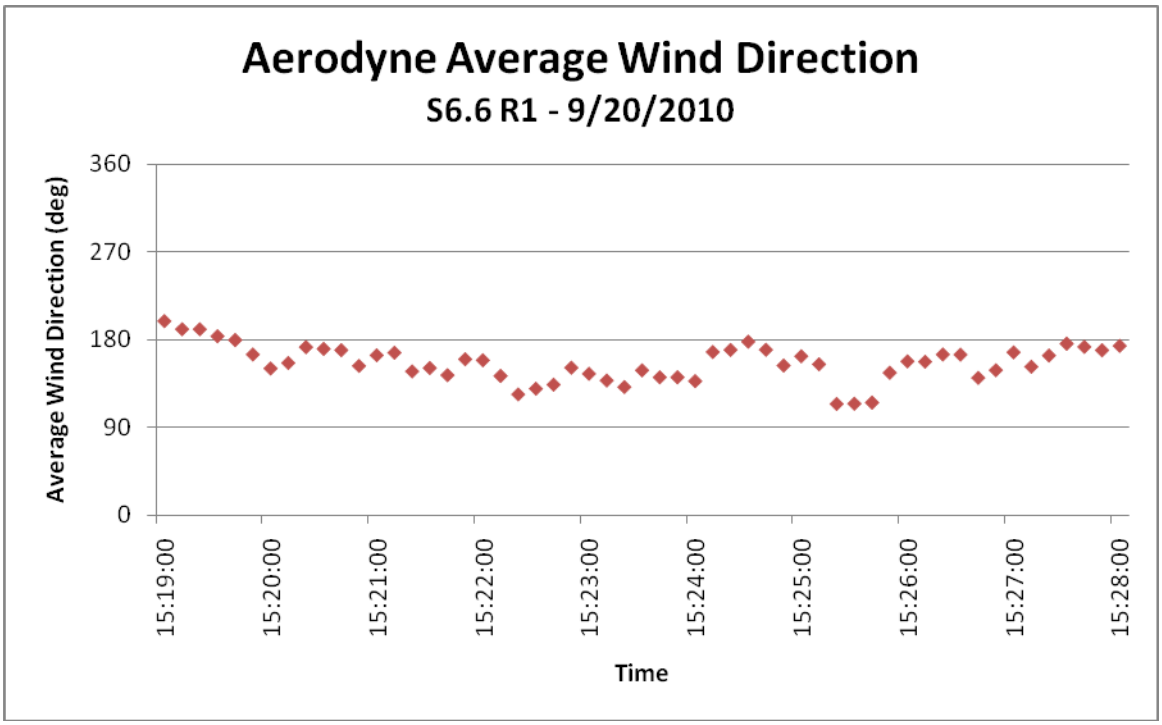


Figure J-53b. Wind Direction vs Time for Steam Flare Test S6.6 R1

Air Flare Tests Graphs

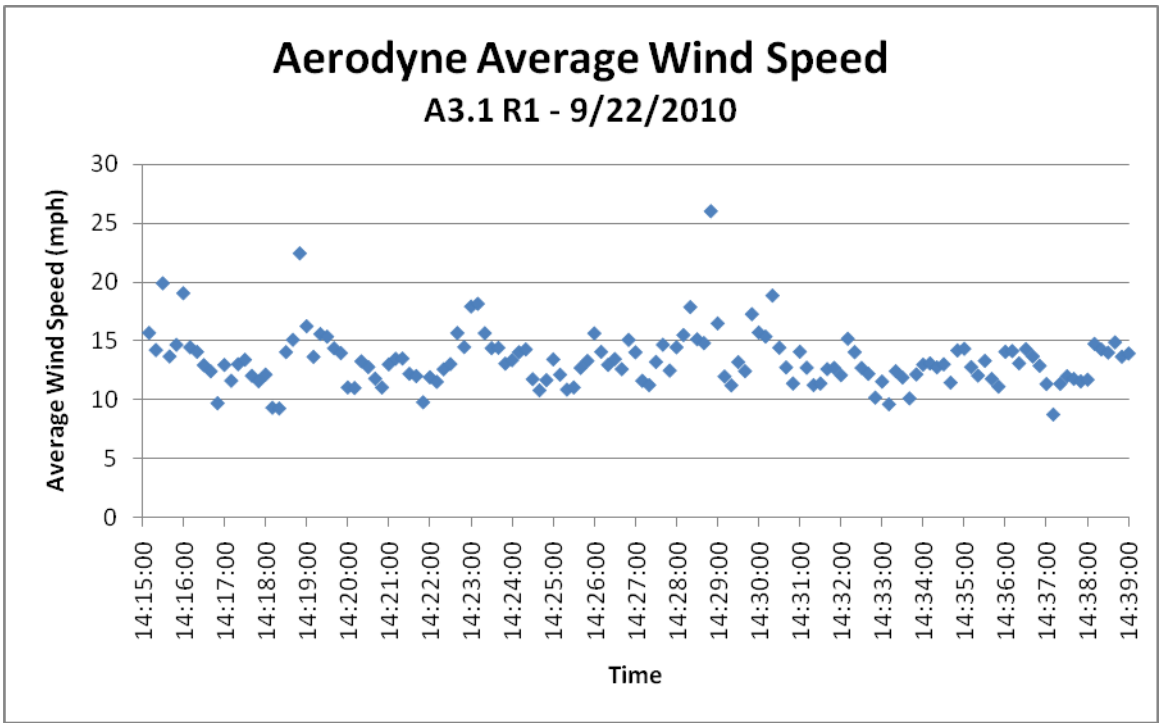


Figure J-54a. Wind Speed vs Time for Air Flare Test A3.1 R1

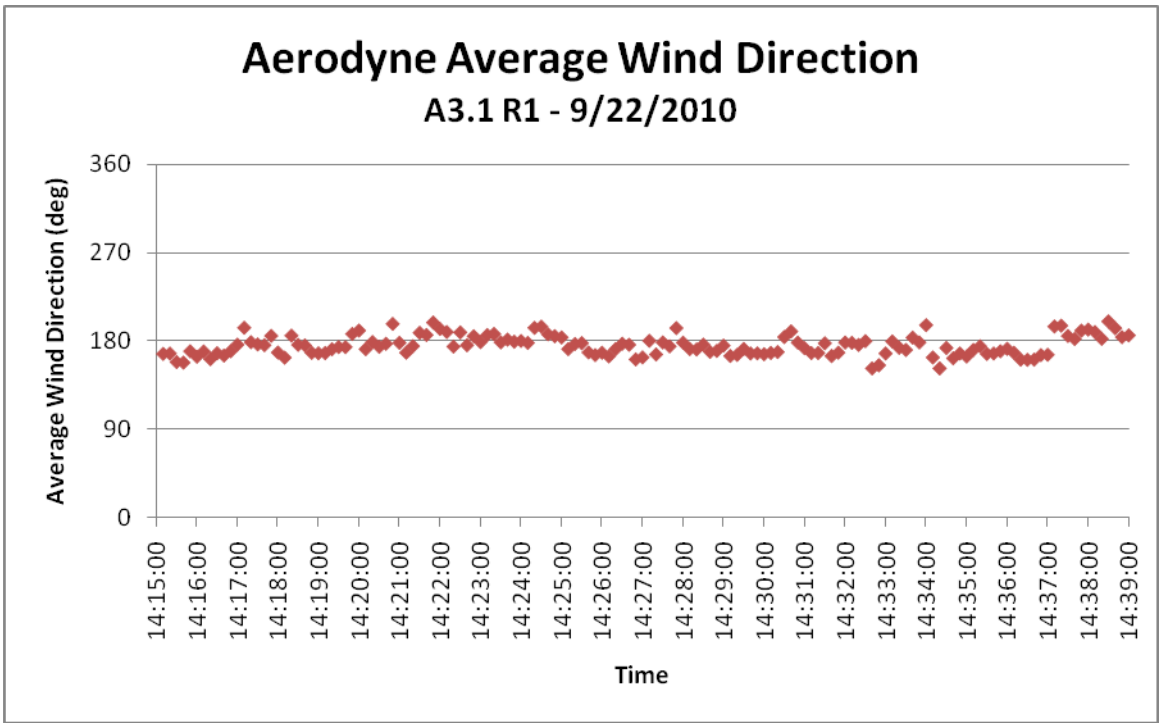


Figure J-54b. Wind Direction vs Time for Air Flare Test A3.1 R1

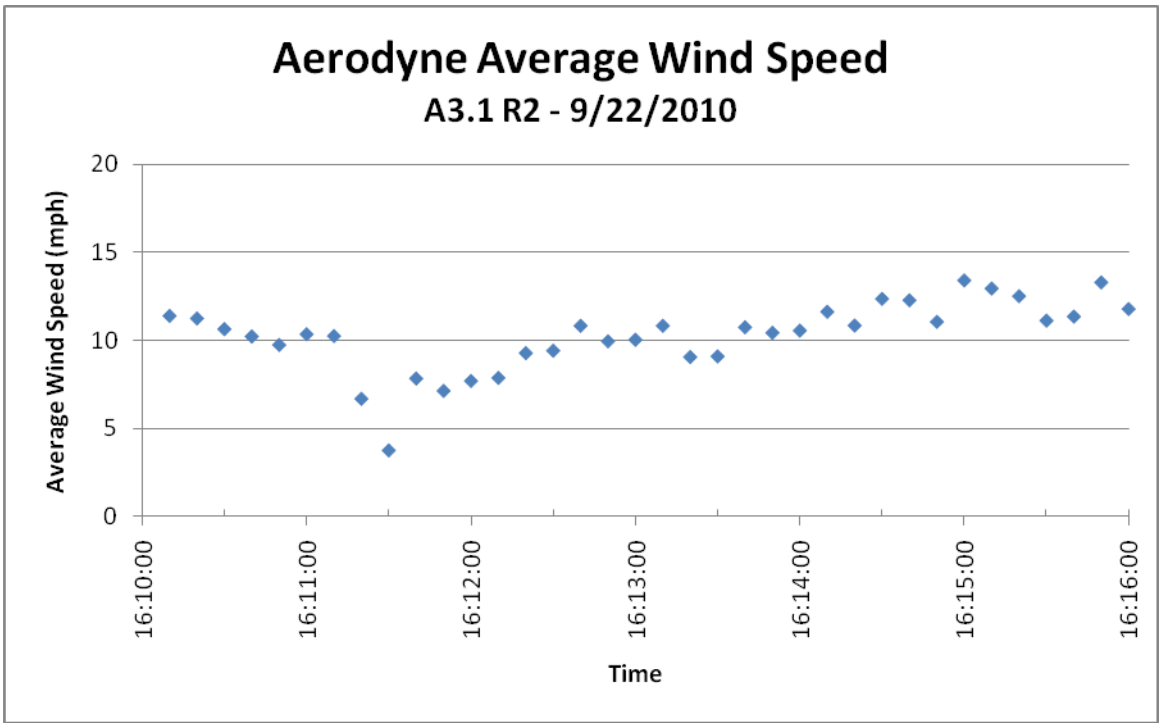


Figure J-55a. Wind Speed vs Time for Air Flare Test A3.1 R2

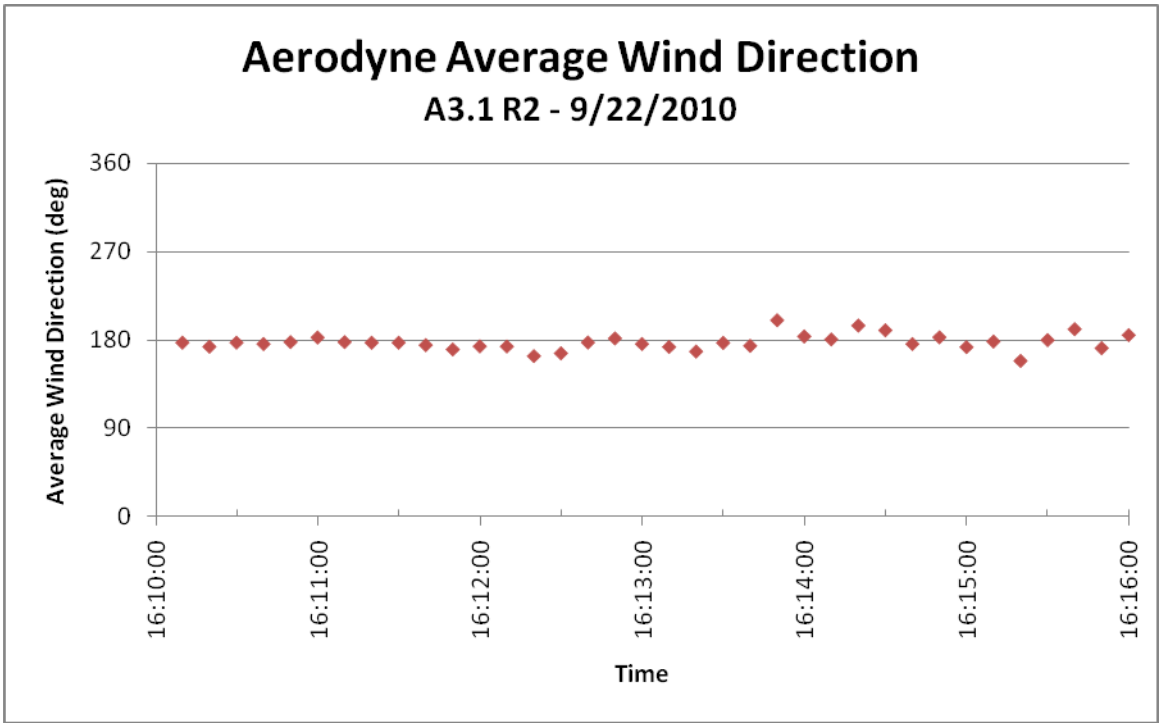


Figure J-55b. Wind Direction vs Time for Air Flare Test A3.1 R2

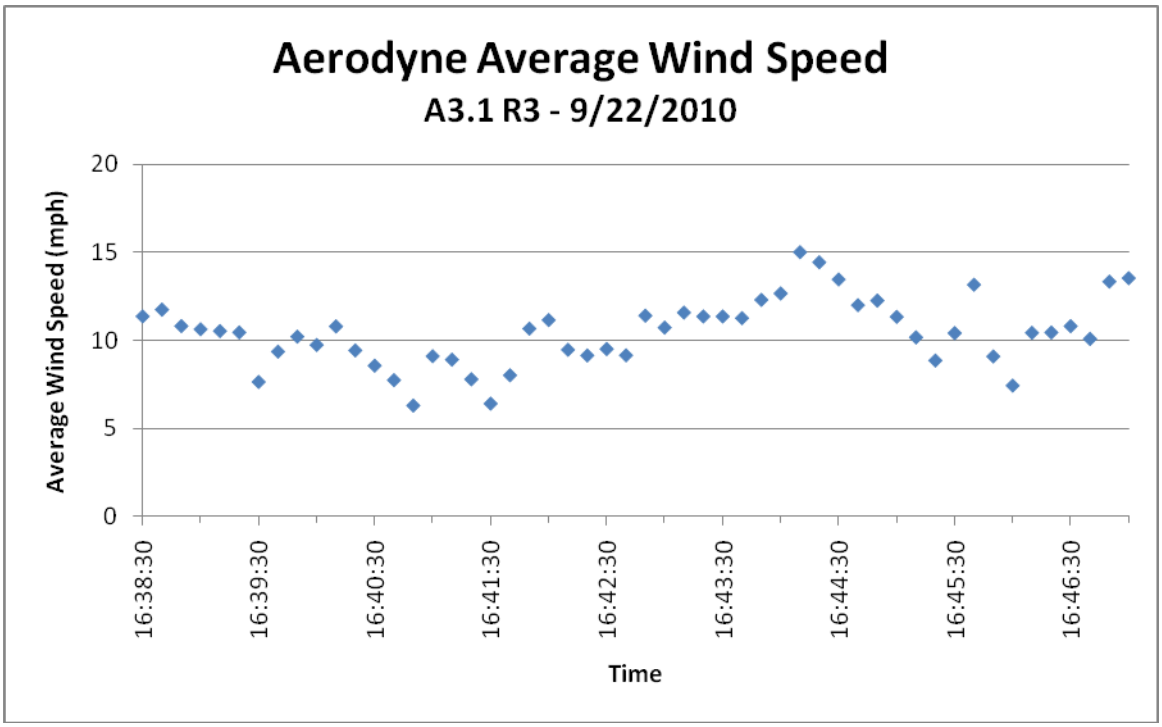


Figure J-56a. Wind Speed vs Time for Air Flare Test A3.1 R3

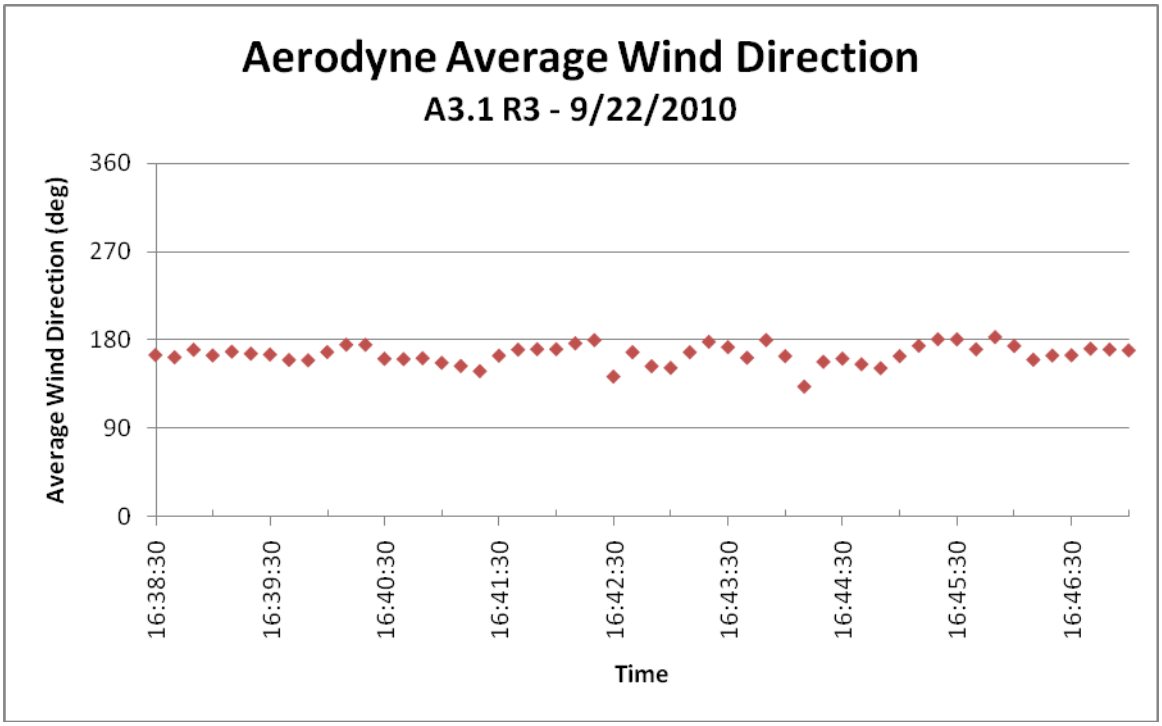


Figure J-56b. Wind Direction vs Time for Air Flare Test A3.1 R3

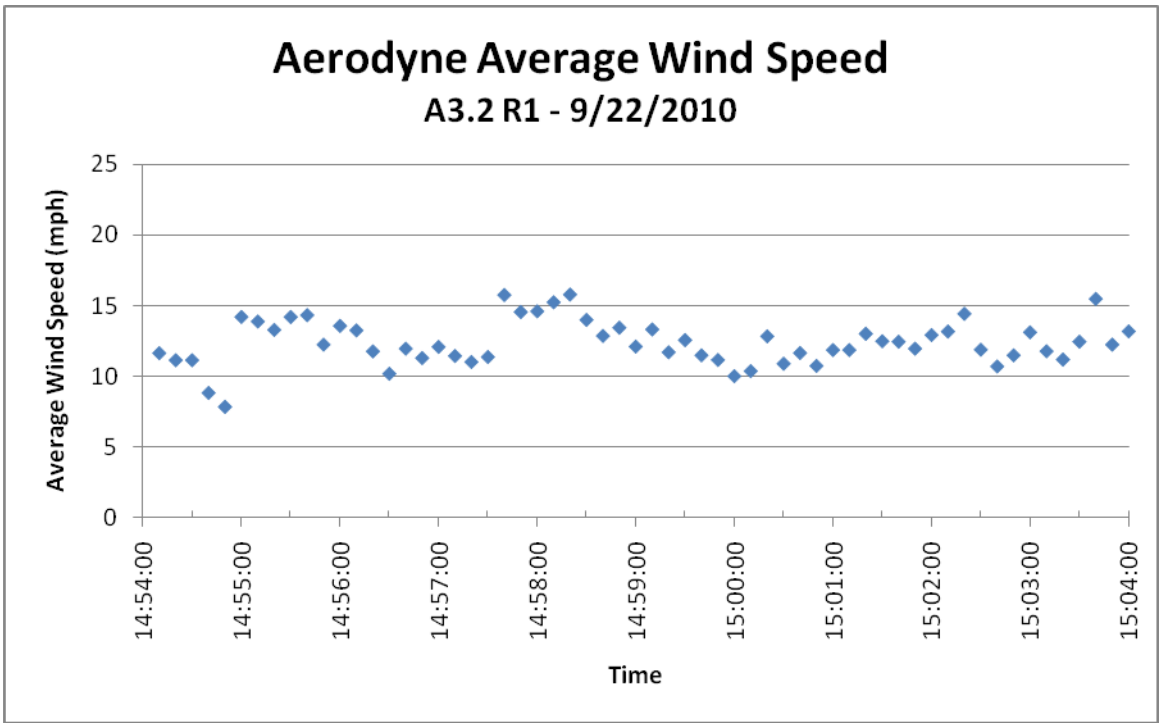


Figure J-57a. Wind Speed vs Time for Air Flare Test A3.2 R1

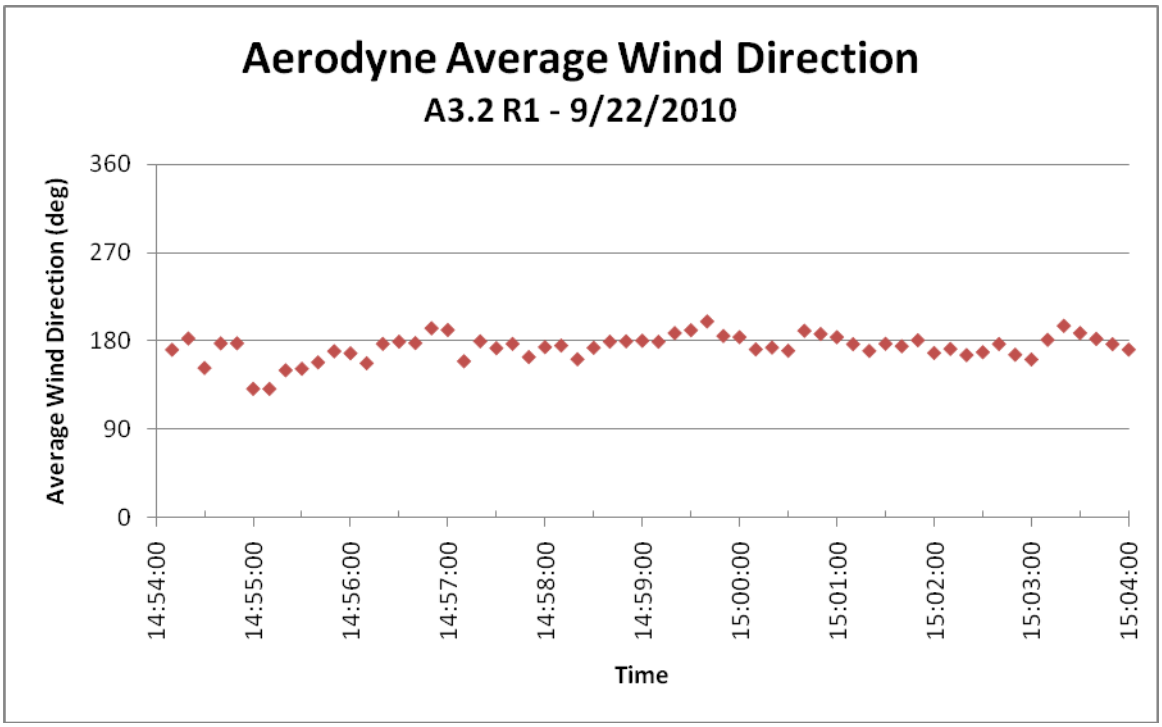


Figure J-57b. Wind Direction vs Time for Air Flare Test A3.2 R1

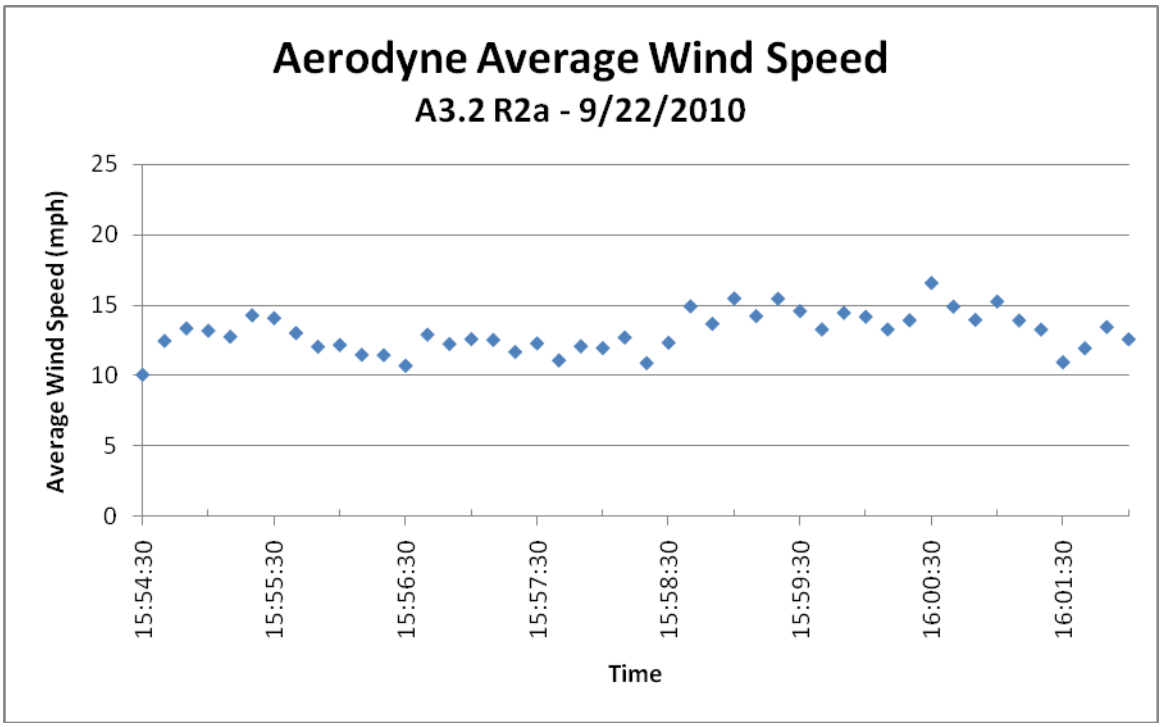


Figure J-58a. Wind Speed vs Time for Air Flare Test A3.2 R2a

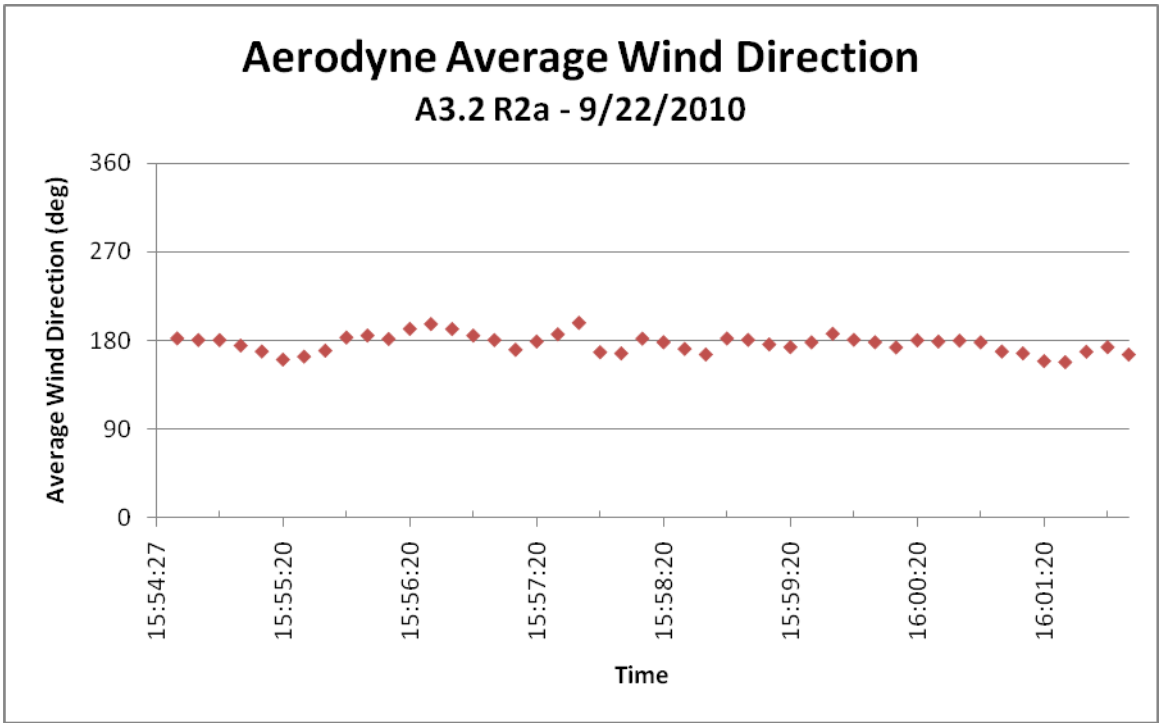


Figure J-58b. Wind Direction vs Time for Air Flare Test A3.2 R2a

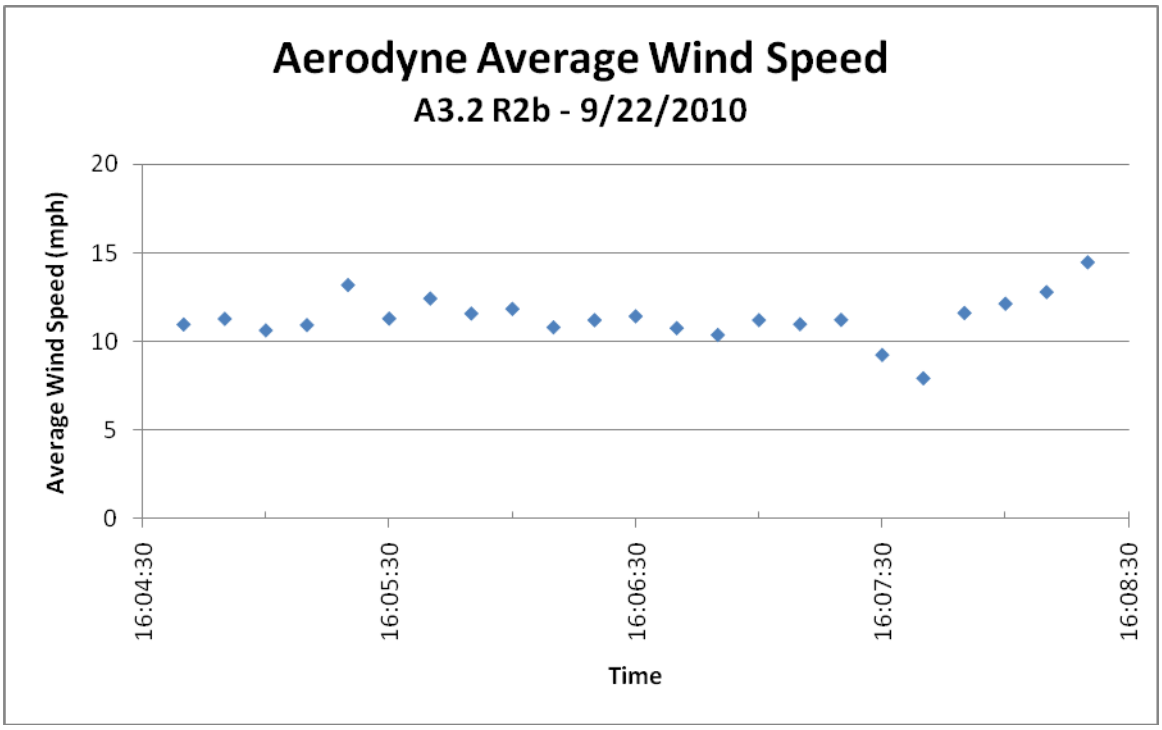


Figure J-59a. Wind Speed vs Time for Air Flare Test A3.2 R2b

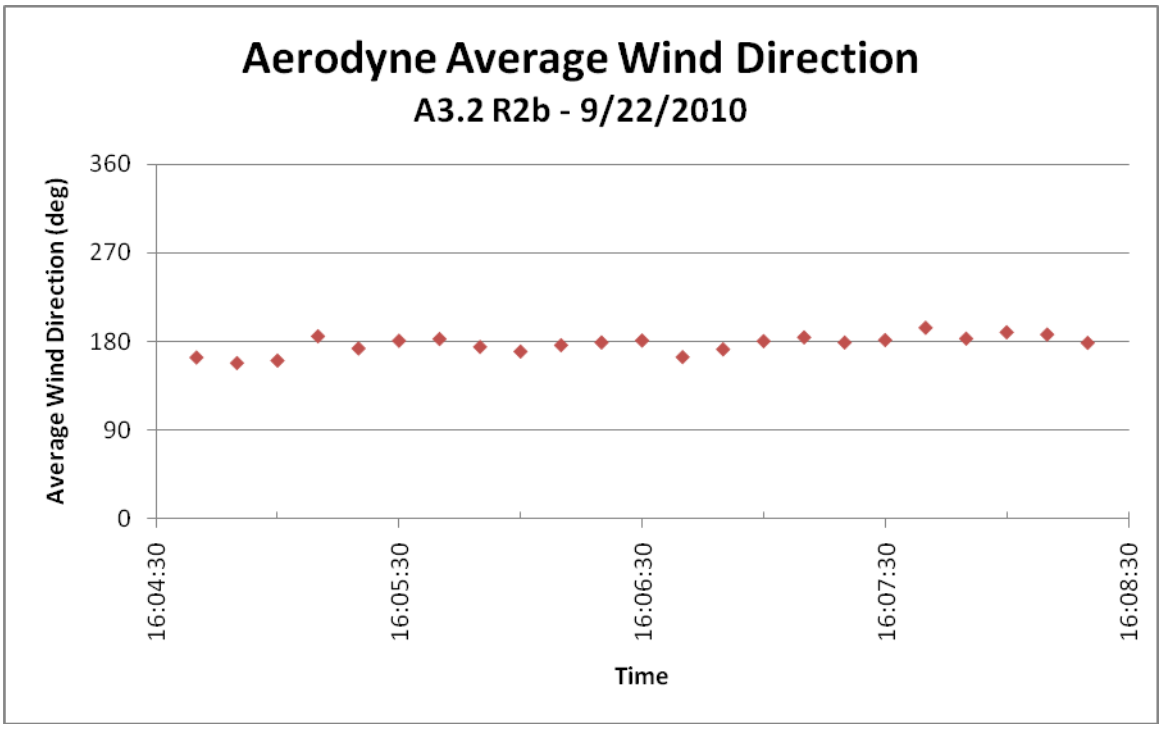


Figure J-59b. Wind Direction vs Time for Air Flare Test A3.2 R2b

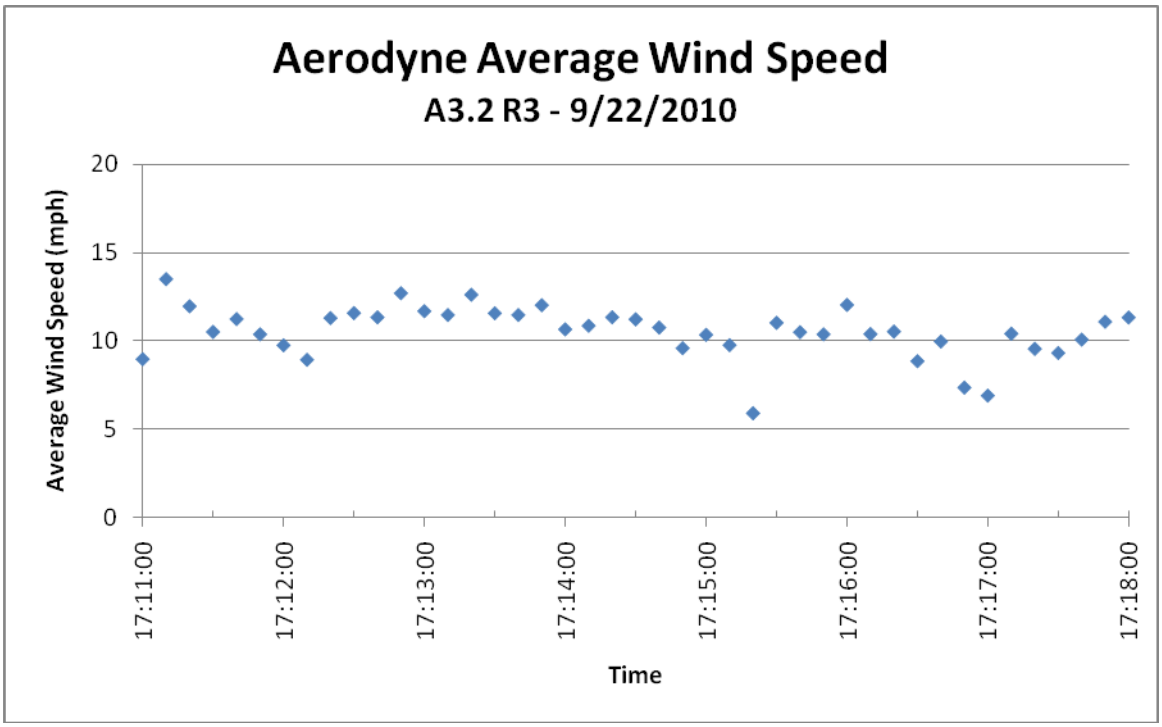


Figure J-60a. Wind Speed vs Time for Air Flare Test A3.2 R3

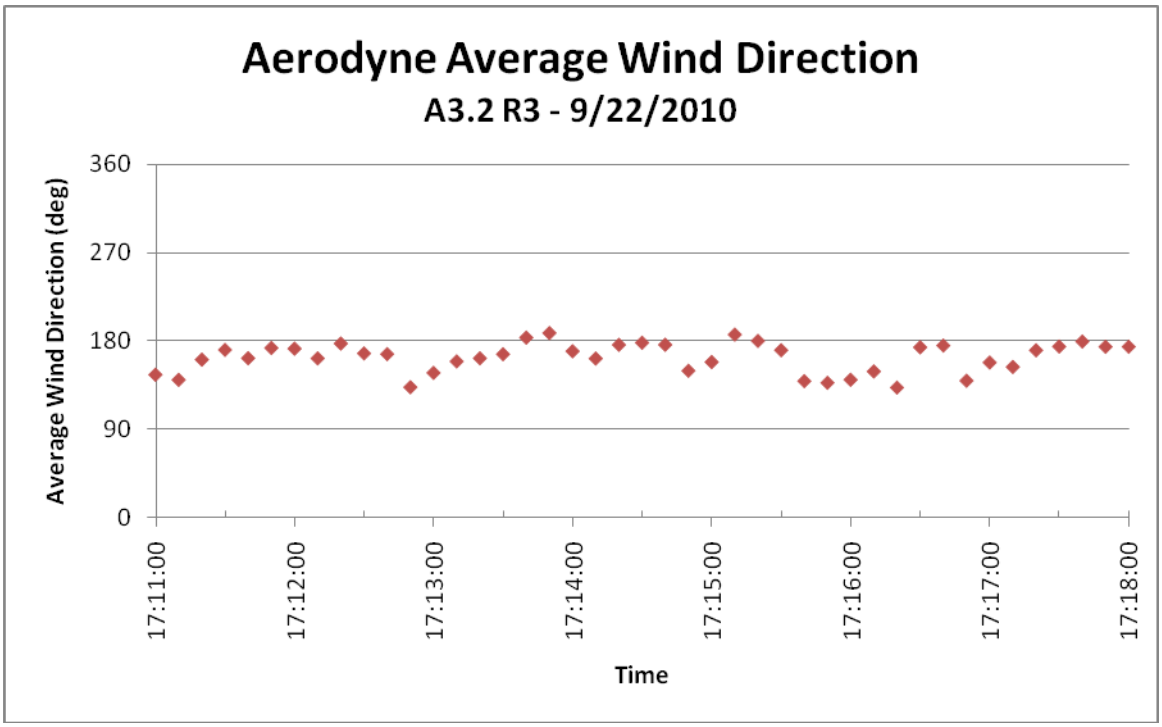


Figure J-60b. Wind Direction vs Time for Air Flare Test A3.2 R3

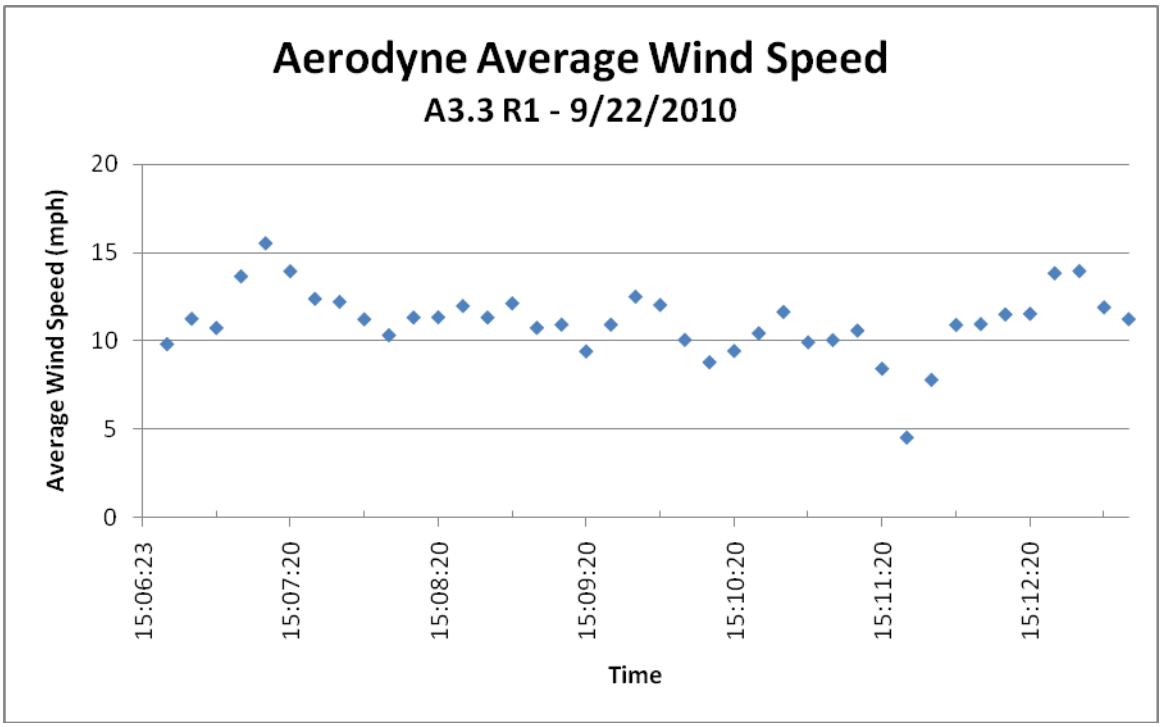


Figure J-61a. Wind Speed vs Time for Air Flare Test A3.3 R1

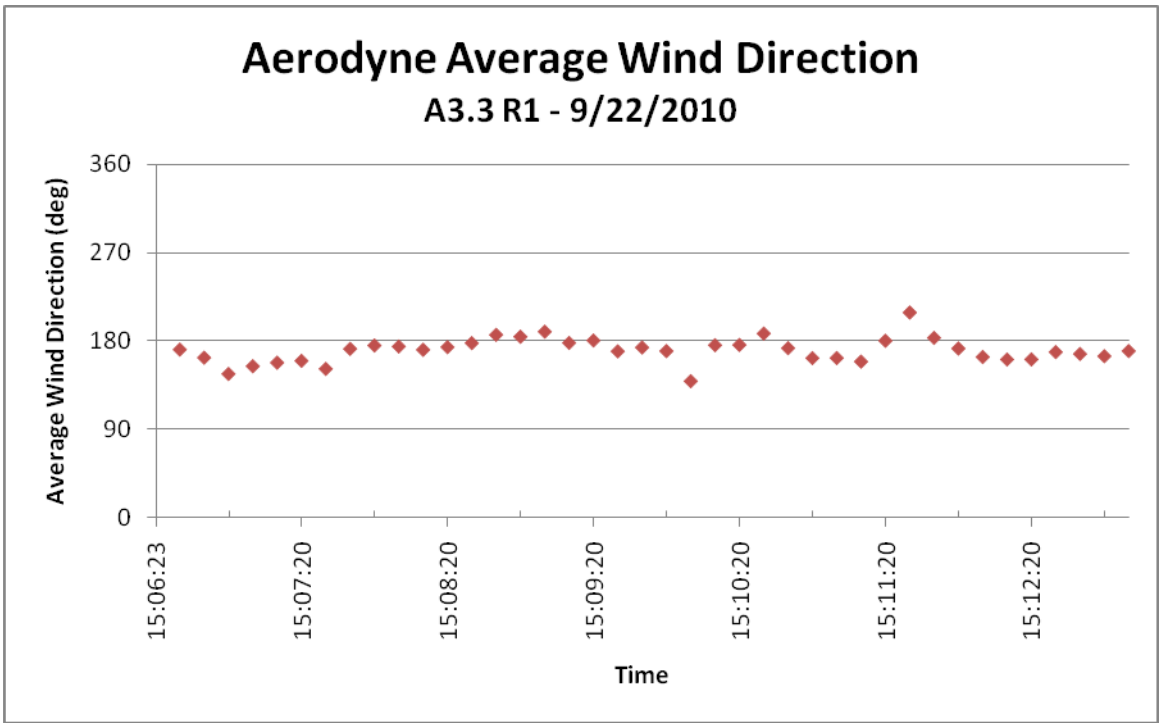


Figure J-61b. Wind Direction vs Time for Air Flare Test A3.3 R1

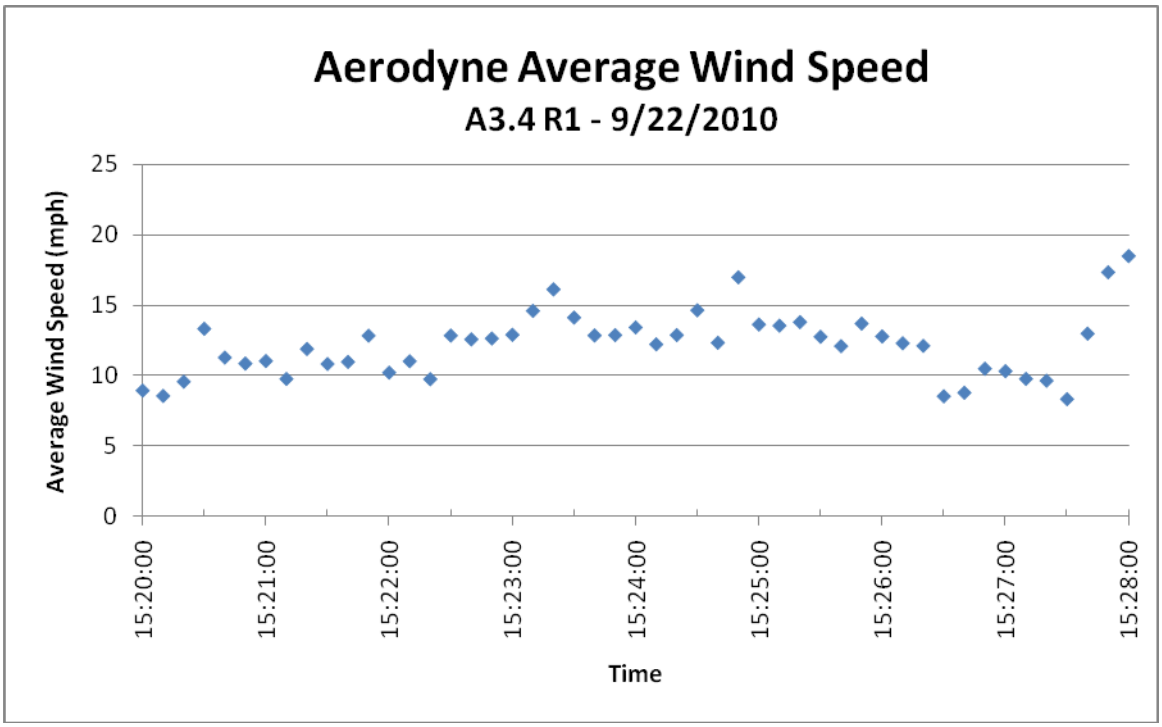


Figure J-62a. Wind Speed vs Time for Air Flare Test A3.4 R1

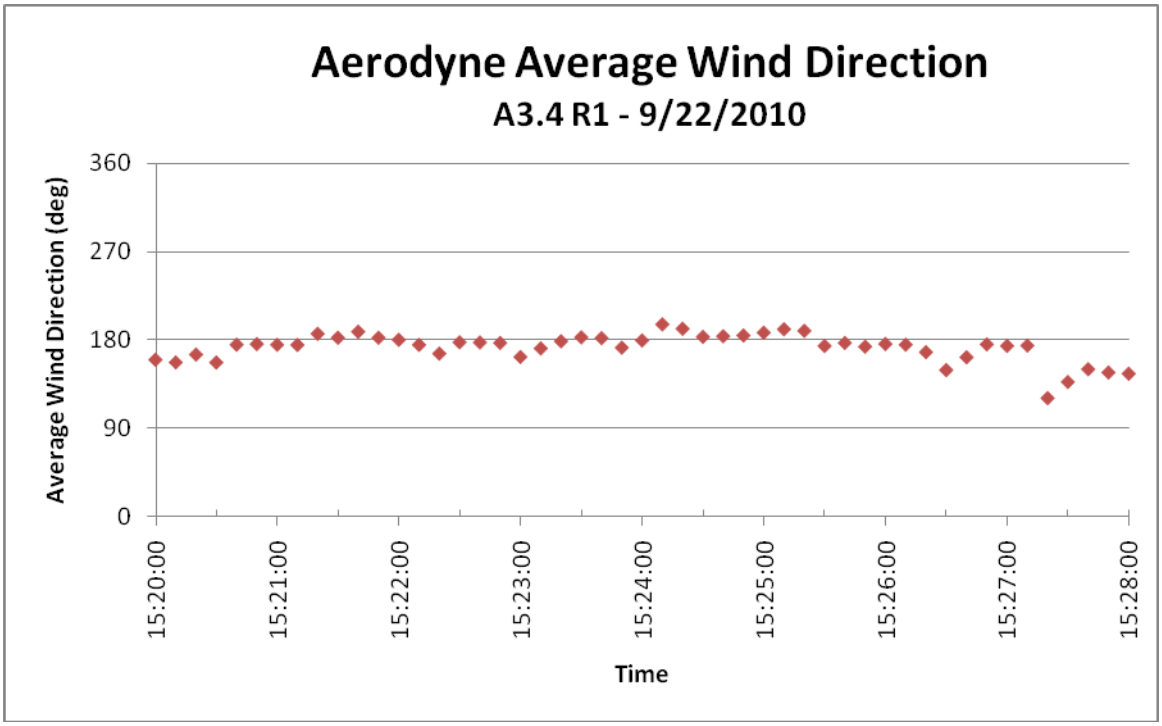


Figure J-62b. Wind Direction vs Time for Air Flare Test A3.4 R1

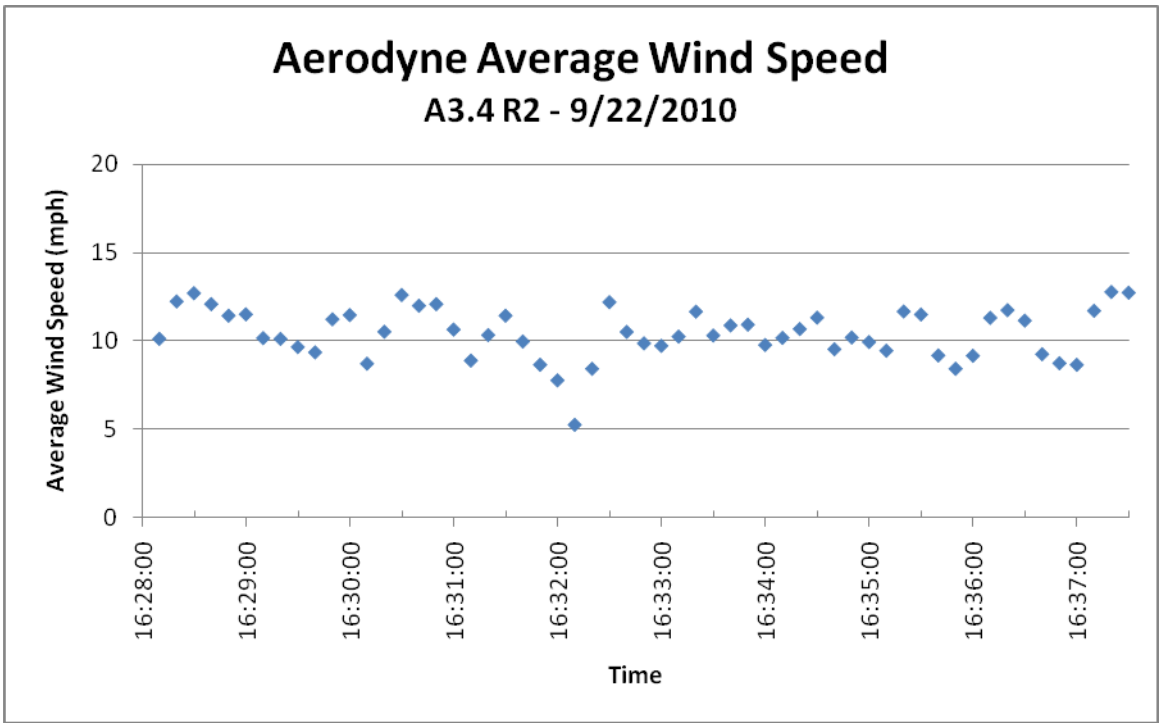


Figure J-63a. Wind Speed vs Time for Air Flare Test A3.4 R2

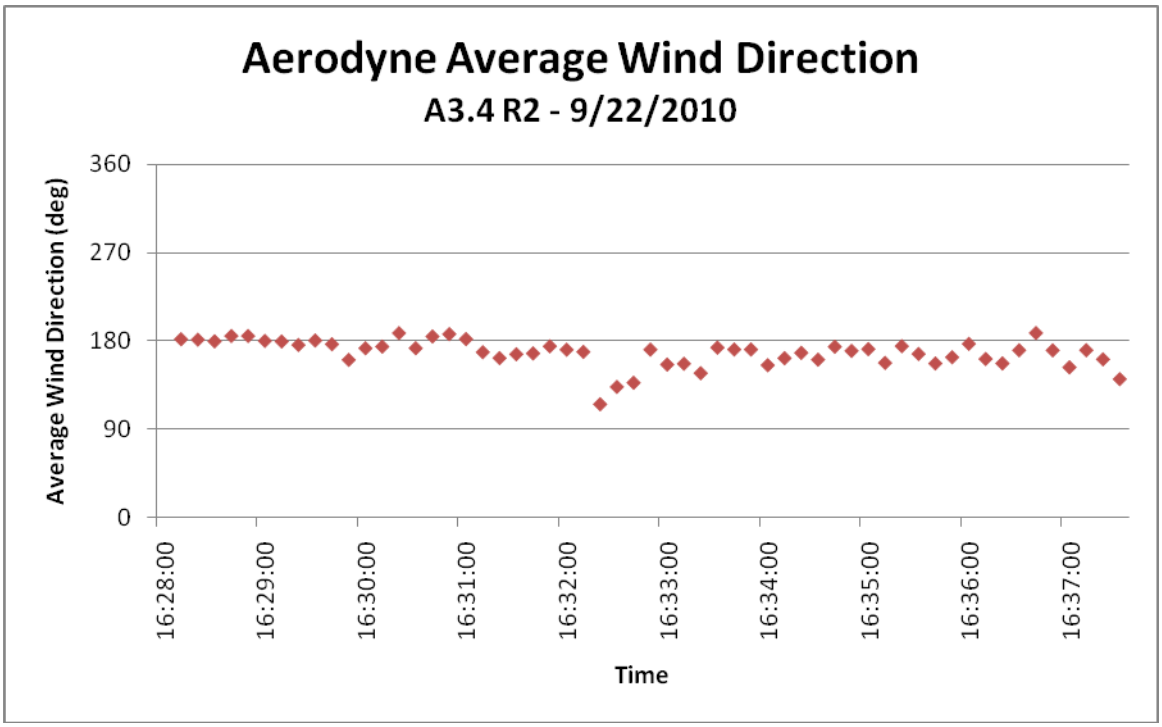


Figure J-63b. Wind Direction vs Time for Air Flare Test A3.4 R2

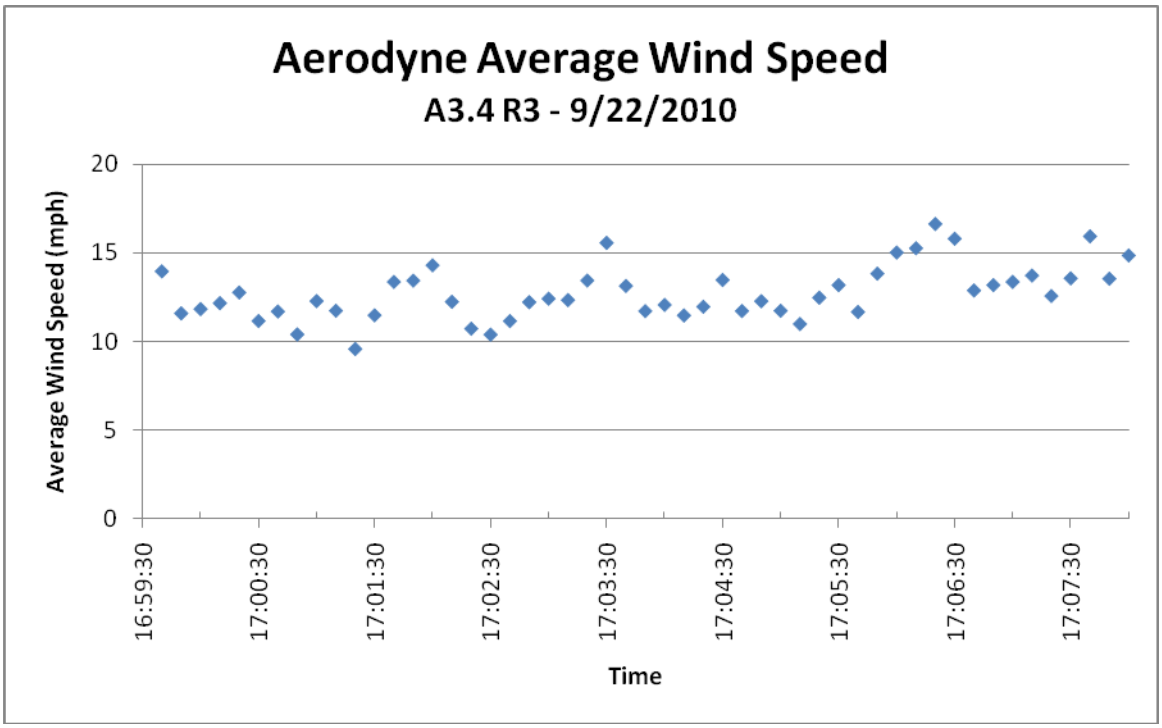


Figure J-64a. Wind Speed vs Time for Air Flare Test A3.4 R3

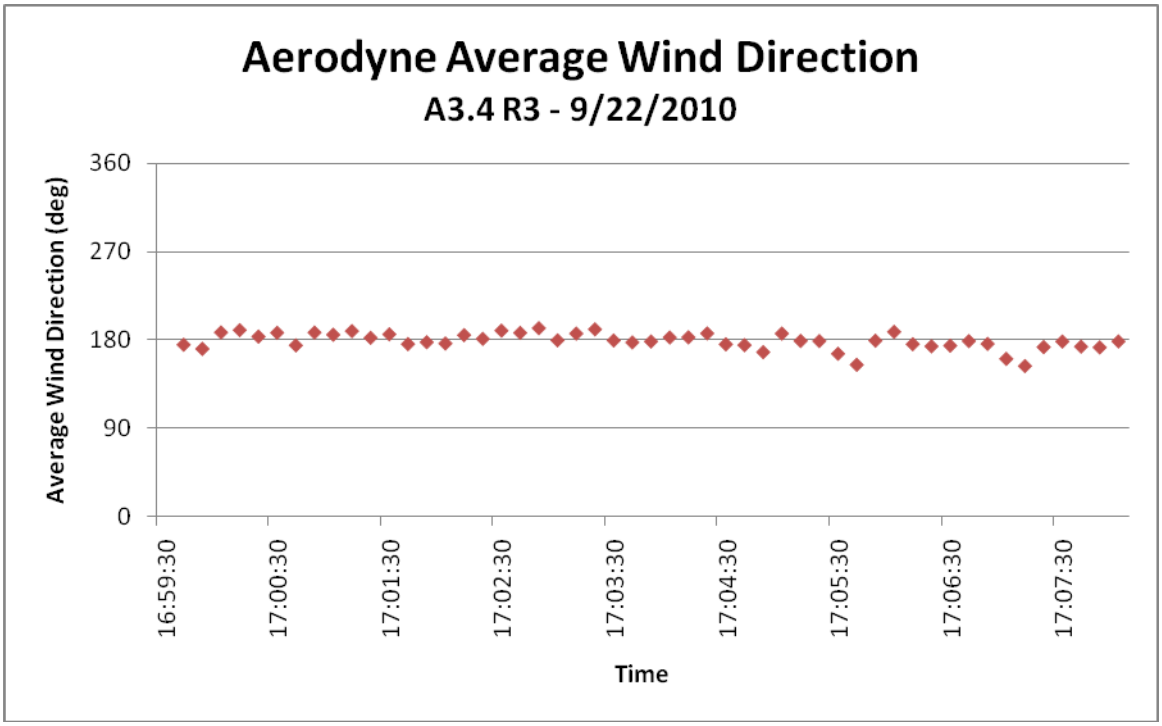


Figure J-64b. Wind Direction vs Time for Air Flare Test A3.4 R3

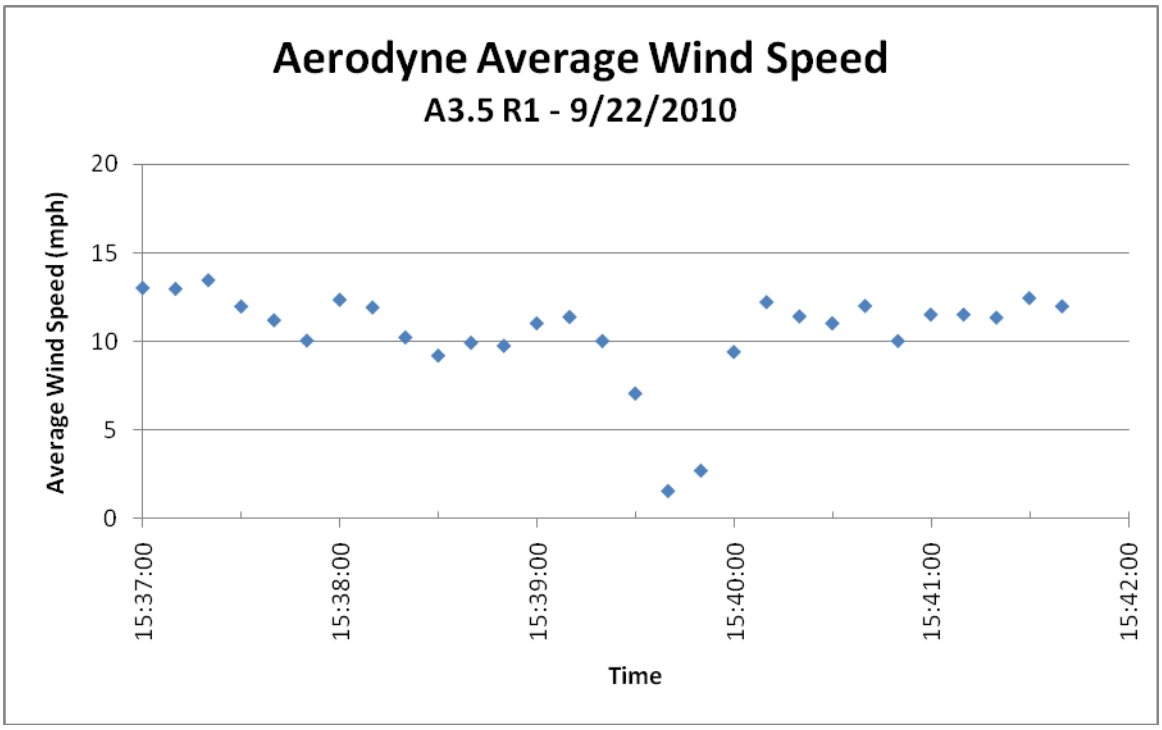


Figure J-65a. Wind Speed vs Time for Air Flare Test A3.5 R1

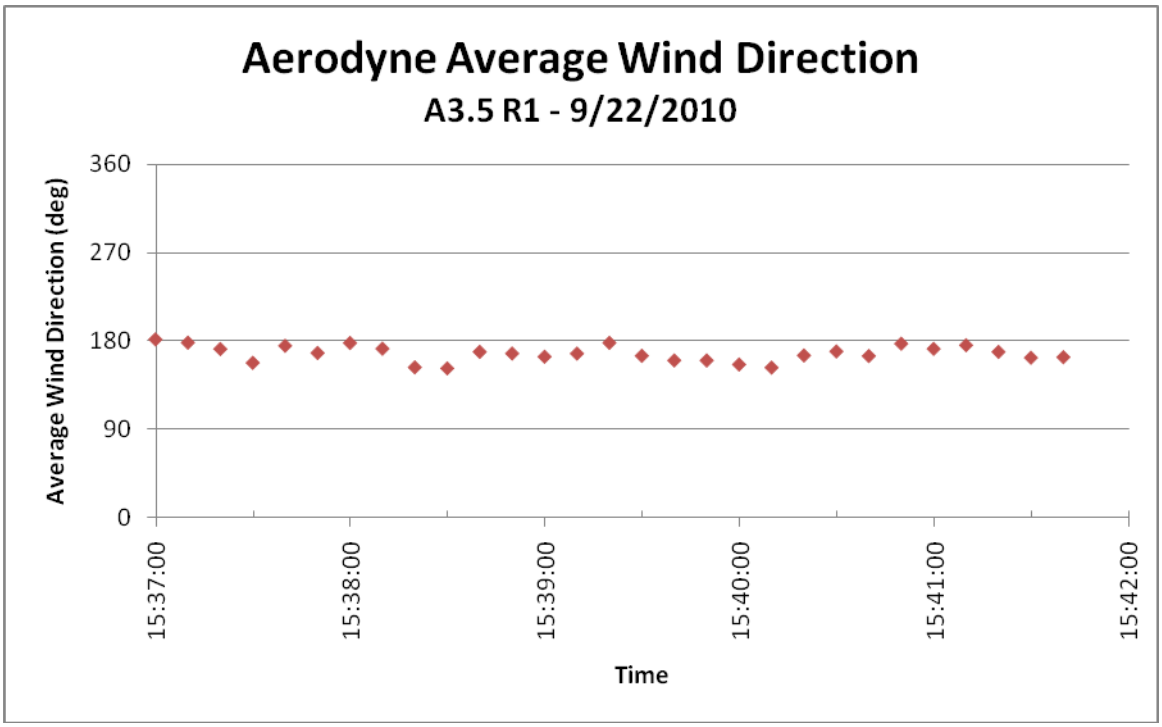


Figure J-65b. Wind Direction vs Time for Air Flare Test A3.5 R1

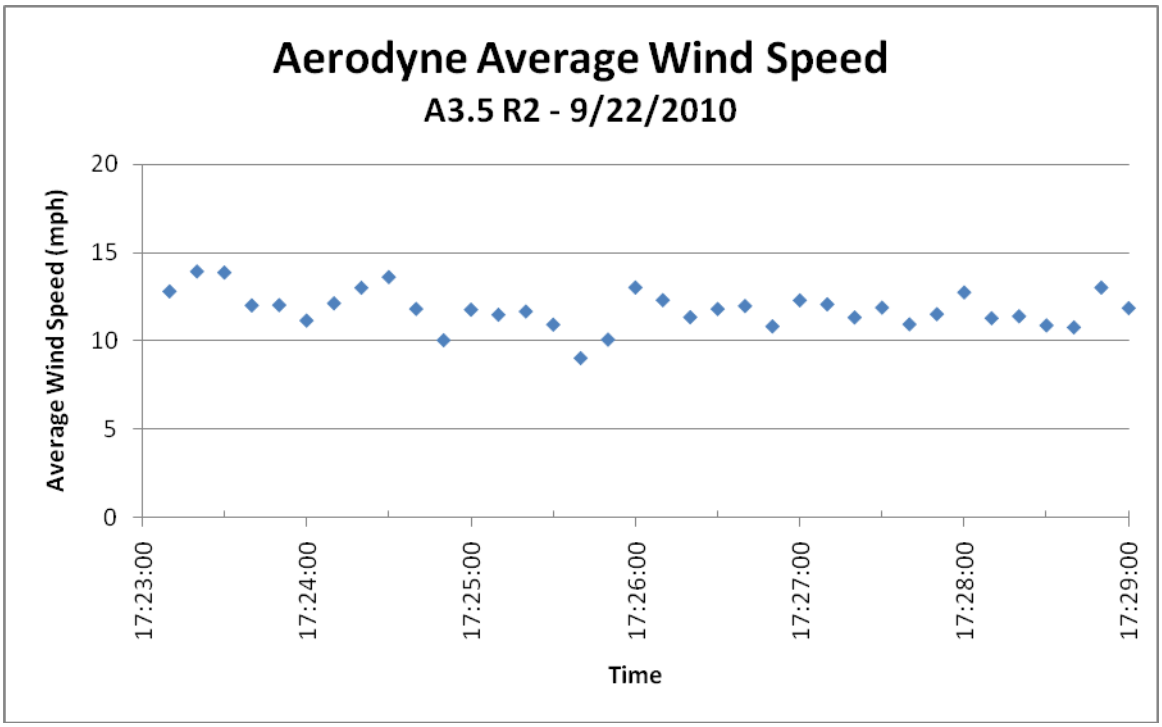


Figure J-66a. Wind Speed vs Time for Air Flare Test A3.5 R2

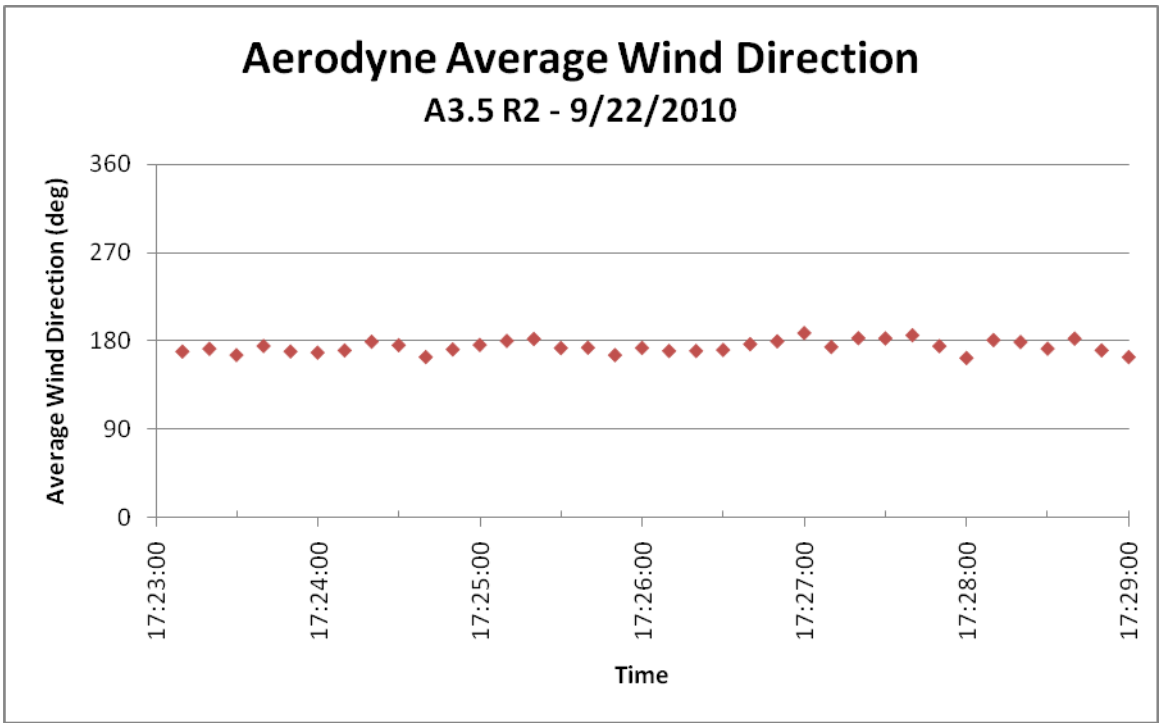


Figure J-66b. Wind Direction vs Time for Air Flare Test A3.5 R2

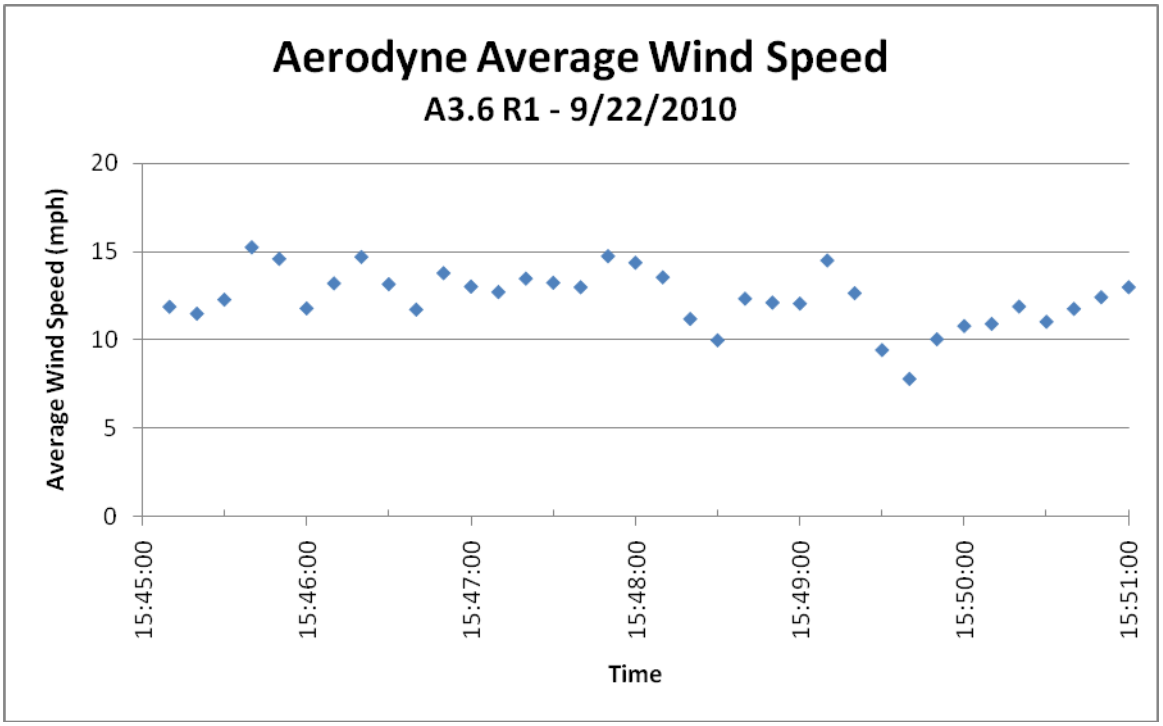


Figure J-67a. Wind Speed vs Time for Air Flare Test A3.6 R1

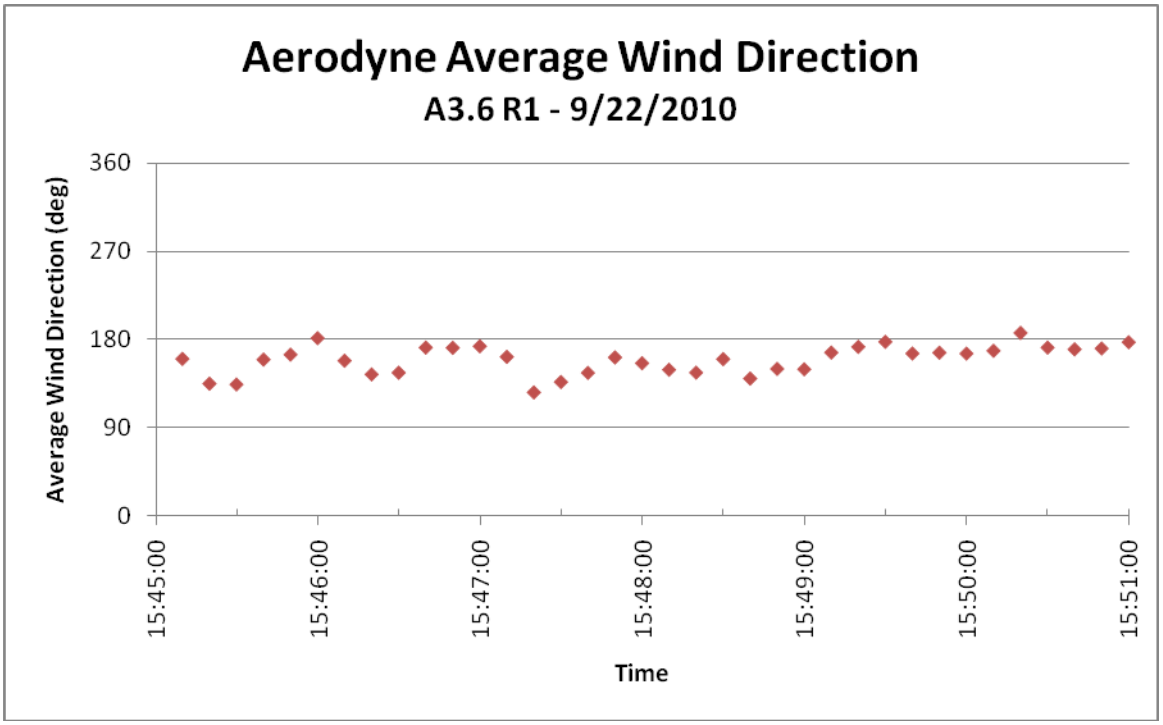


Figure J-67b. Wind Direction vs Time for Air Flare Test A3.6 R1

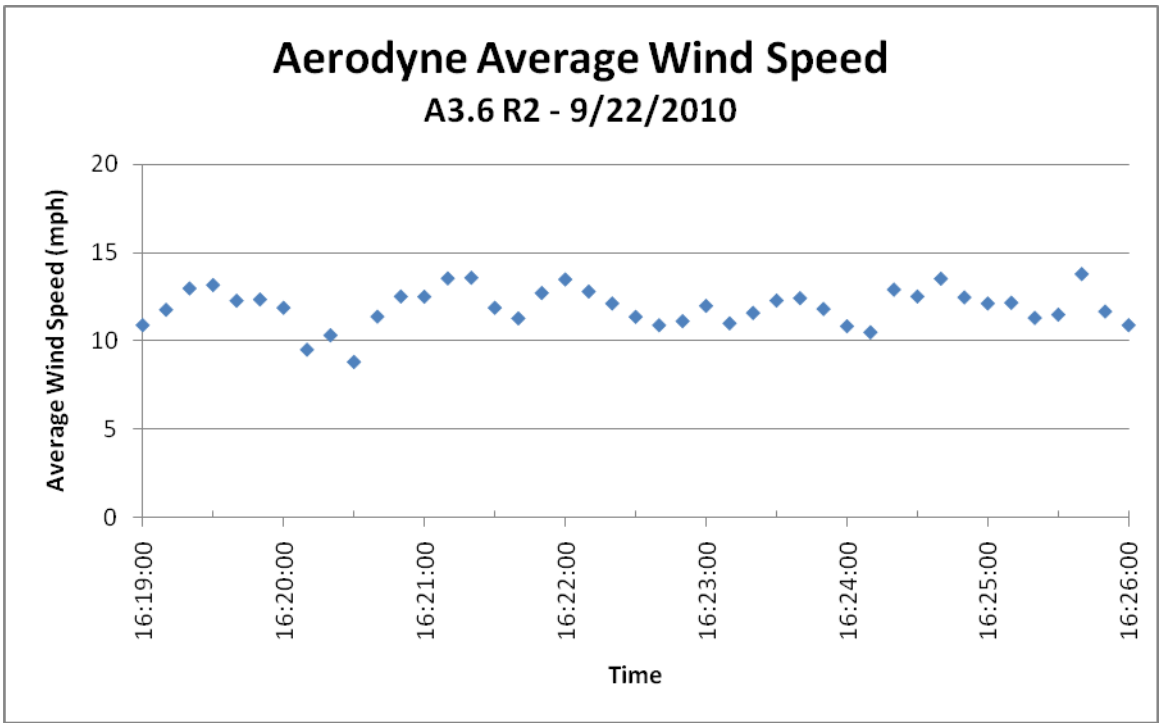


Figure J-68a. Wind Speed vs Time for Air Flare Test A3.6 R2

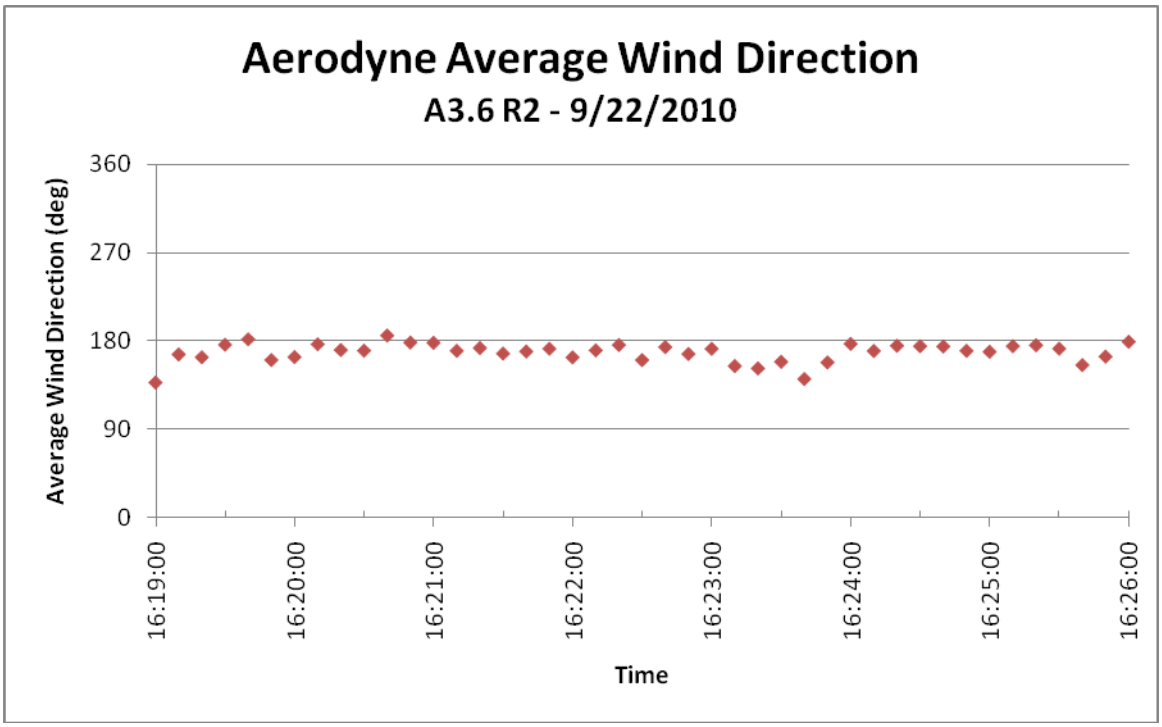


Figure J-68b. Wind Direction vs Time for Air Flare Test A3.6 R2

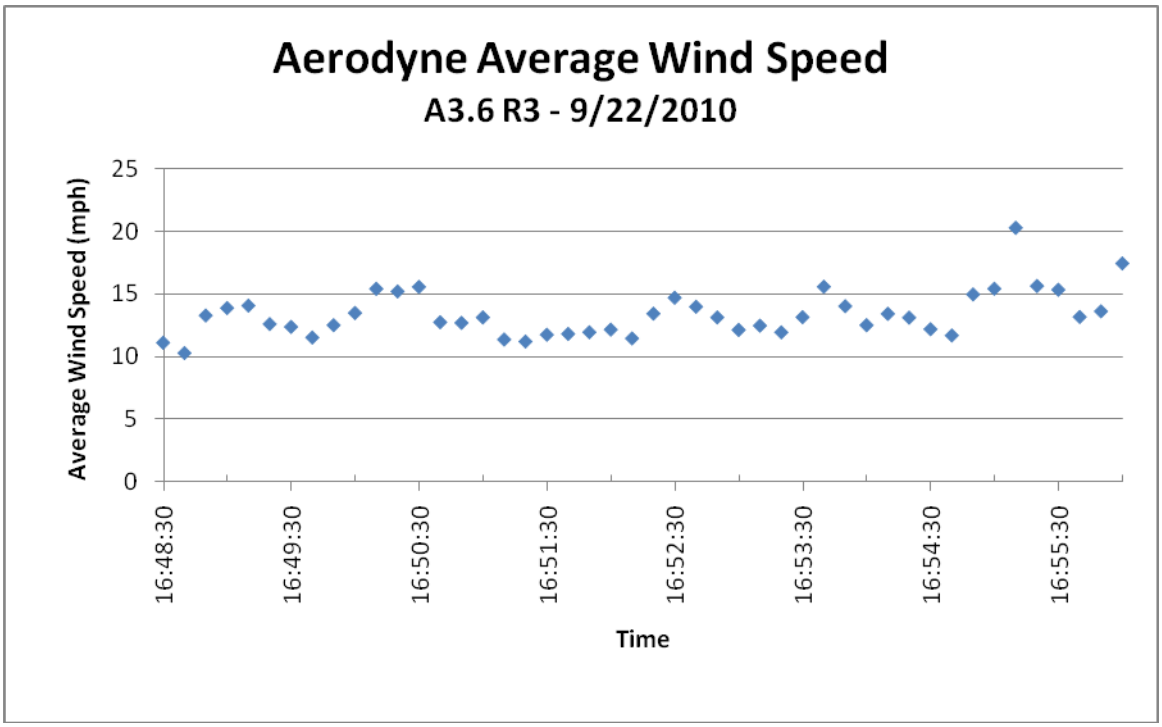


Figure J-69a. Wind Speed vs Time for Air Flare Test A3.6 R3

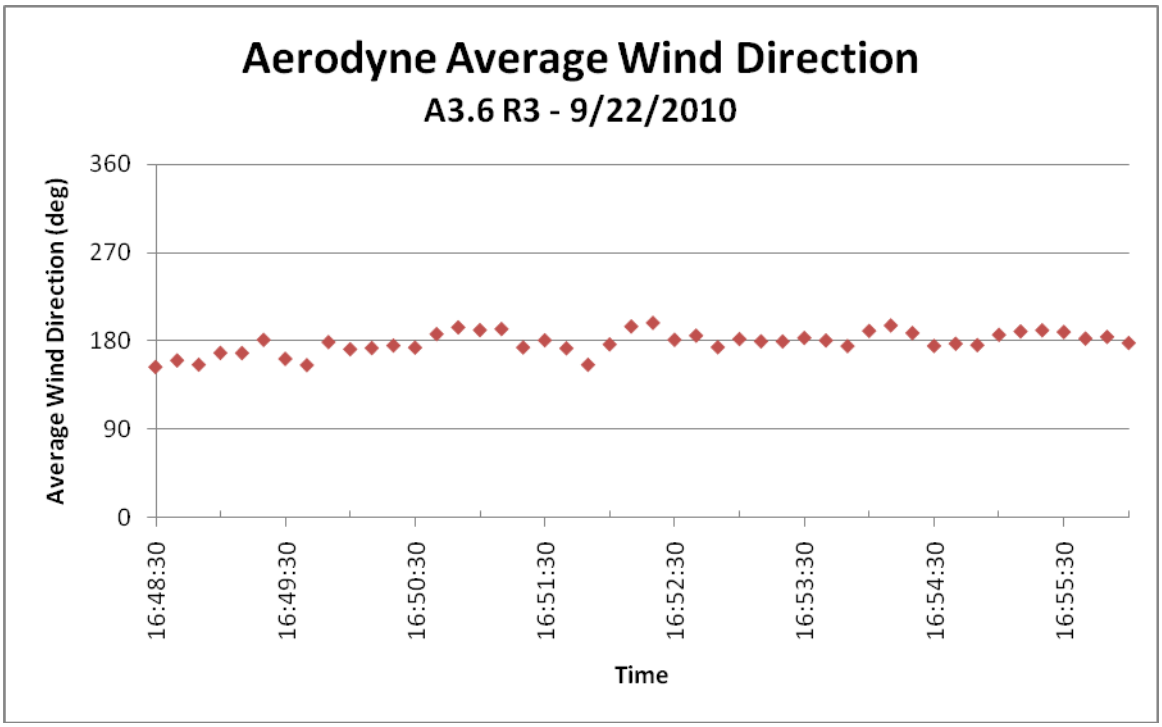


Figure J-69b. Wind Direction vs Time for Air Flare Test A3.6 R3

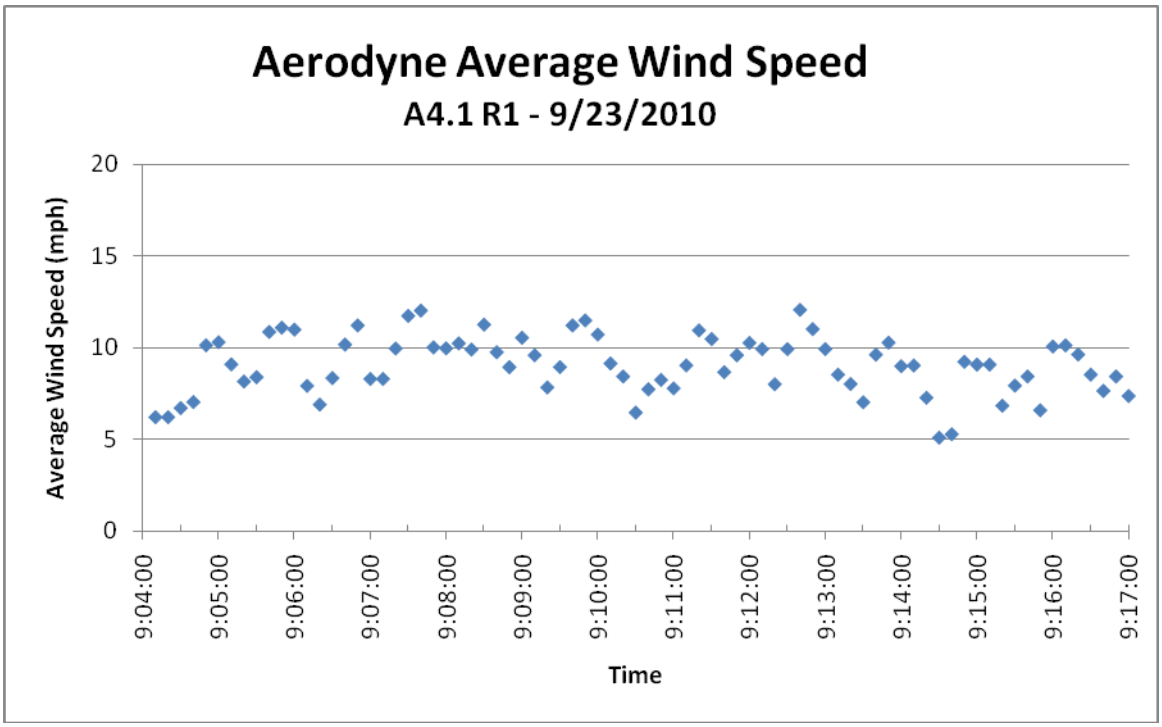


Figure J-70a. Wind Speed vs Time for Air Flare Test A4.1 R1

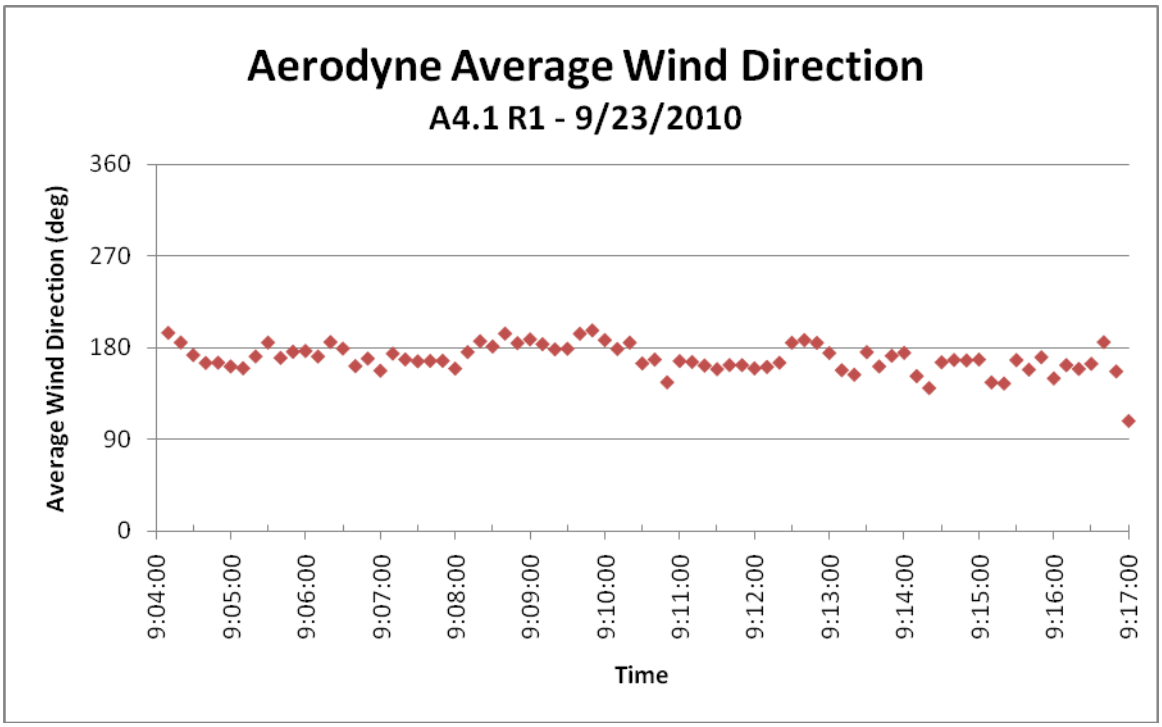


Figure J-70b. Wind Direction vs Time for Air Flare Test A4.1 R1

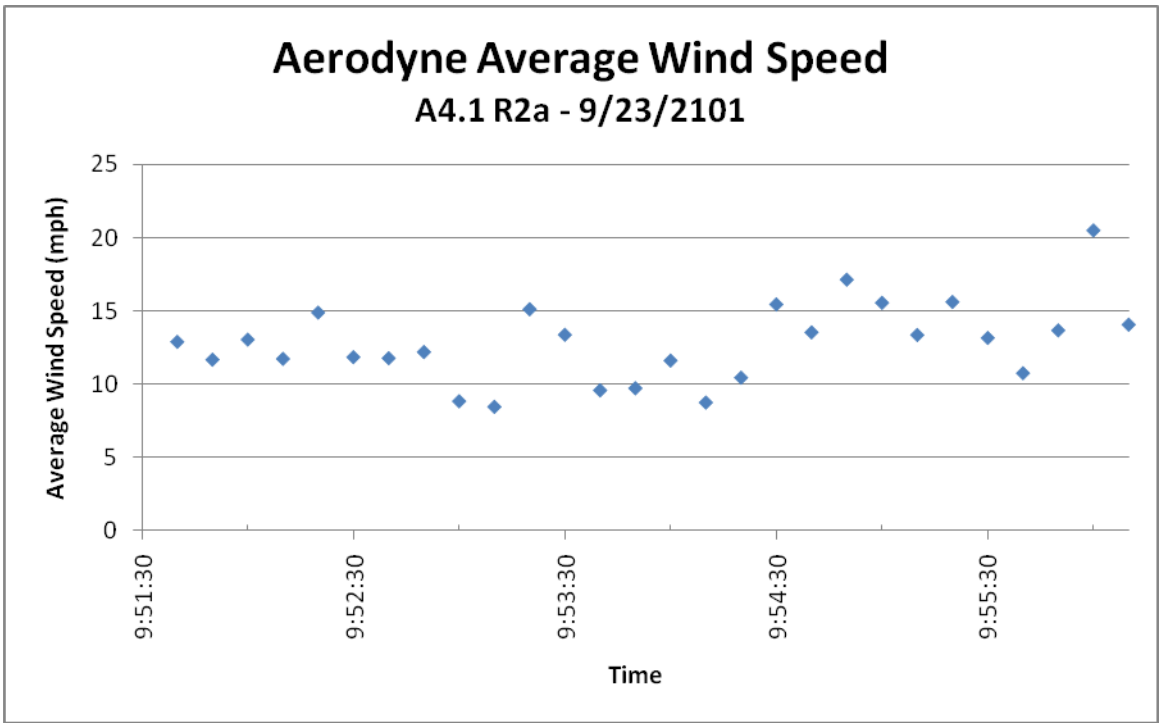


Figure J-71a. Wind Speed vs Time for Air Flare Test A4.1 2a

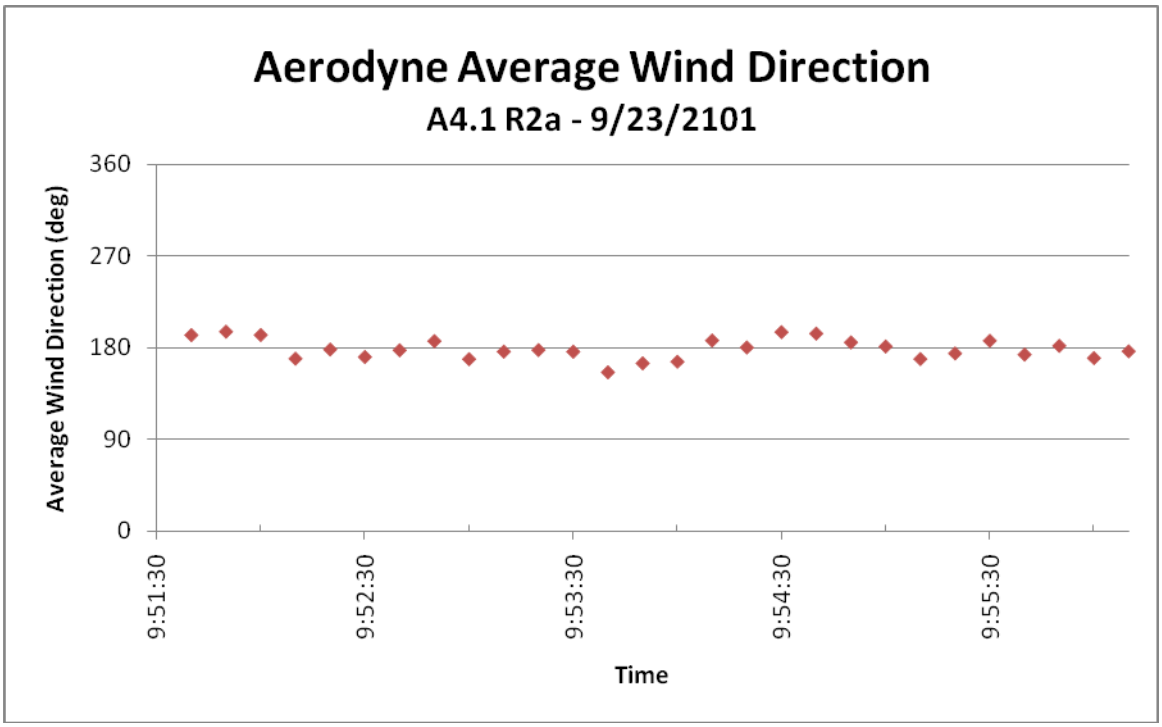


Figure J-71b. Wind Direction vs Time for Air Flare Test A4.1 2a

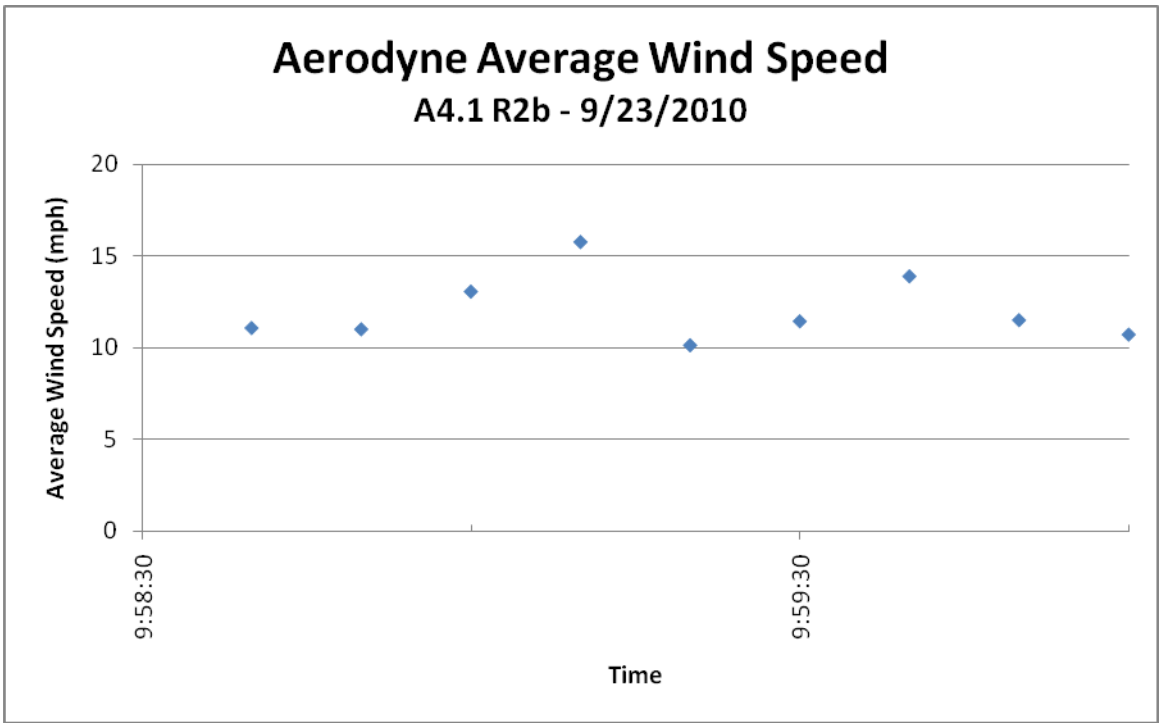


Figure J-72a. Wind Speed vs Time for Air Flare Test A4.1 R2b

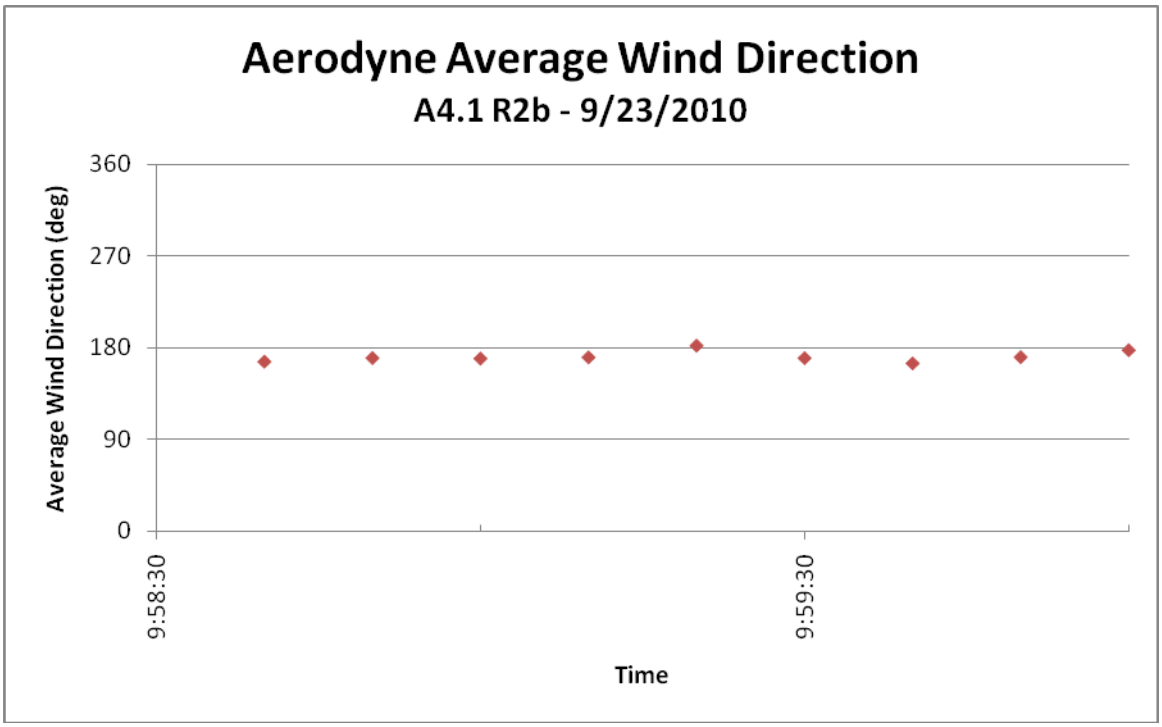


Figure J-72b. Wind Direction vs Time for Air Flare Test A4.1 R2b

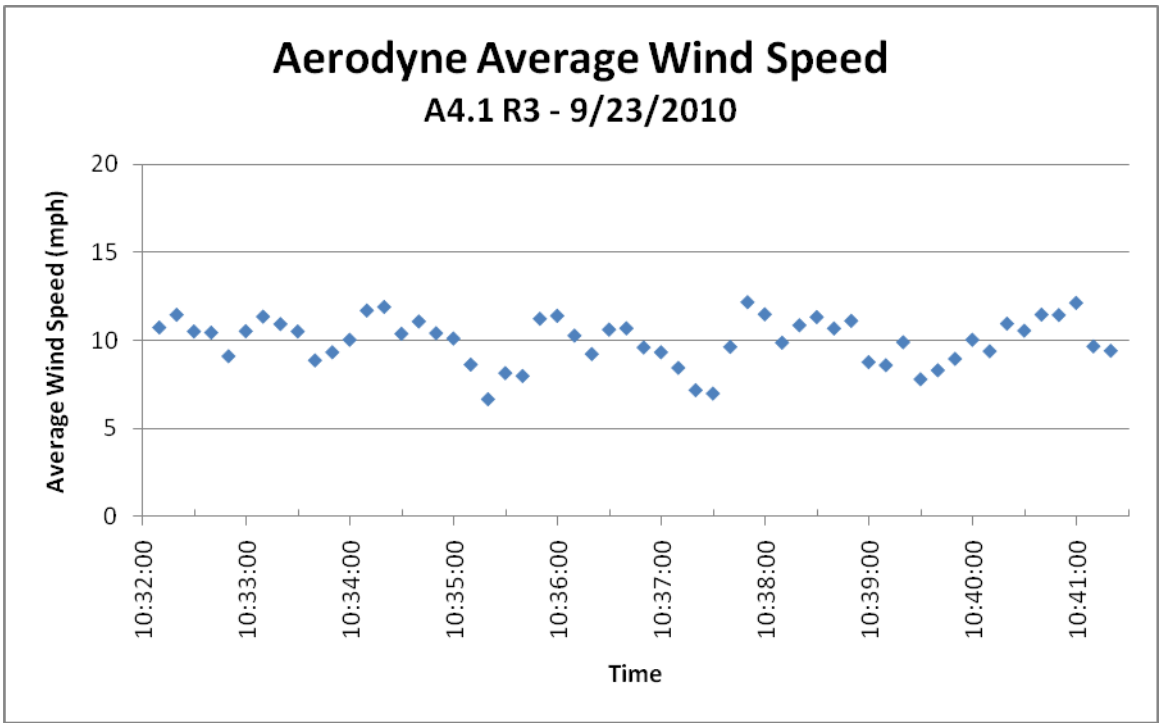


Figure J-73a. Wind Speed vs Time for Air Flare Test A4.1 R3

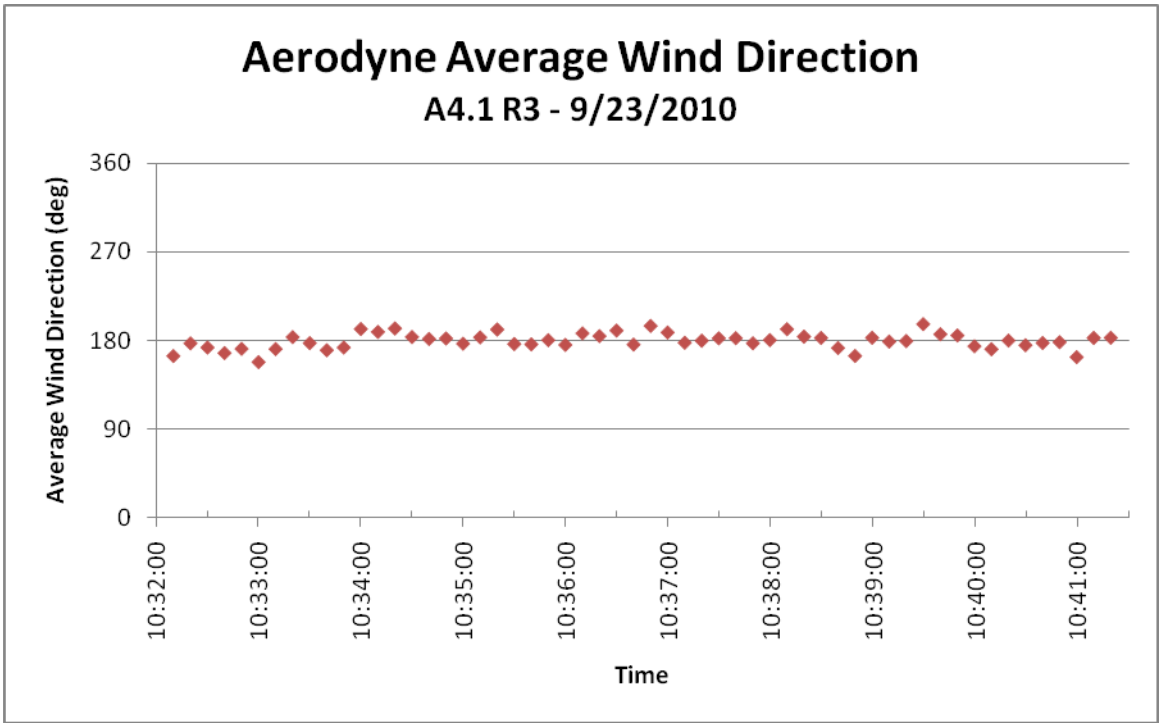


Figure J-73b. Wind Direction vs Time for Air Flare Test A4.1 R3

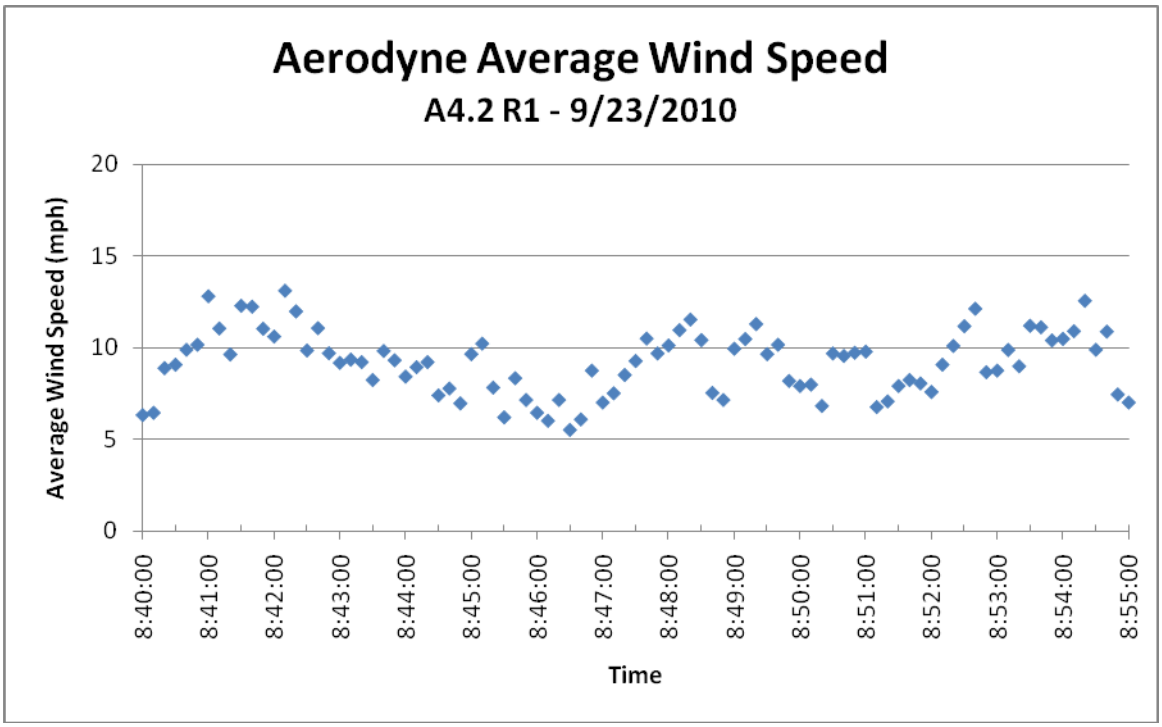


Figure J-74a. Wind Speed vs Time for Air Flare Test A4.2 R1

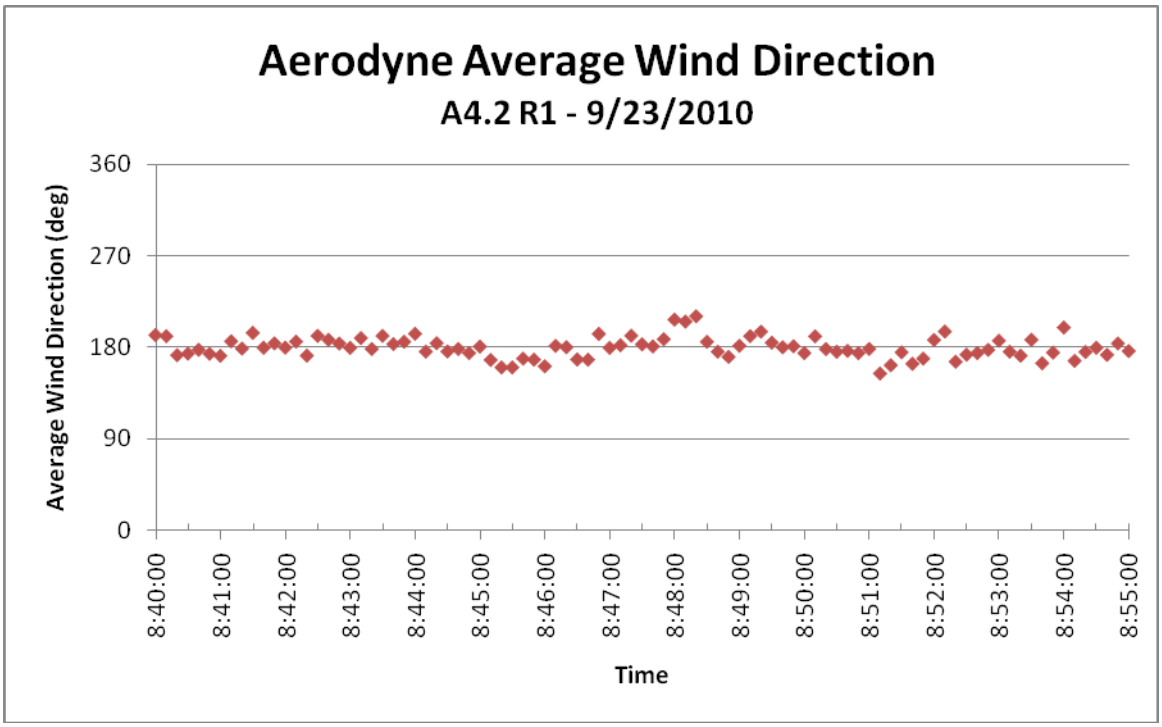


Figure J-74b. Wind Direction vs Time for Air Flare Test A4.2 R1

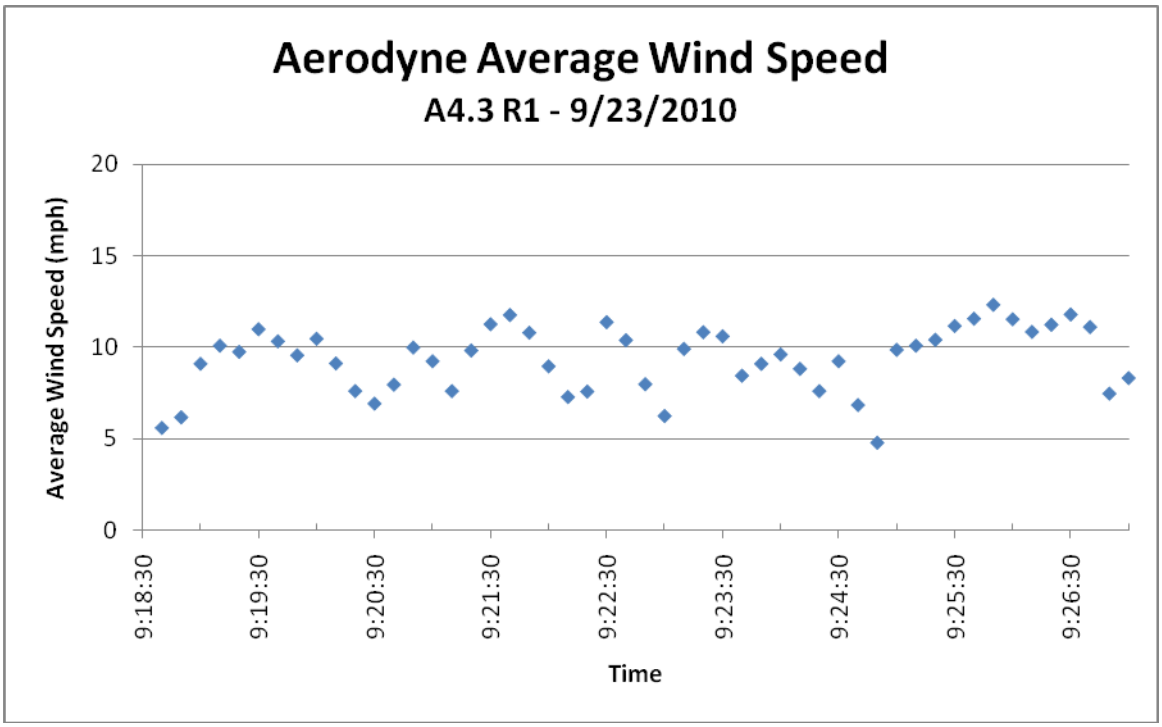


Figure J-75a. Wind Speed vs Time for Air Flare Test A4.3 R1

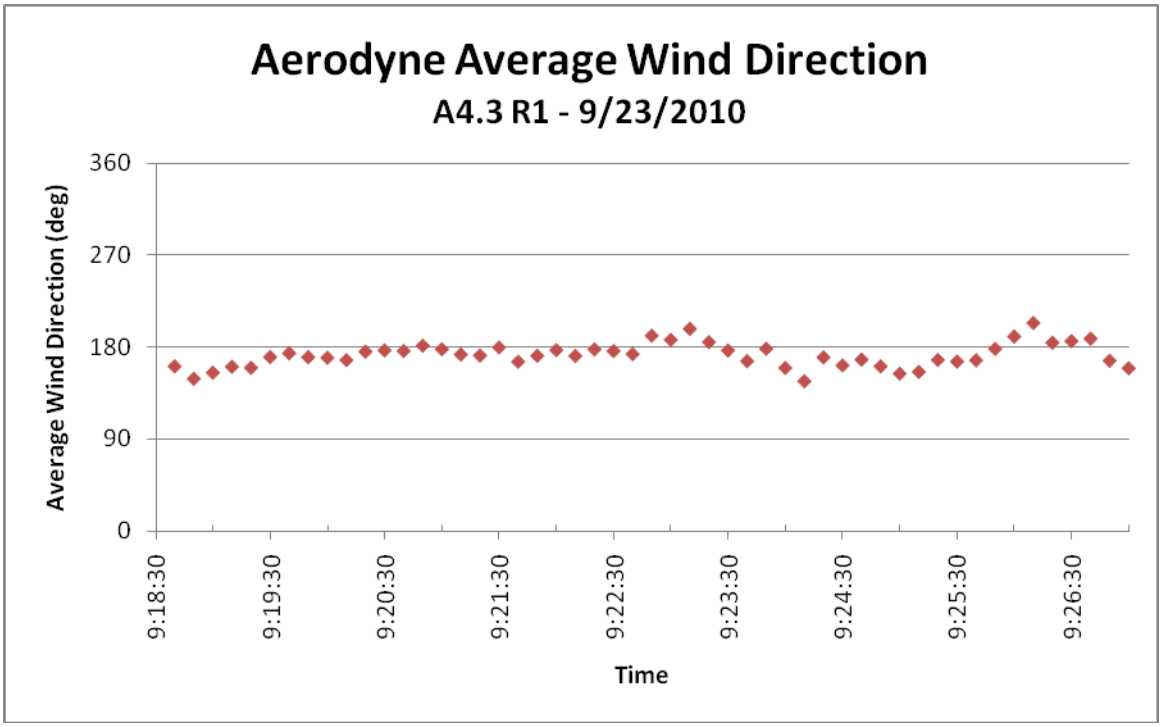


Figure J-75b. Wind Direction vs Time for Air Flare Test A4.3 R1

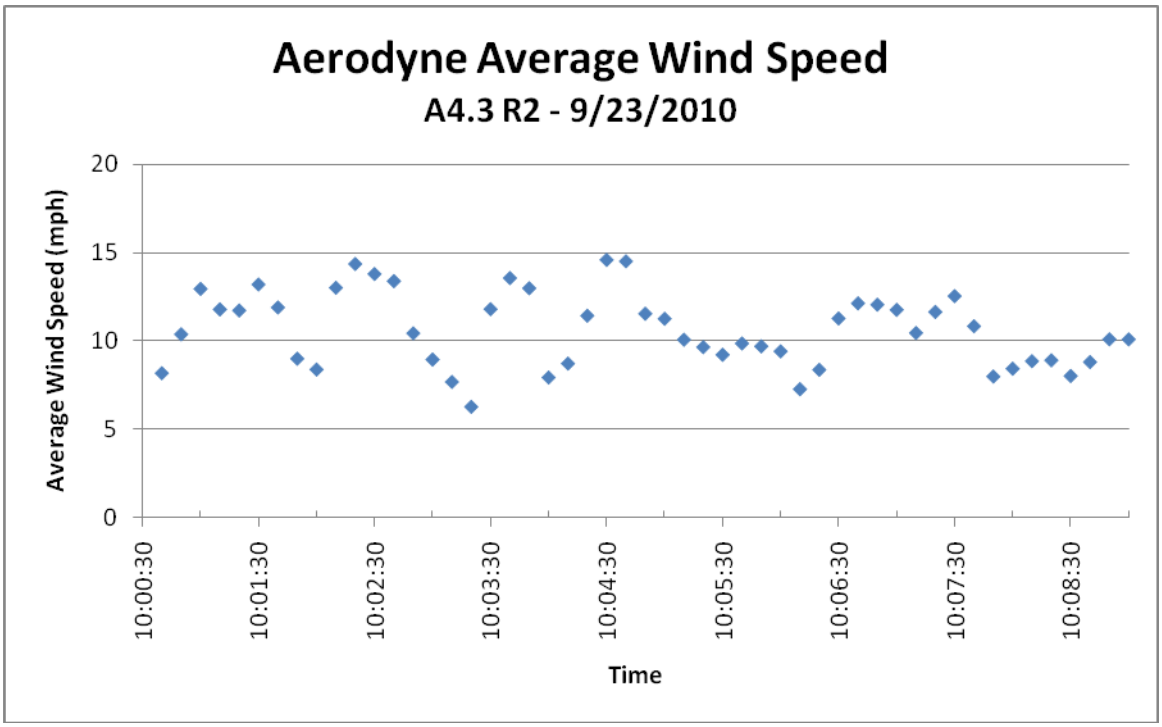


Figure J-76a. Wind Speed vs Time for Air Flare Test A4.3 R2

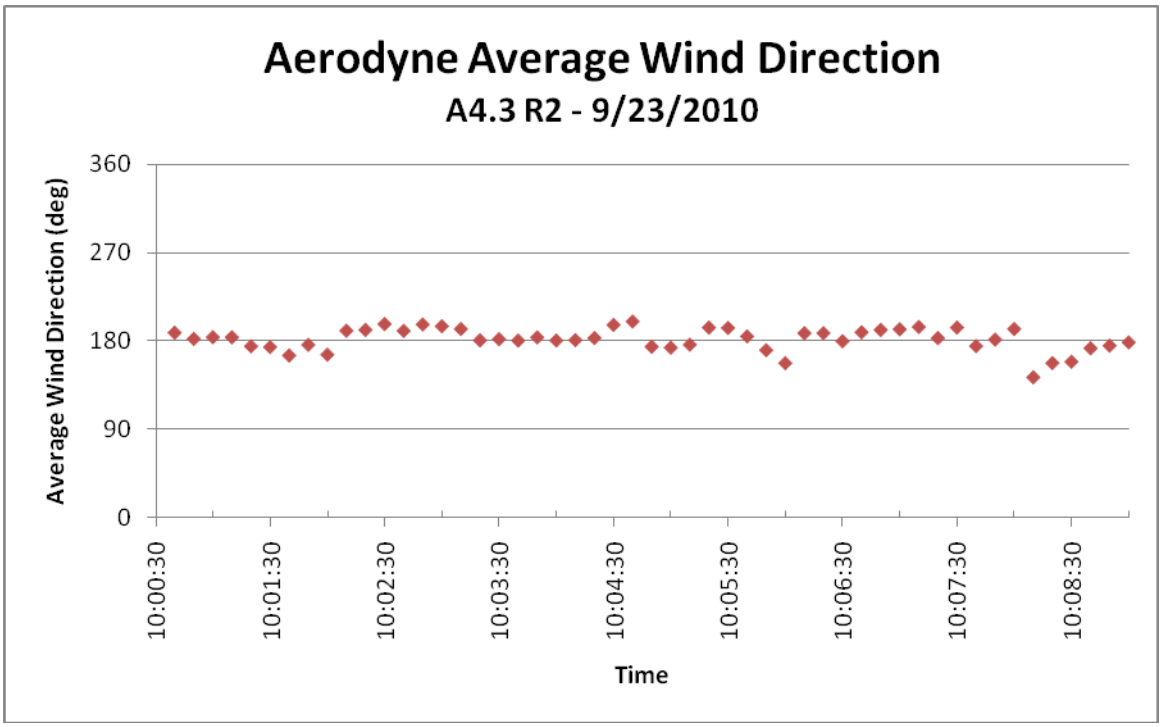


Figure J-76b. Wind Direction vs Time for Air Flare Test A4.3 R2

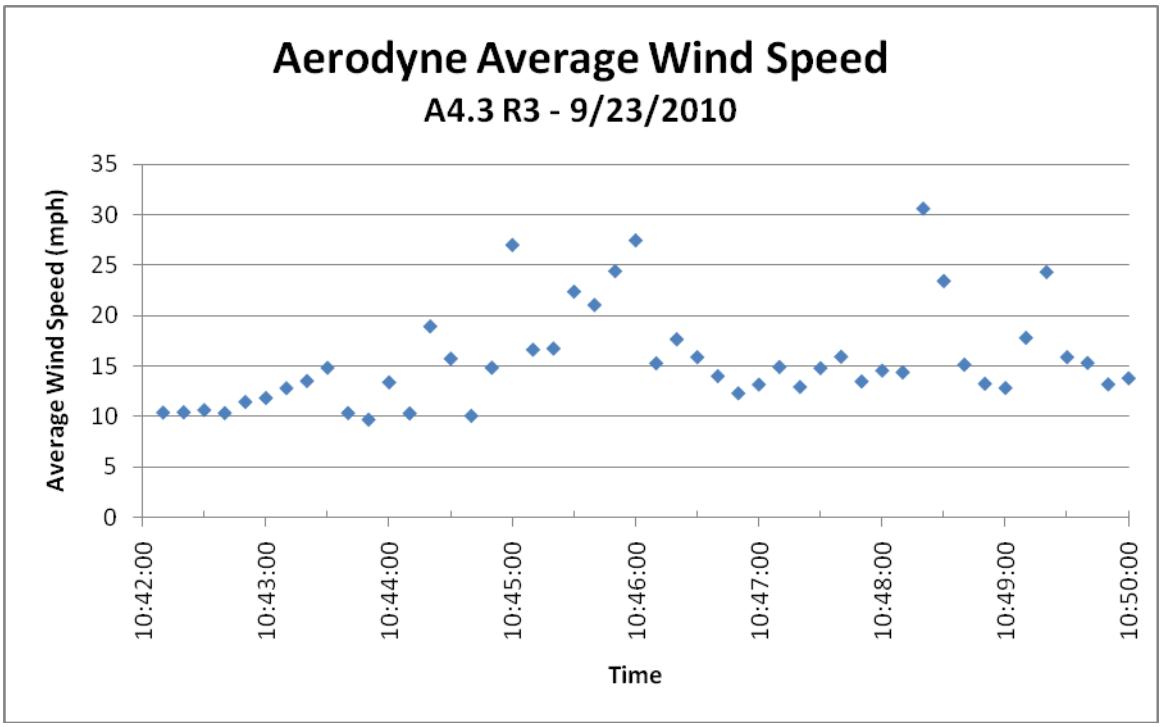


Figure J-77a. Wind Speed vs Time for Air Flare Test A4.3 R3

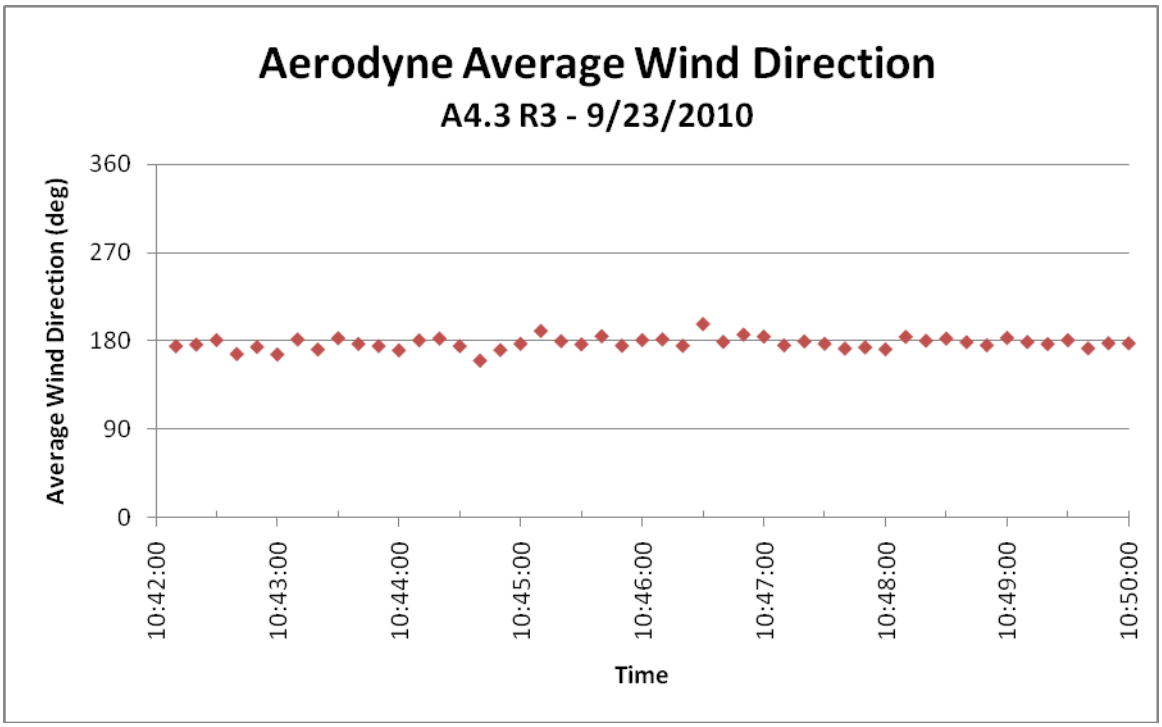


Figure J-77b. Wind Direction vs Time for Air Flare Test A4.3 R3

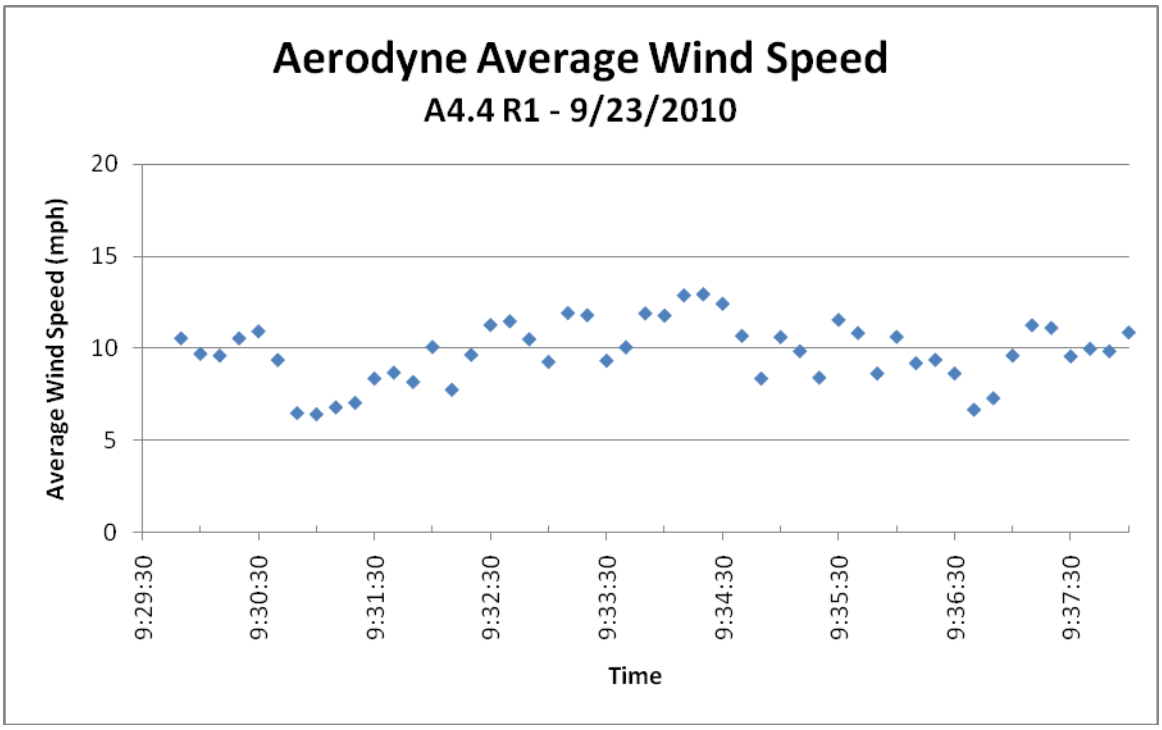


Figure J-78a. Wind Speed vs Time for Air Flare Test A4.4 R1

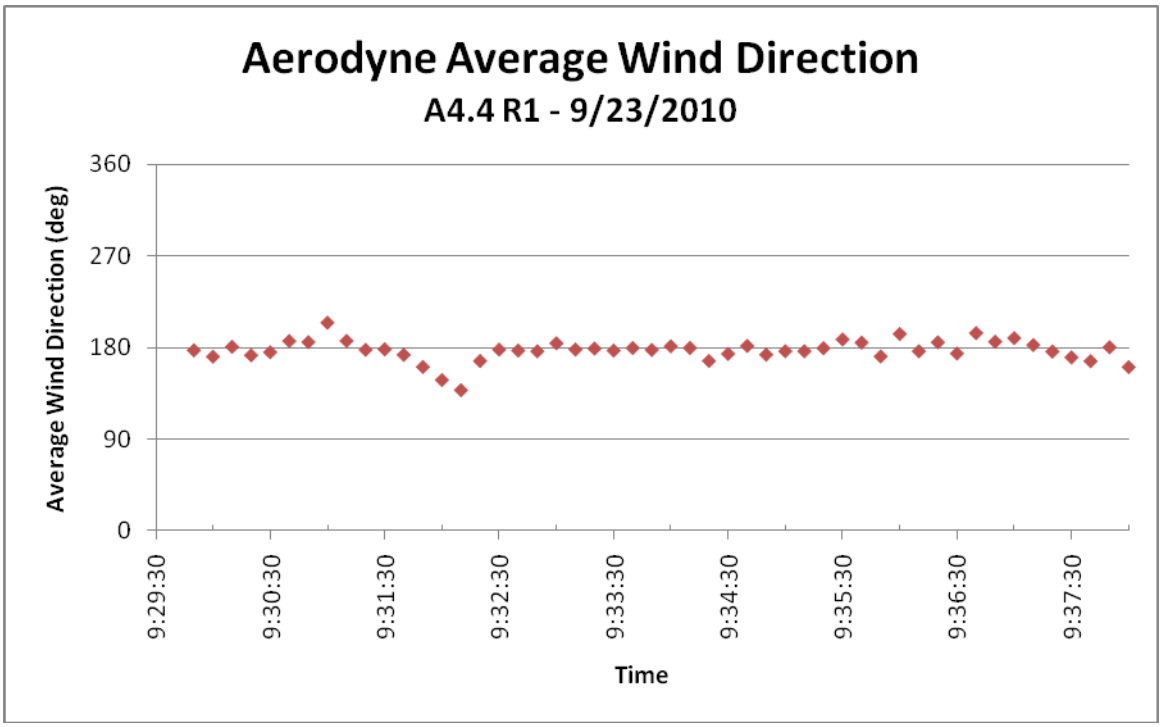


Figure J-78b. Wind Direction vs Time for Air Flare Test A4.4 R1

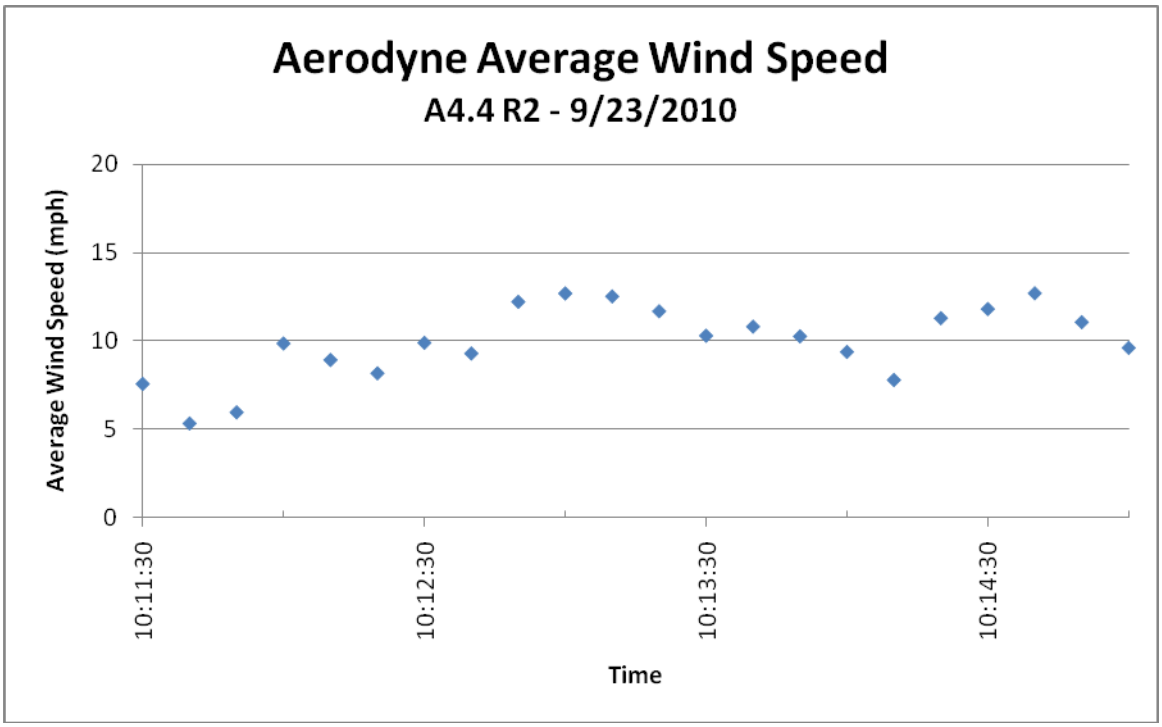


Figure J-79a. Wind Speed vs Time for Air Flare Test A4.4 R2

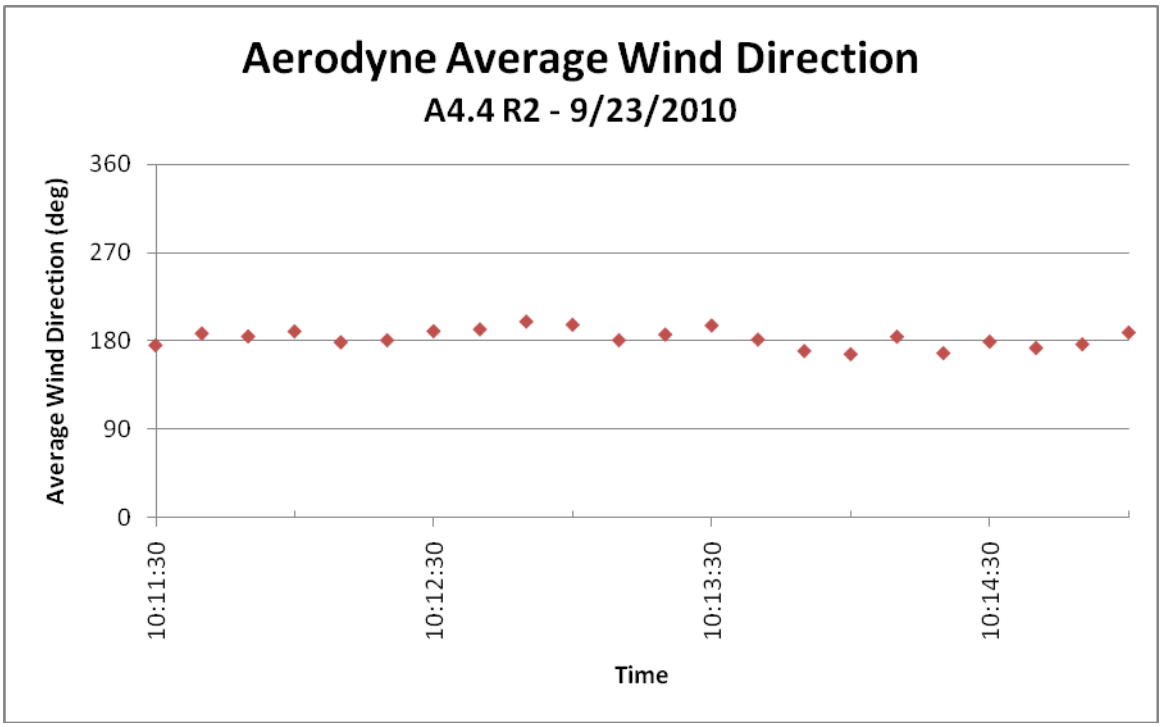


Figure J-79b. Wind Direction vs Time for Air Flare Test A4.4 R2

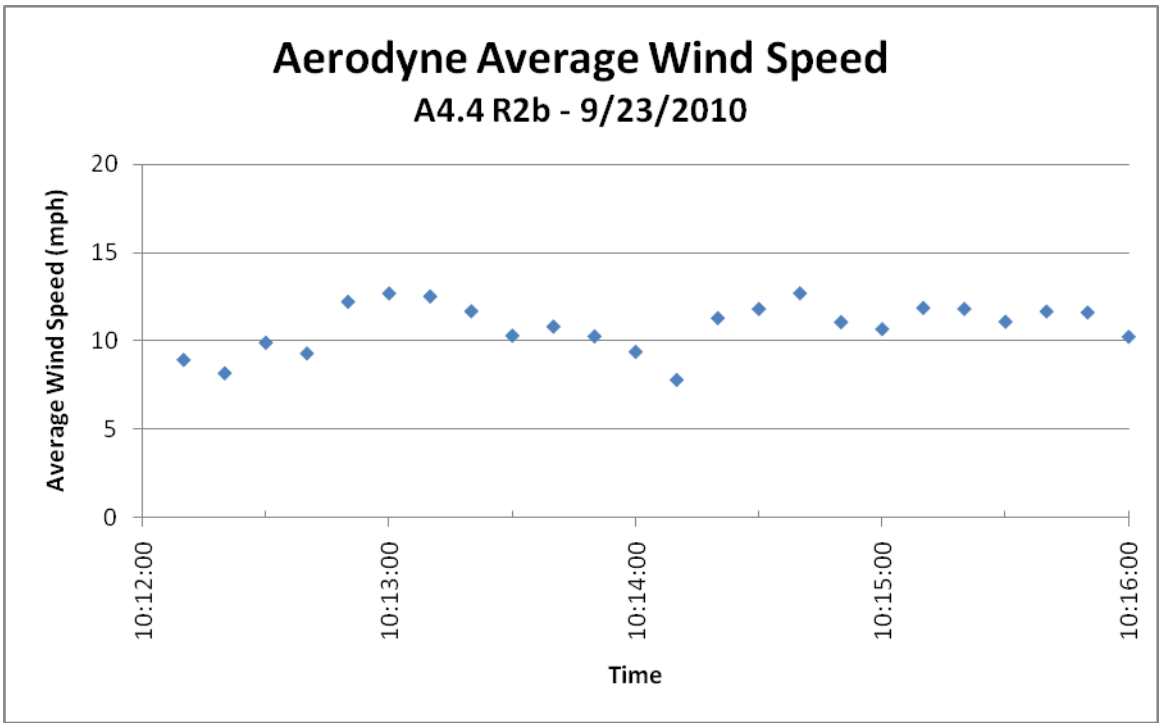


Figure J-80a. Wind Speed vs Time for Air Flare Test A4.4 R2b

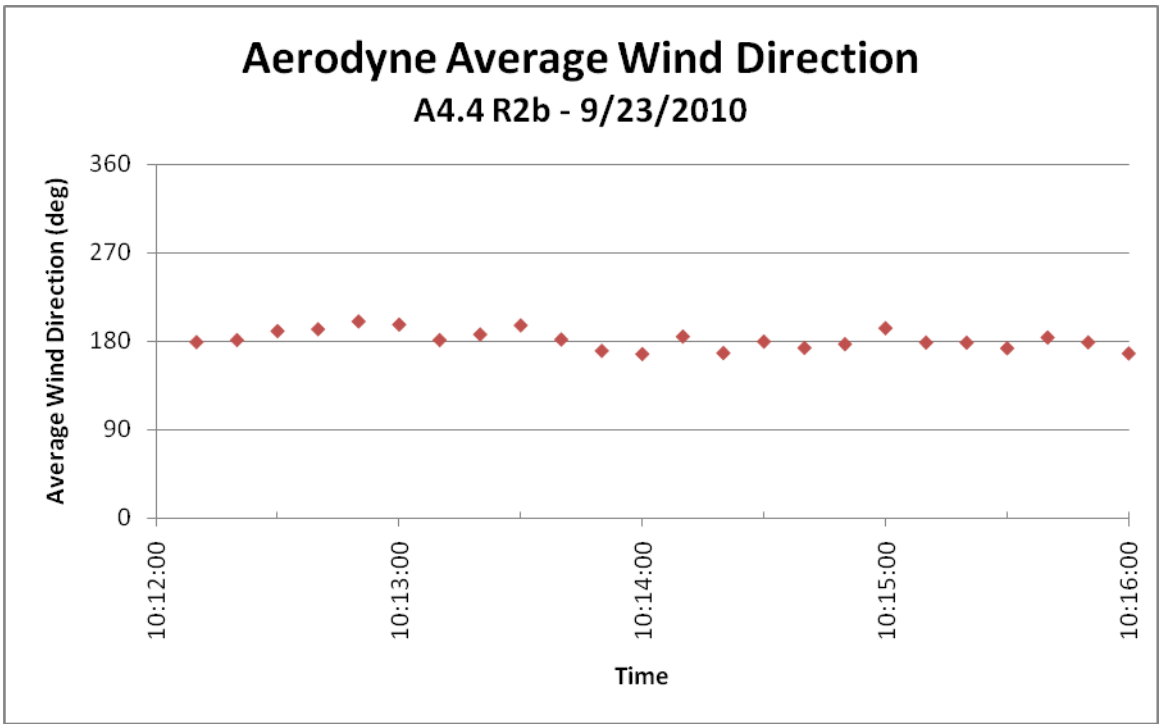


Figure J-80b. Wind Direction vs Time for Air Flare Test A4.4 R2b

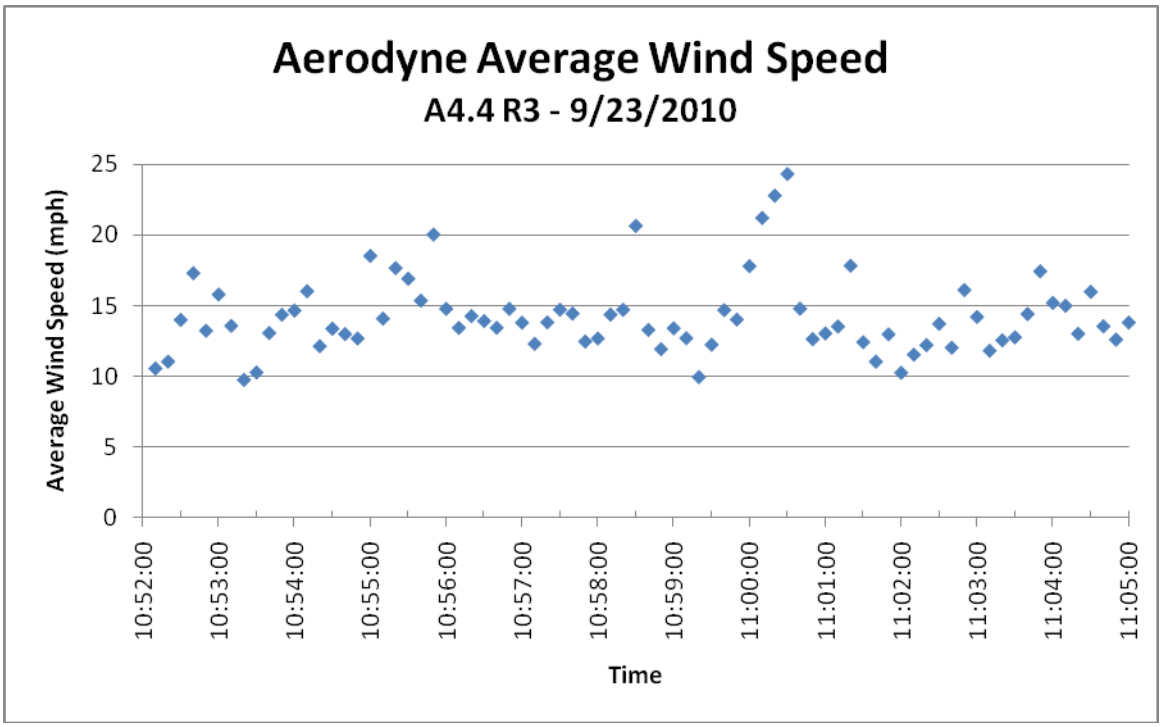


Figure J-81a. Wind Speed vs Time for Air Flare Test A4.4 R3

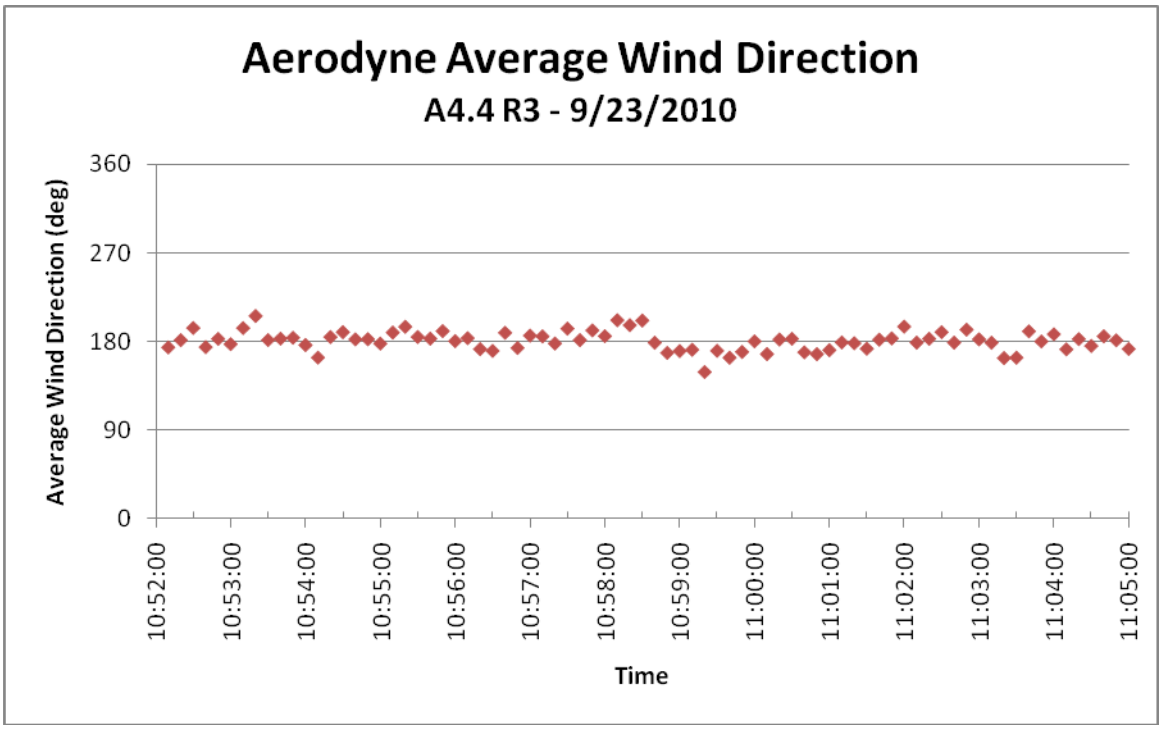


Figure J-81b. Wind Direction vs Time for Air Flare Test A4.4 R3

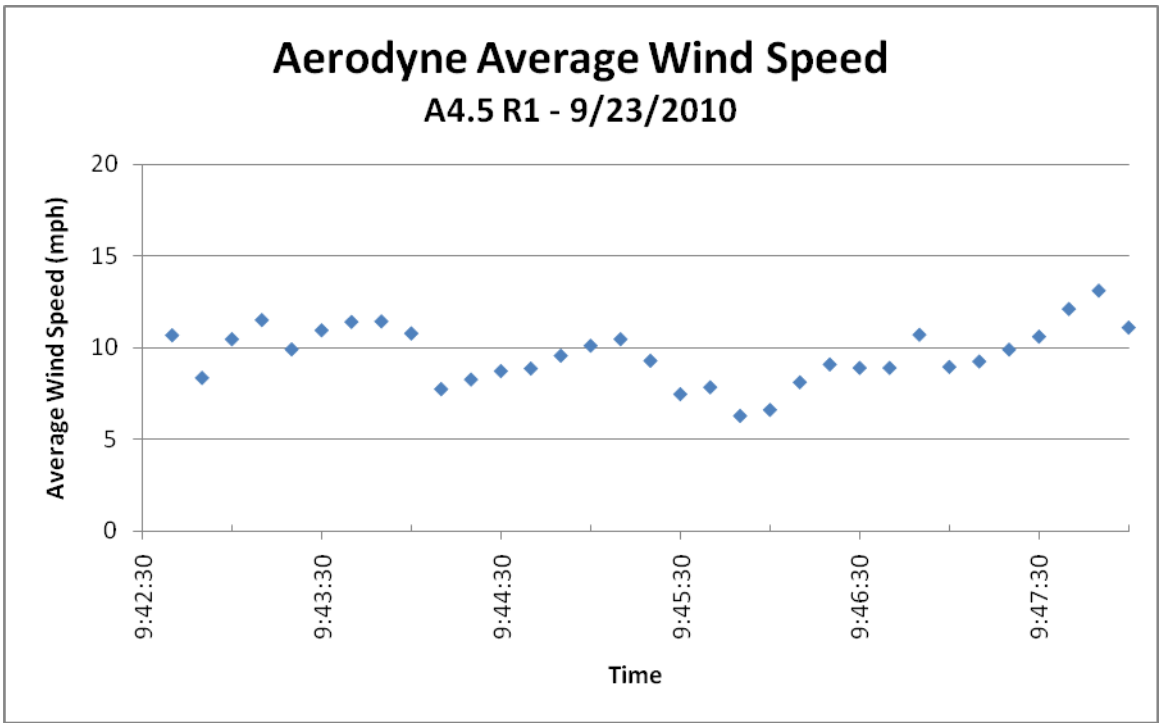


Figure J-82a. Wind Speed vs Time for Air Flare Test A4.5 R1

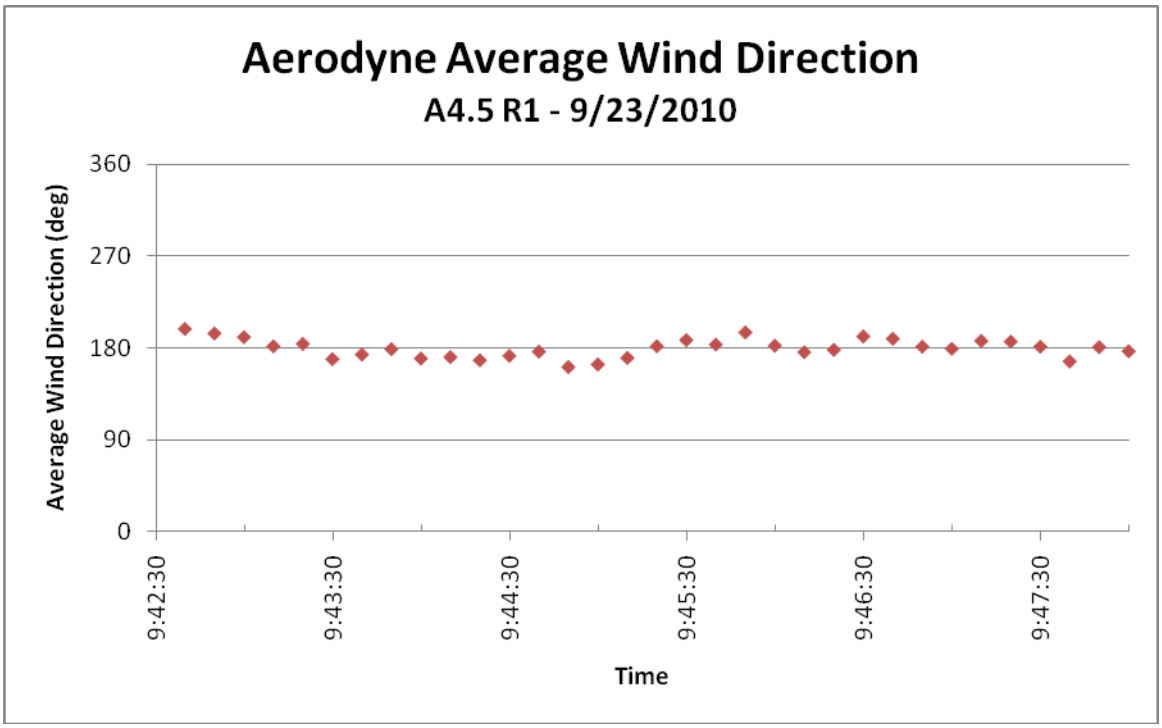


Figure J-82b. Wind Direction vs Time for Air Flare Test A4.5 R1

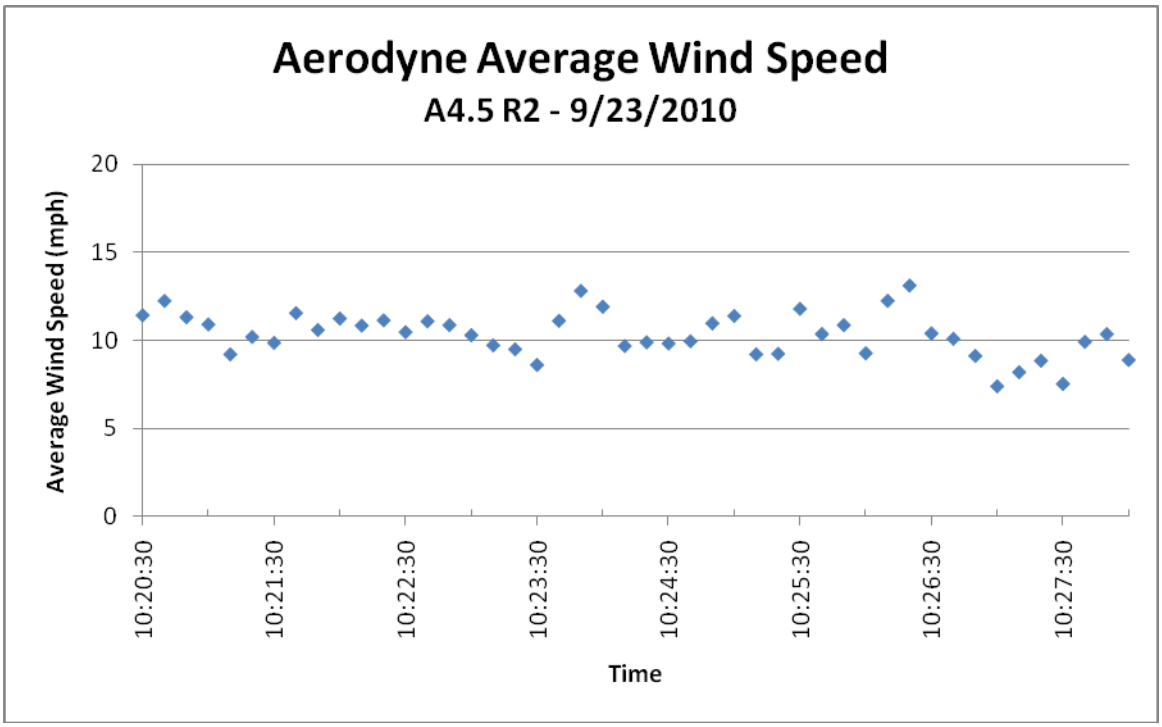


Figure J-83a. Wind Speed vs Time for Air Flare Test A4.5 R2

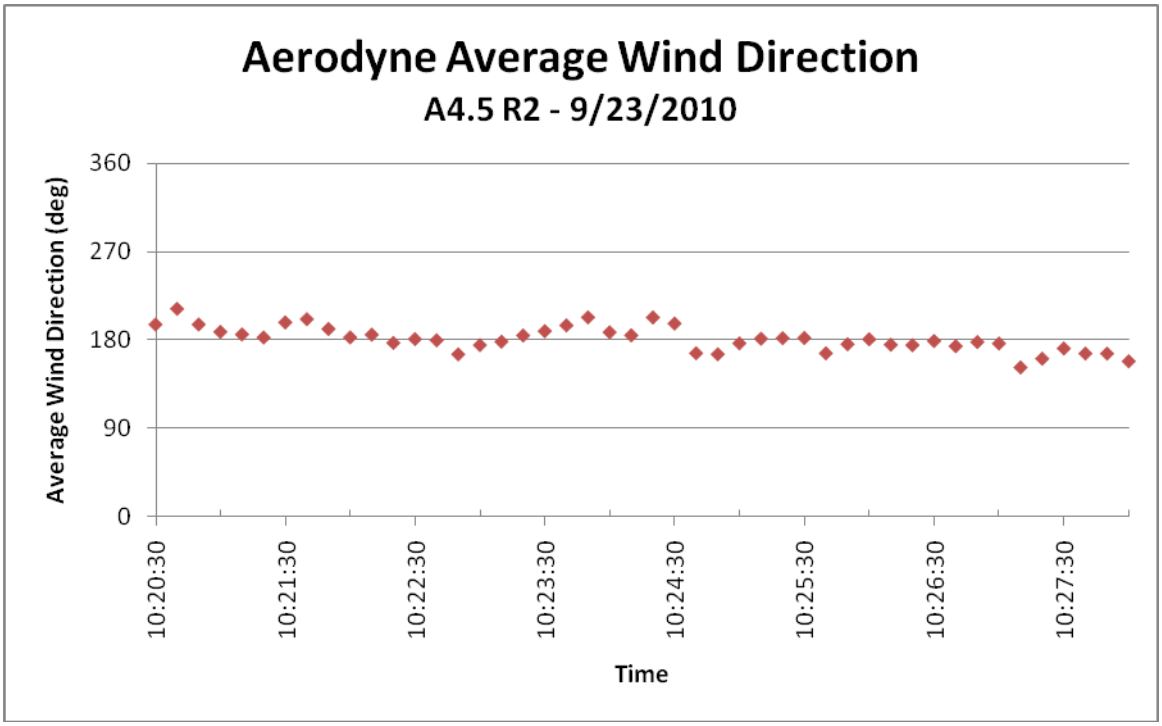


Figure J-83b. Wind Direction vs Time for Air Flare Test A4.5 R2

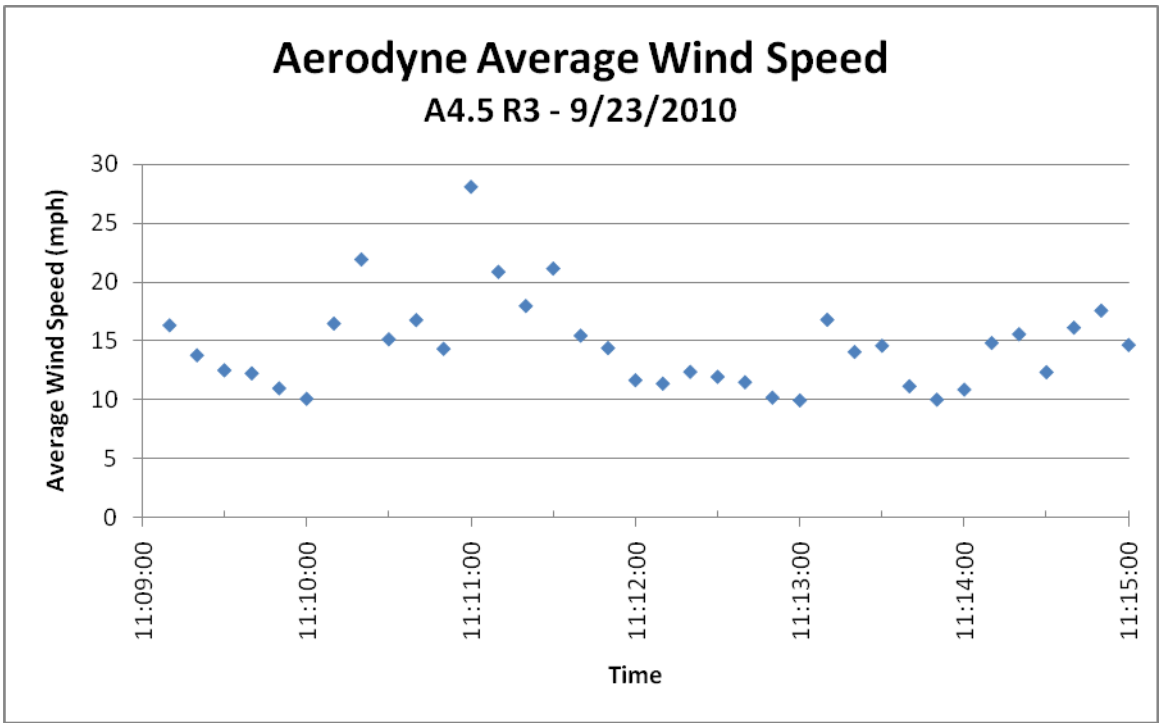


Figure J-84a. Wind Speed vs Time for Air Flare Test A4.5 R3

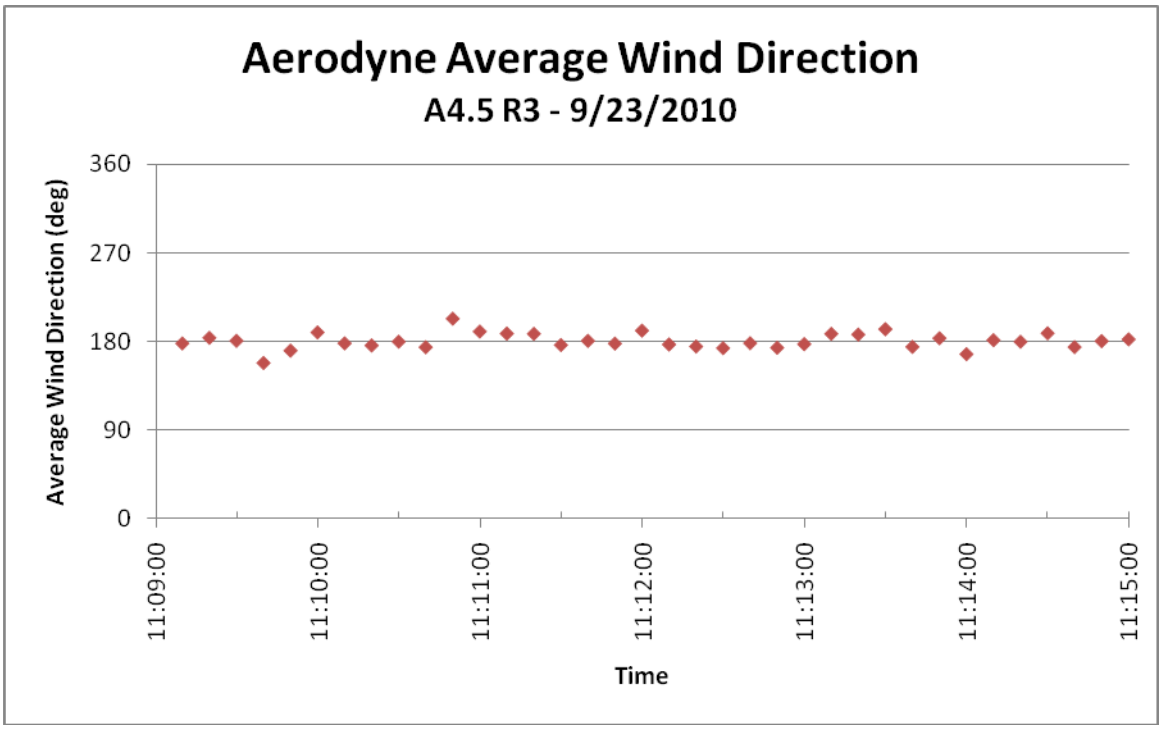


Figure J-84b. Wind Direction vs Time for Air Flare Test A4.5 R3

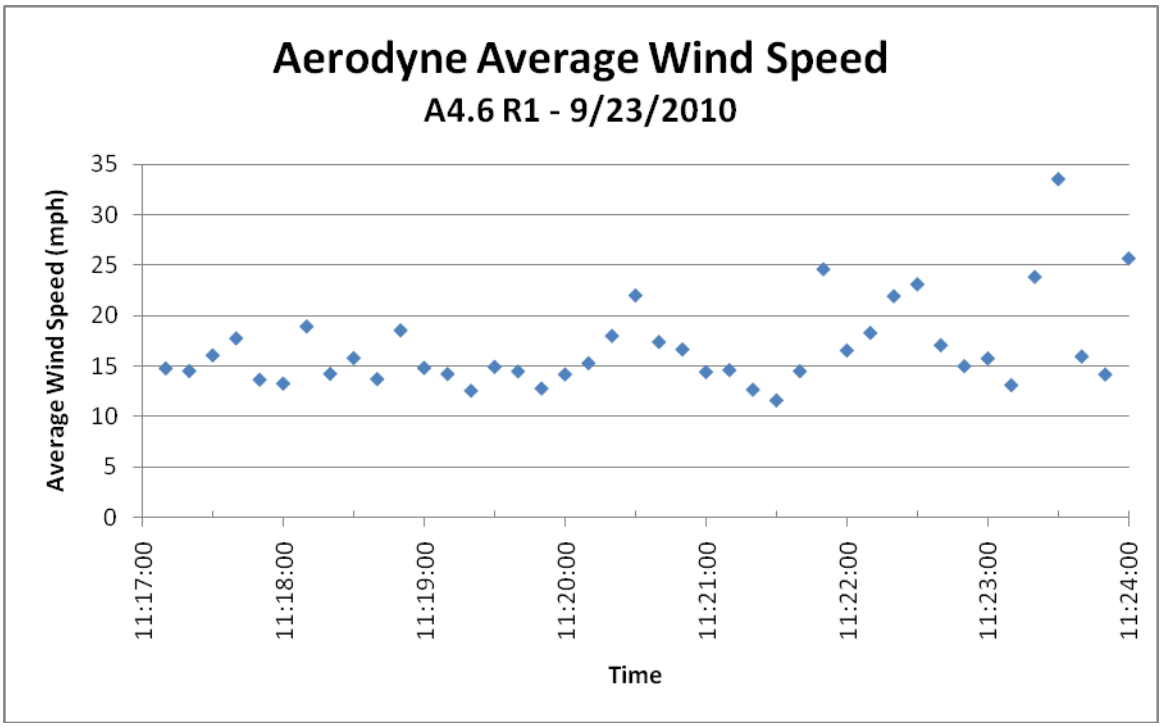


Figure J-85a. Wind Speed vs Time for Air Flare Test A4.6 R1

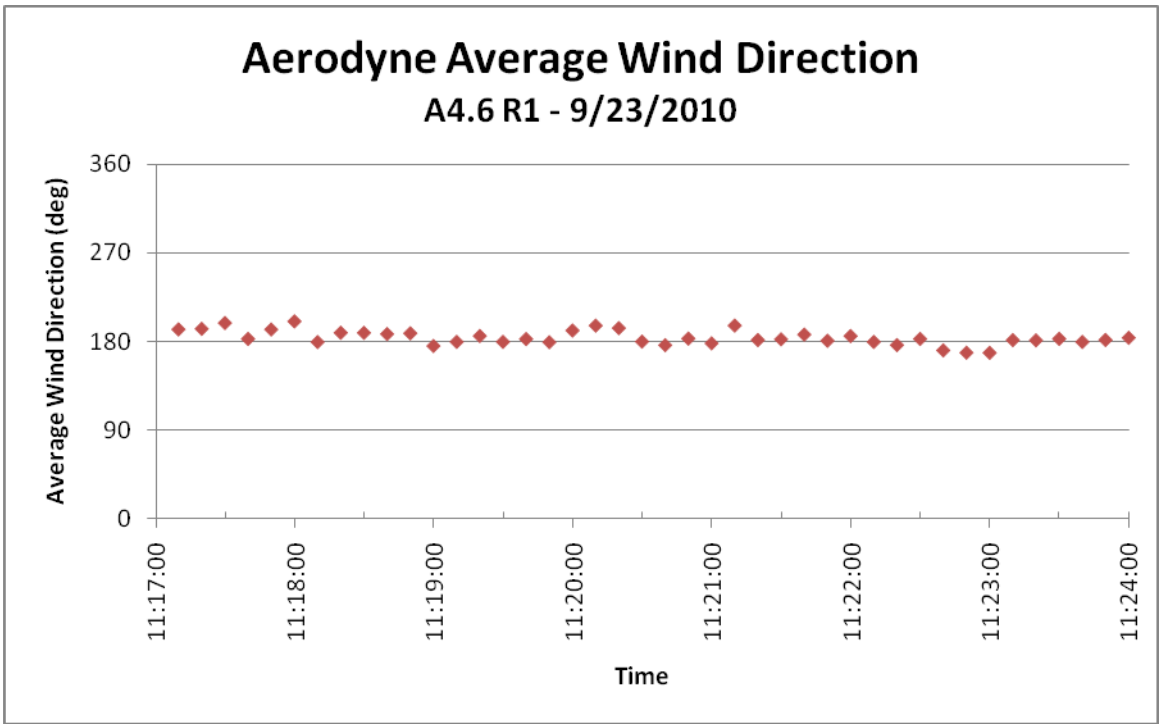


Figure J-85b. Wind Direction vs Time for Air Flare Test A4.6 R1

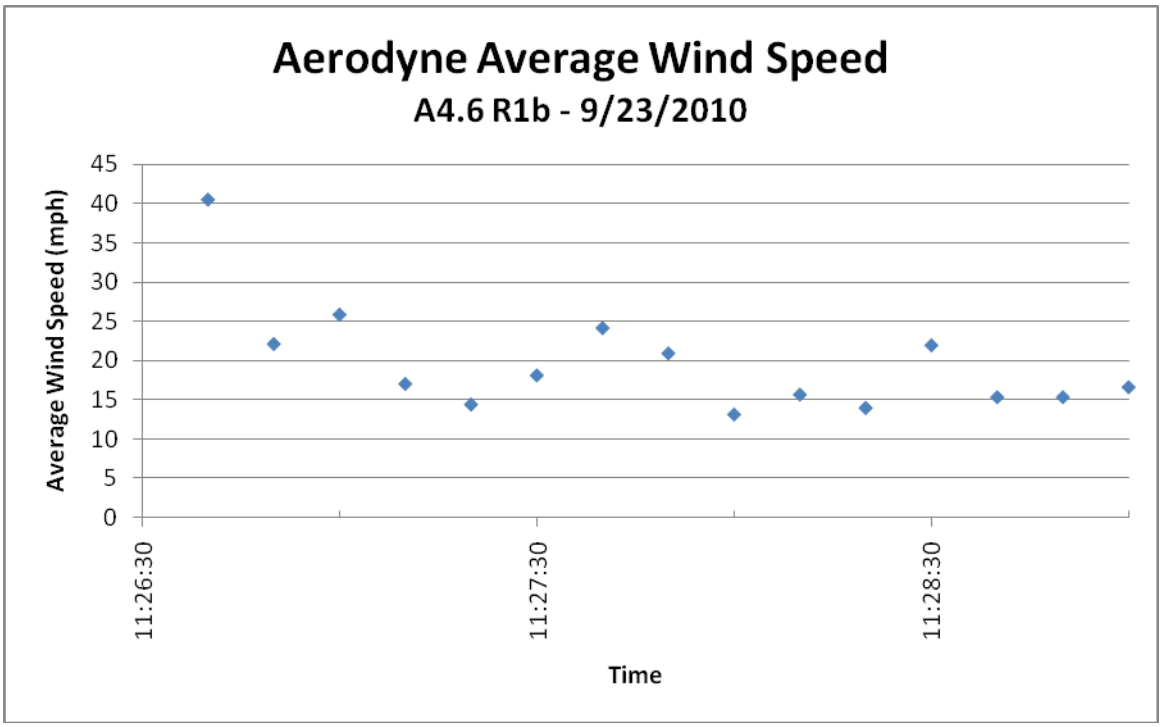


Figure J-86a. Wind Speed vs Time for Air Flare Test A4.6 R1b

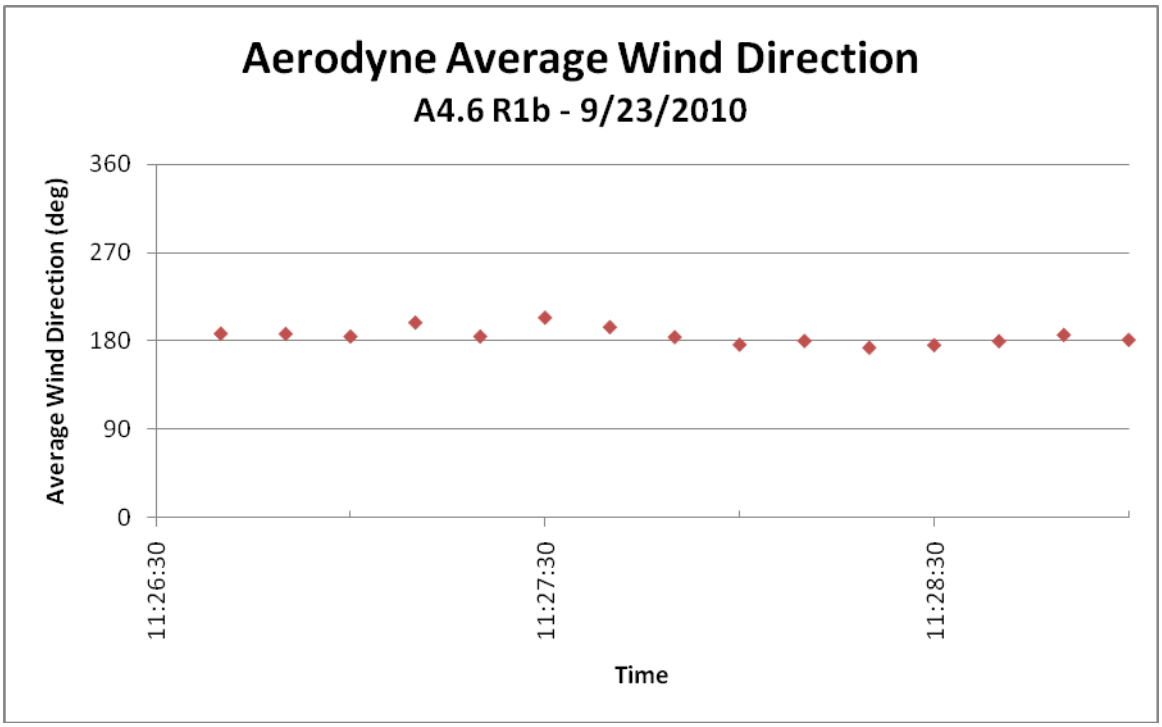


Figure J-86b. Wind Direction vs Time for Air Flare Test A4.6 R1b

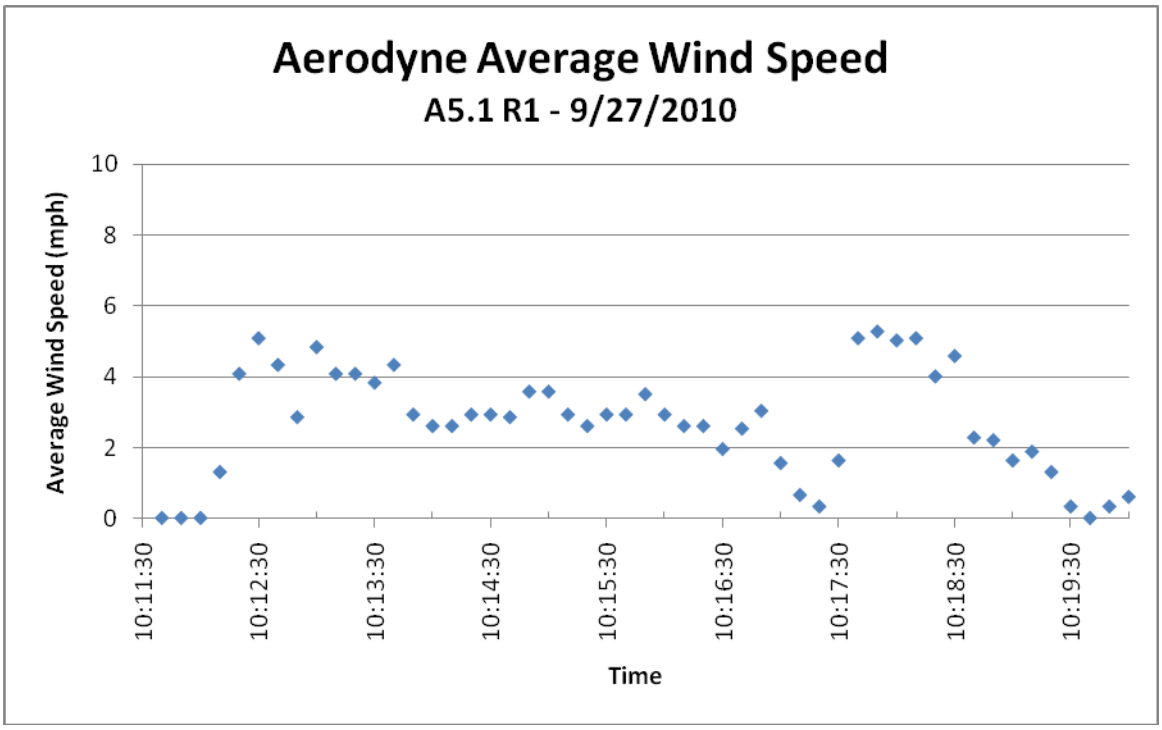


Figure J-87a. Wind Speed vs Time for Air Flare Test A5.1 R1

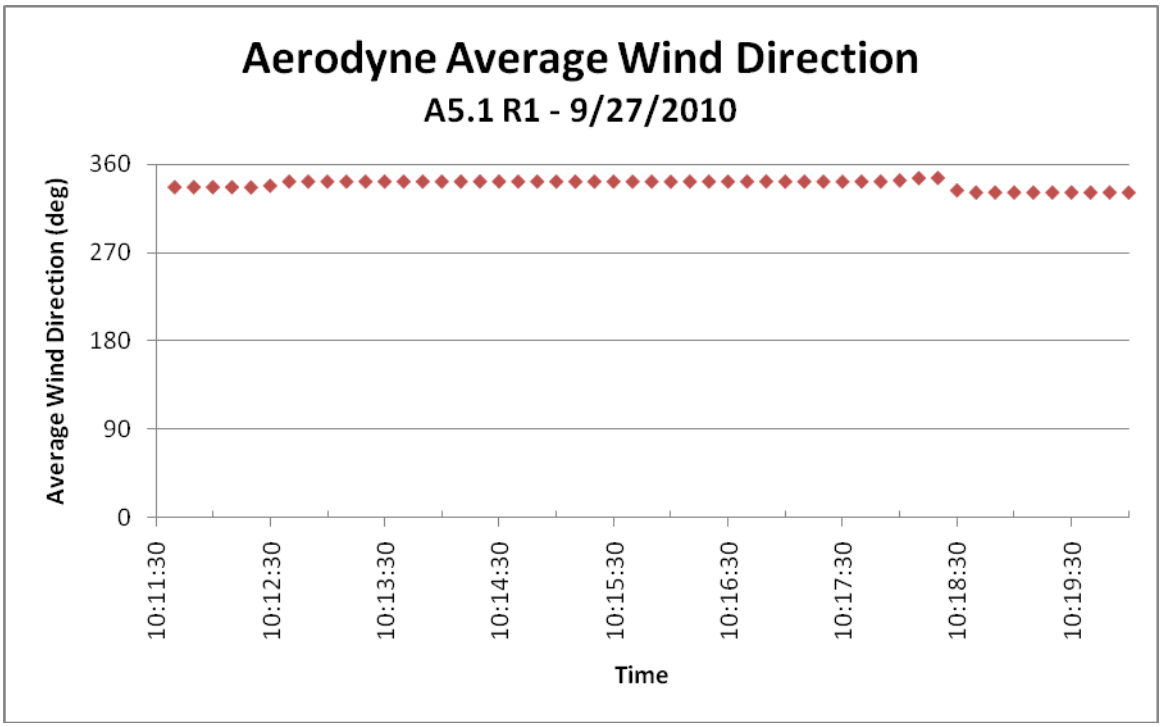


Figure J-87b. Wind Direction vs Time for Air Flare Test A5.1 R1

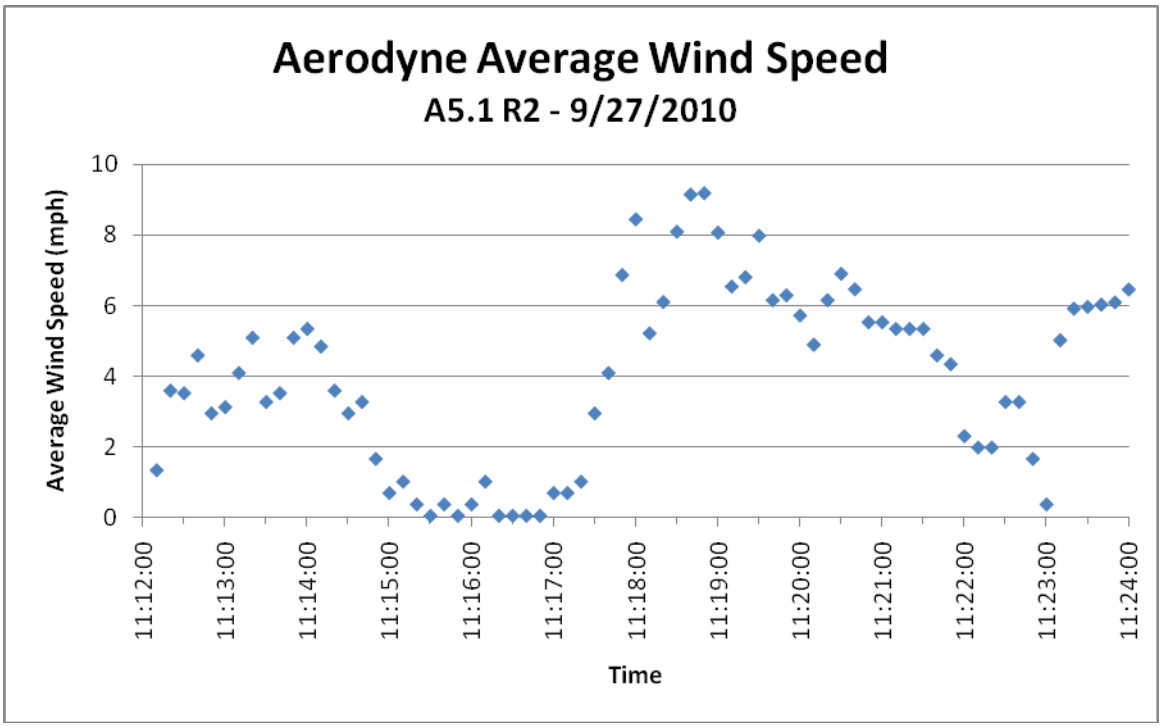


Figure J-88a. Wind Speed vs Time for Air Flare Test A5.1 R2

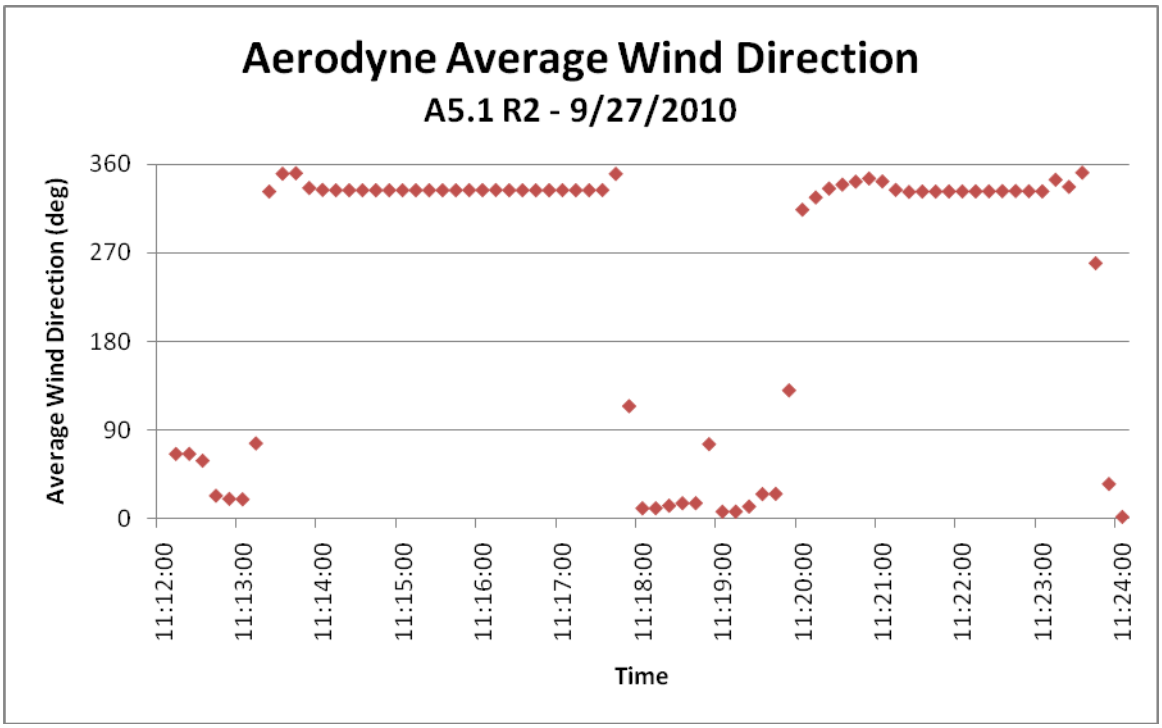


Figure J-88b. Wind Direction vs Time for Air Flare Test A5.1 R2

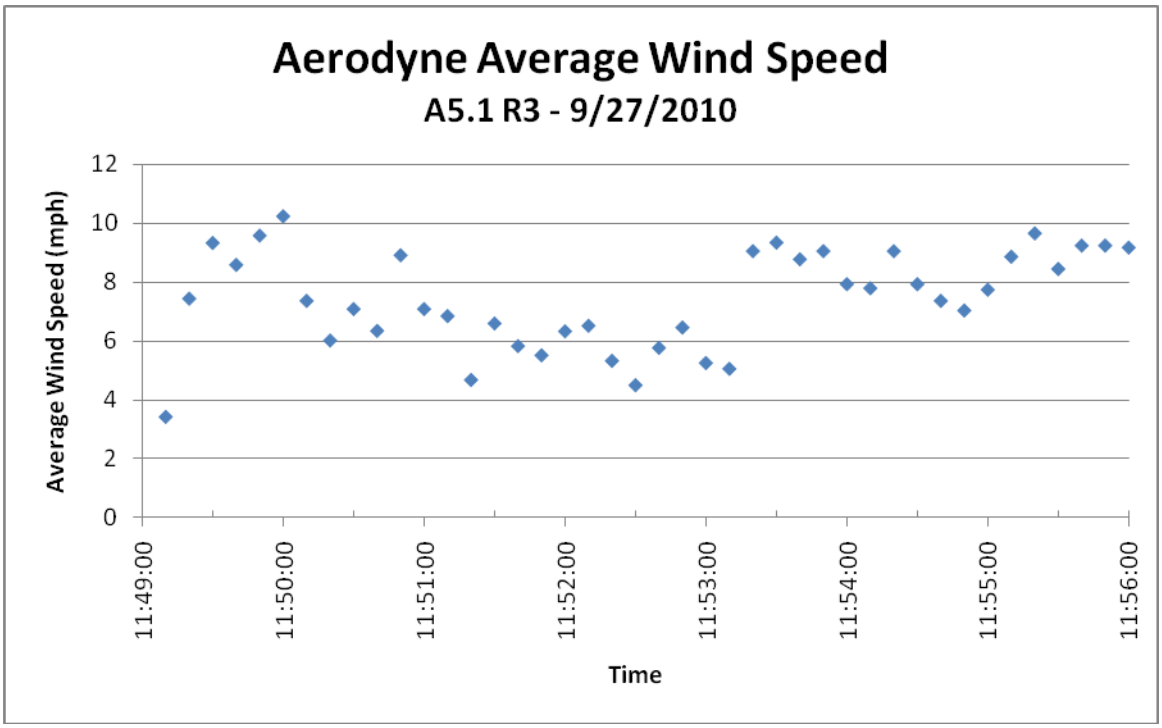


Figure J-89a. Wind Speed vs Time for Air Flare Test A5.1 R3

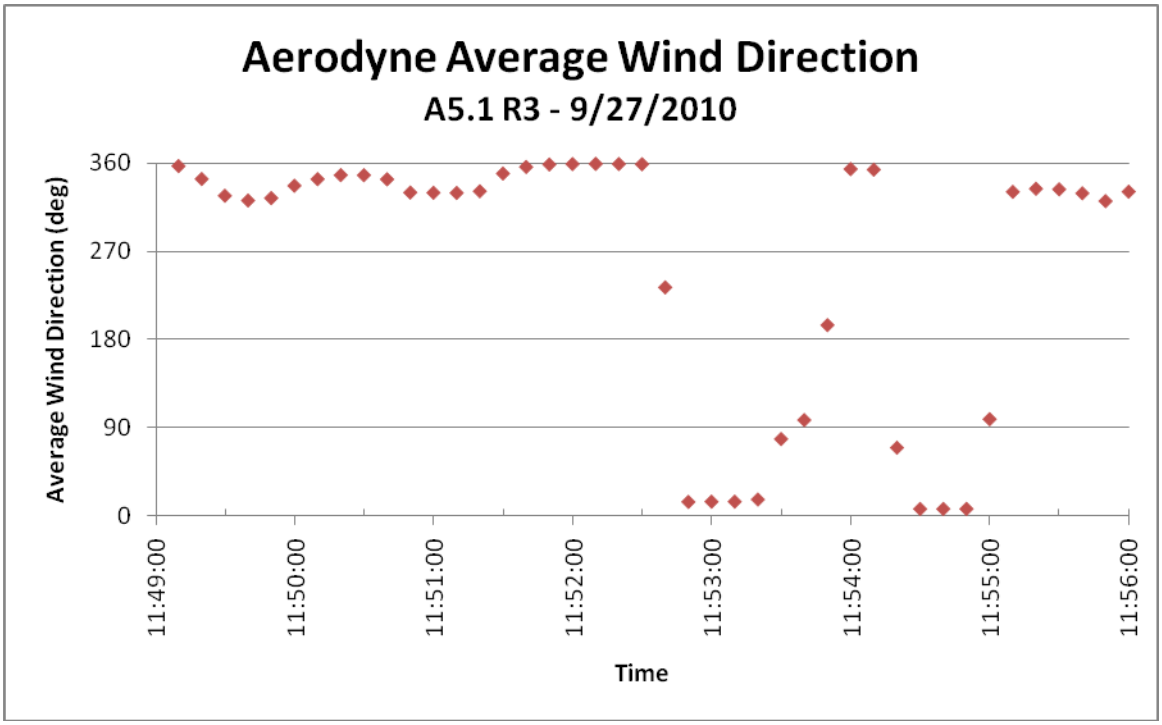


Figure J-89b. Wind Direction vs Time for Air Flare Test A5.1 R3

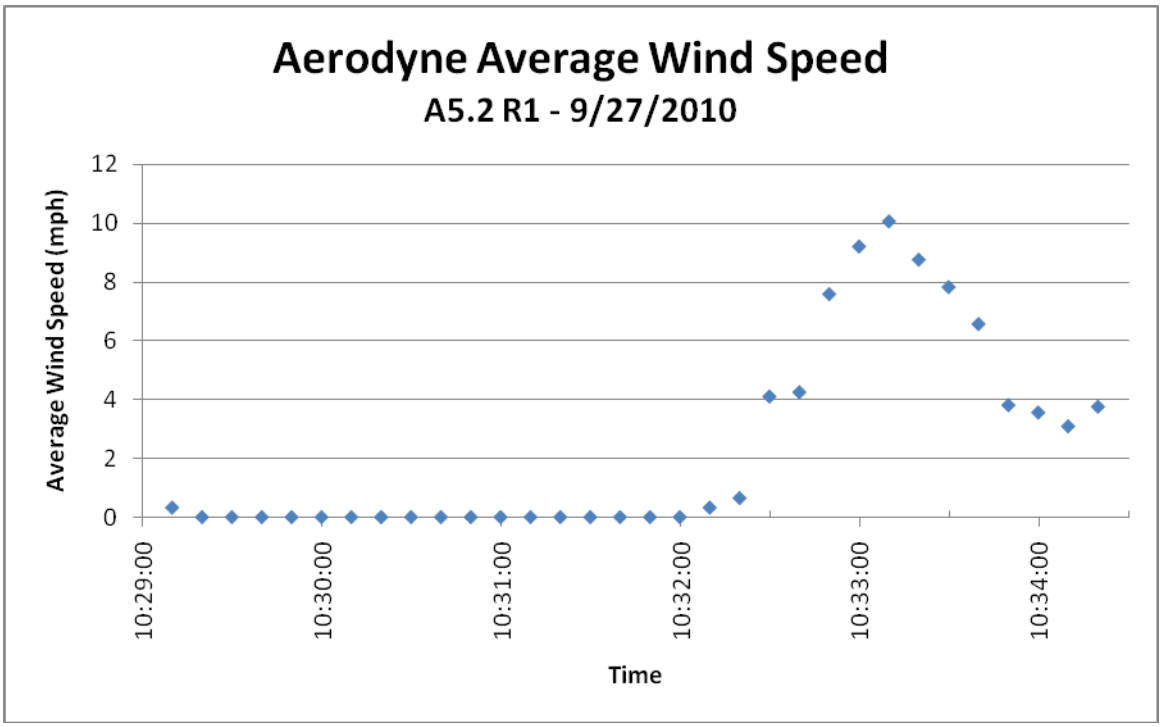


Figure J-90a. Wind Speed vs Time for Air Flare Test A5.2 R1

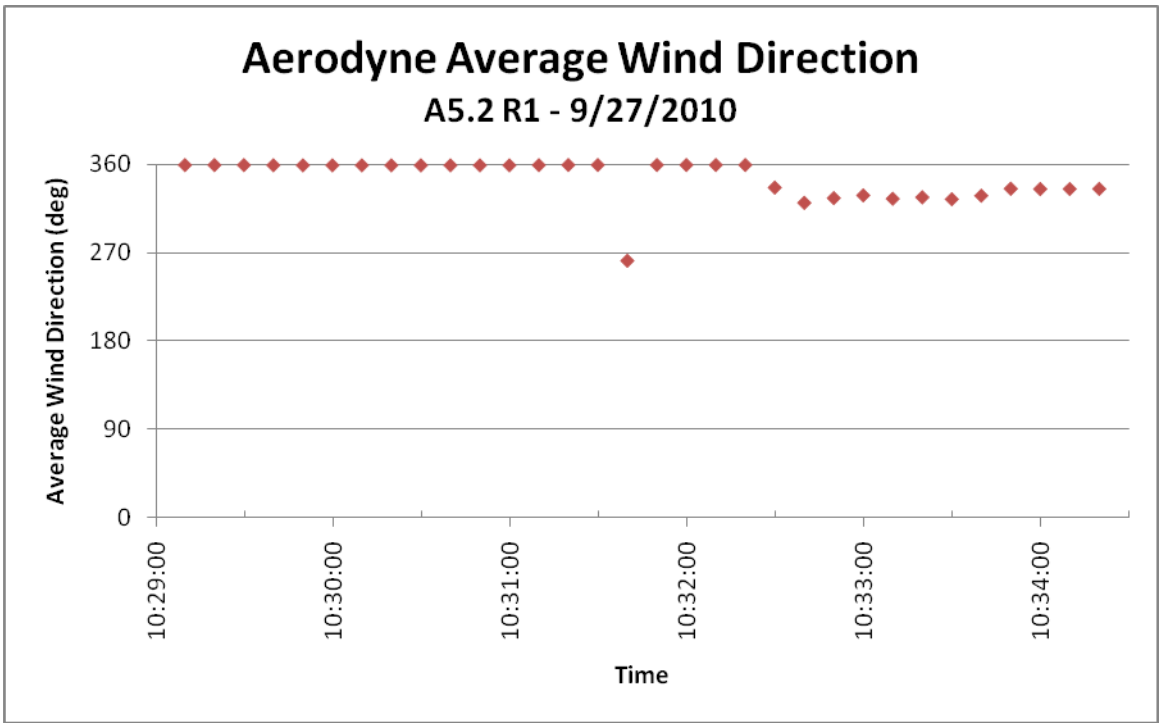


Figure J-90b. Wind Direction vs Time for Air Flare Test A5.2 R1

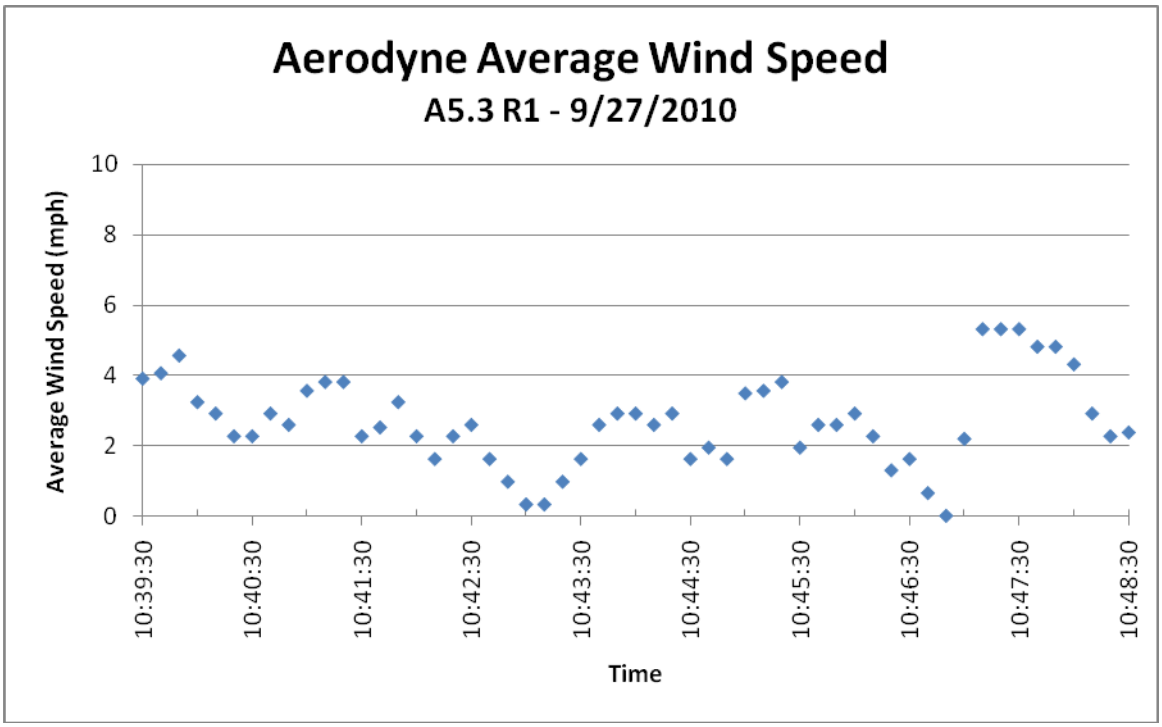


Figure J-91a. Wind Speed vs Time for Air Flare Test A5.3 R1

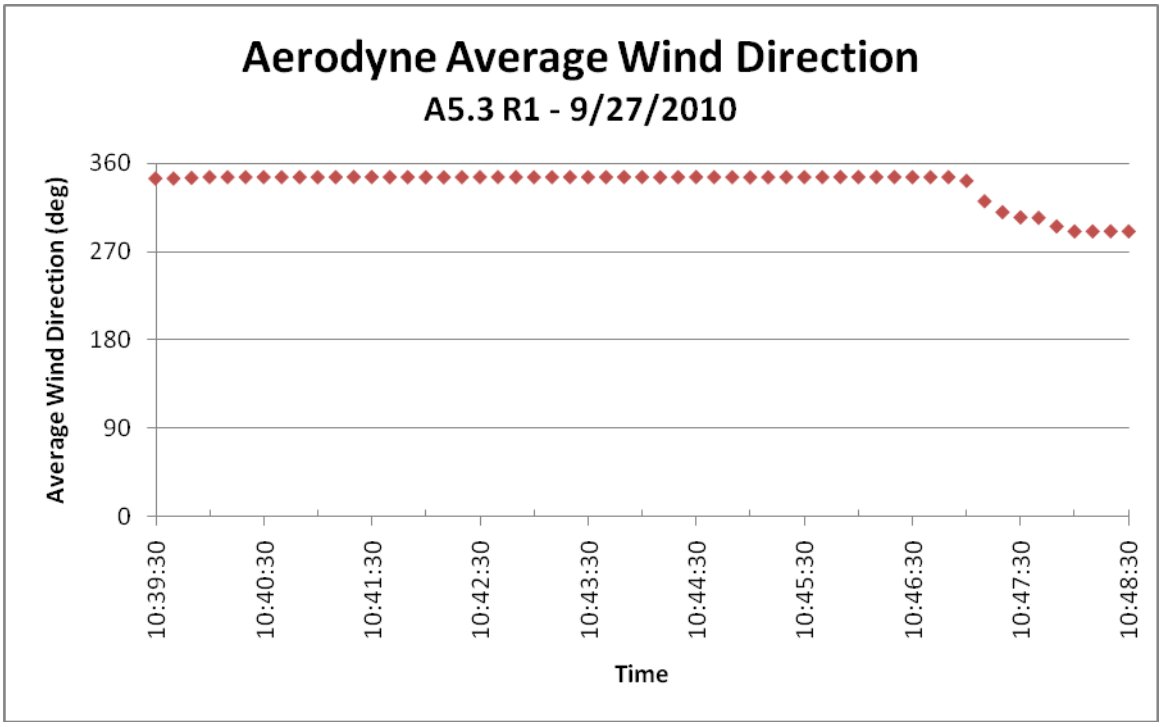


Figure J-91b. Wind Direction vs Time for Air Flare Test A5.3 R1

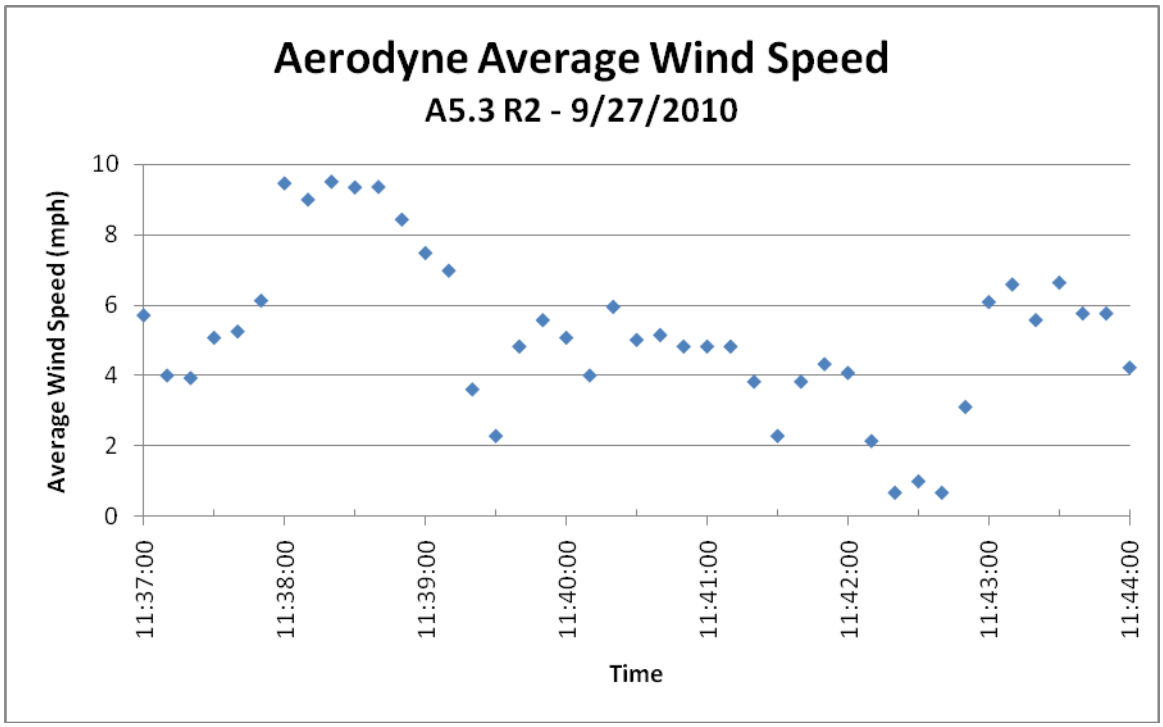


Figure J-92a. Wind Speed vs Time for Air Flare Test A5.3 R2

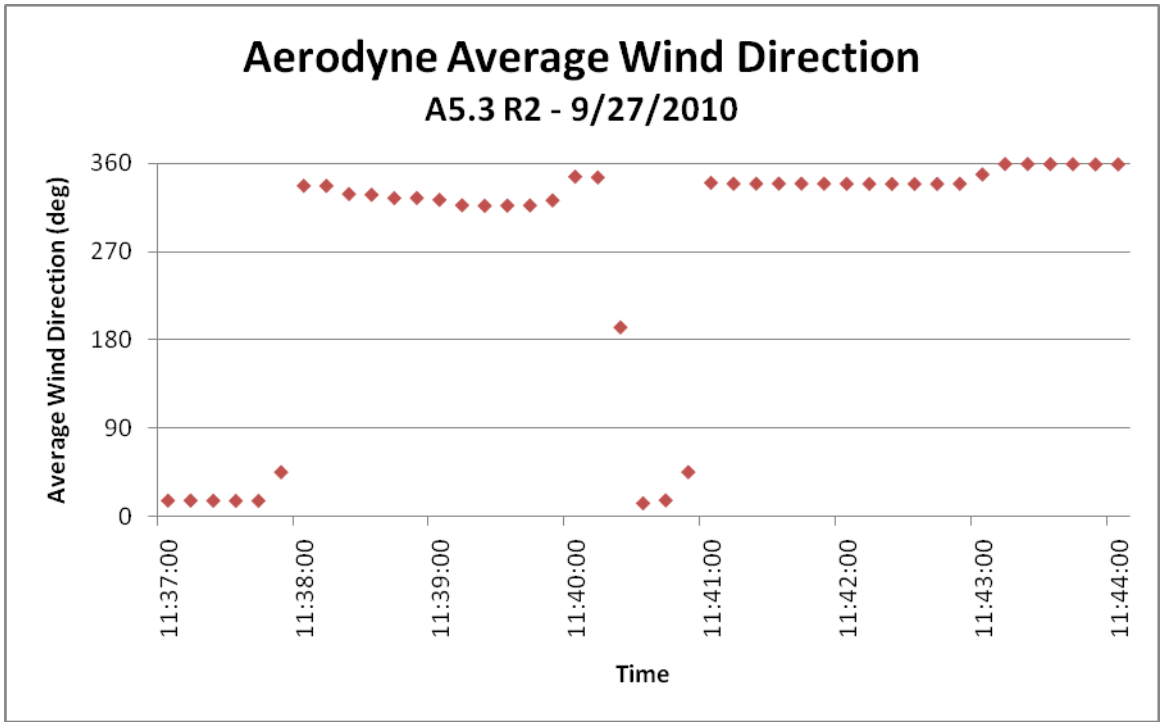


Figure J-92b. Wind Direction vs Time for Air Flare Test A5.3 R2

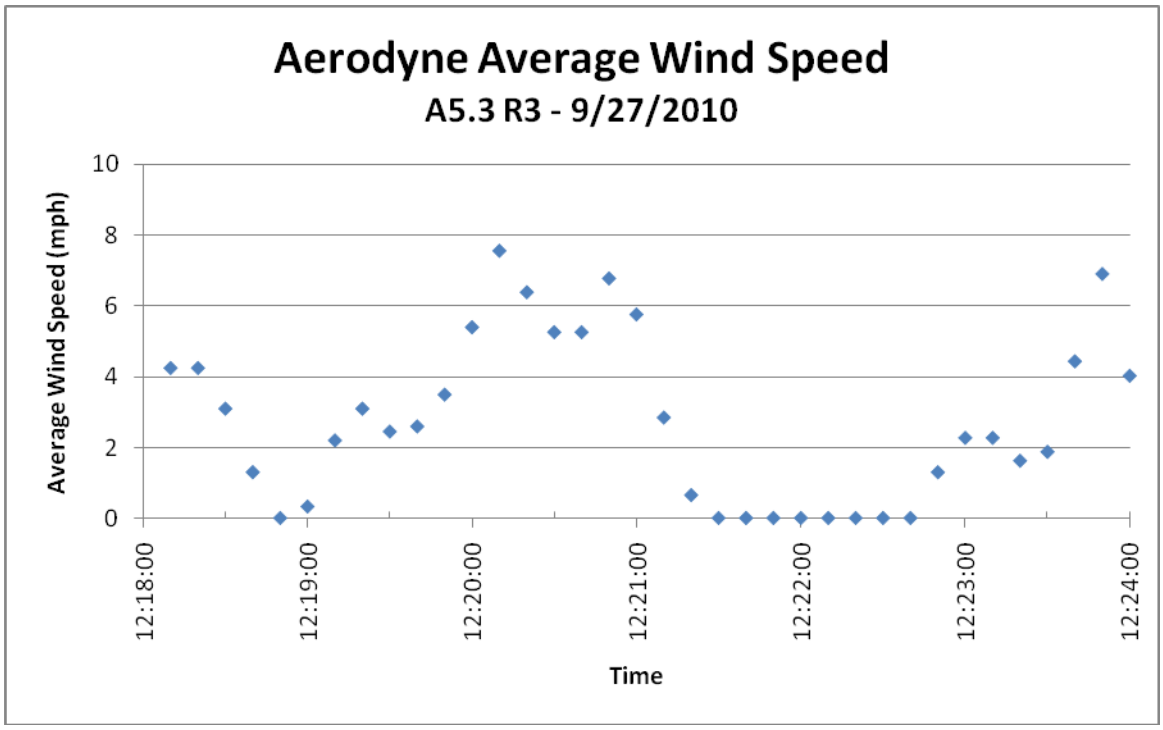


Figure J-93a. Wind Speed vs Time for Air Flare Test A5.3 R3

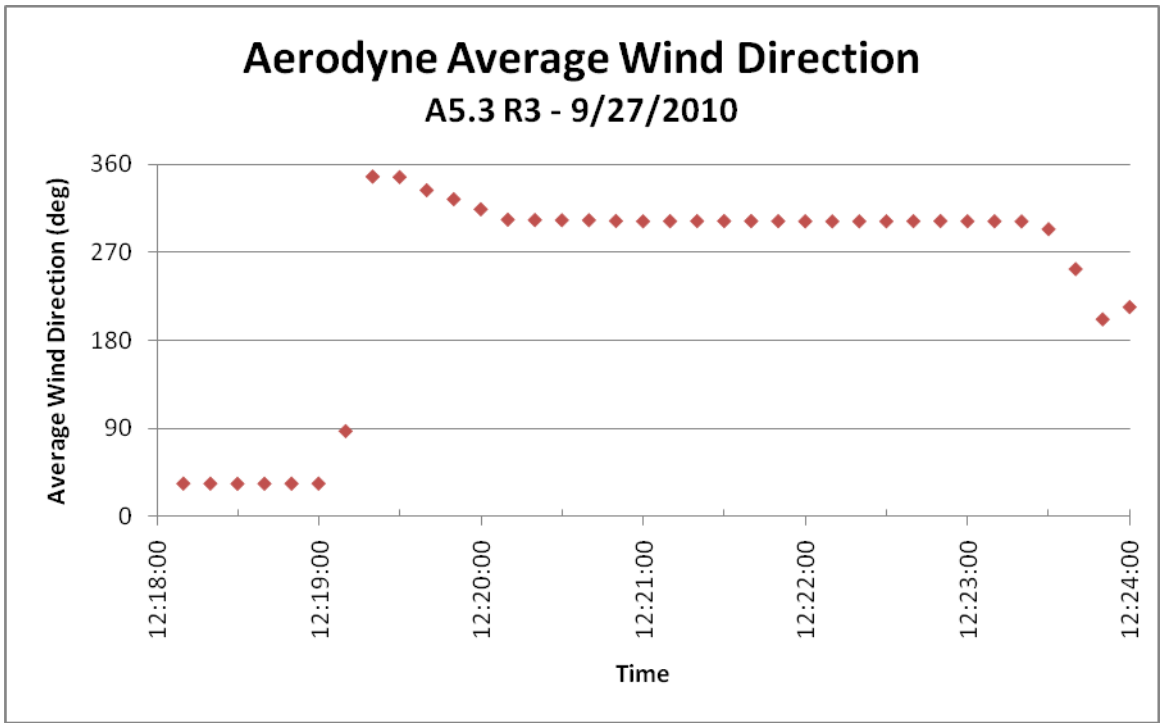


Figure J-93b. Wind Direction vs Time for Air Flare Test A5.3 R3

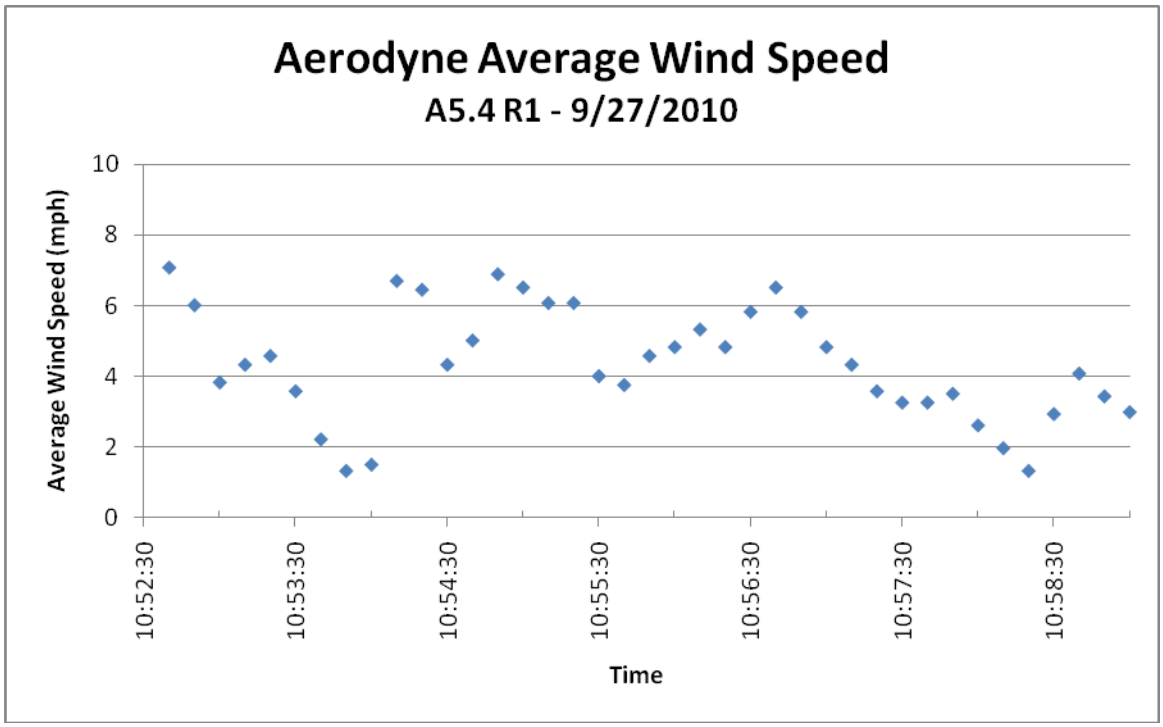


Figure J-94a. Wind Speed vs Time for Air Flare Test A5.4 R1

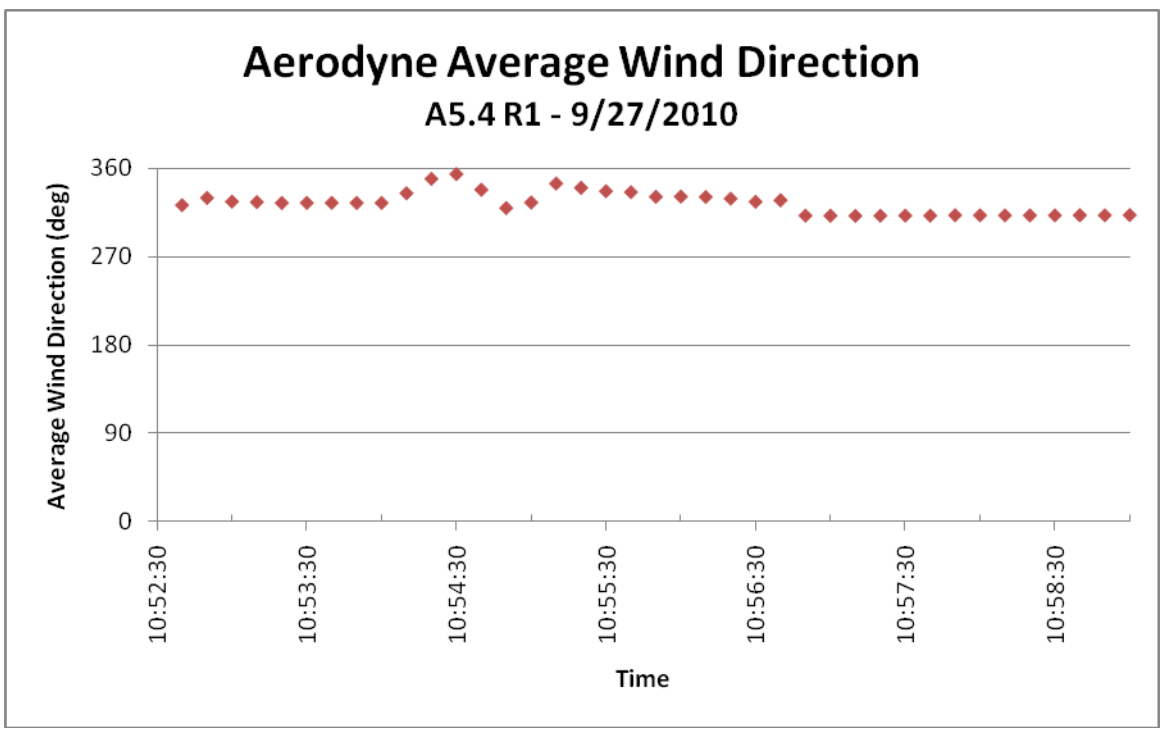


Figure J-94b. Wind Direction vs Time for Air Flare Test A5.4 R1

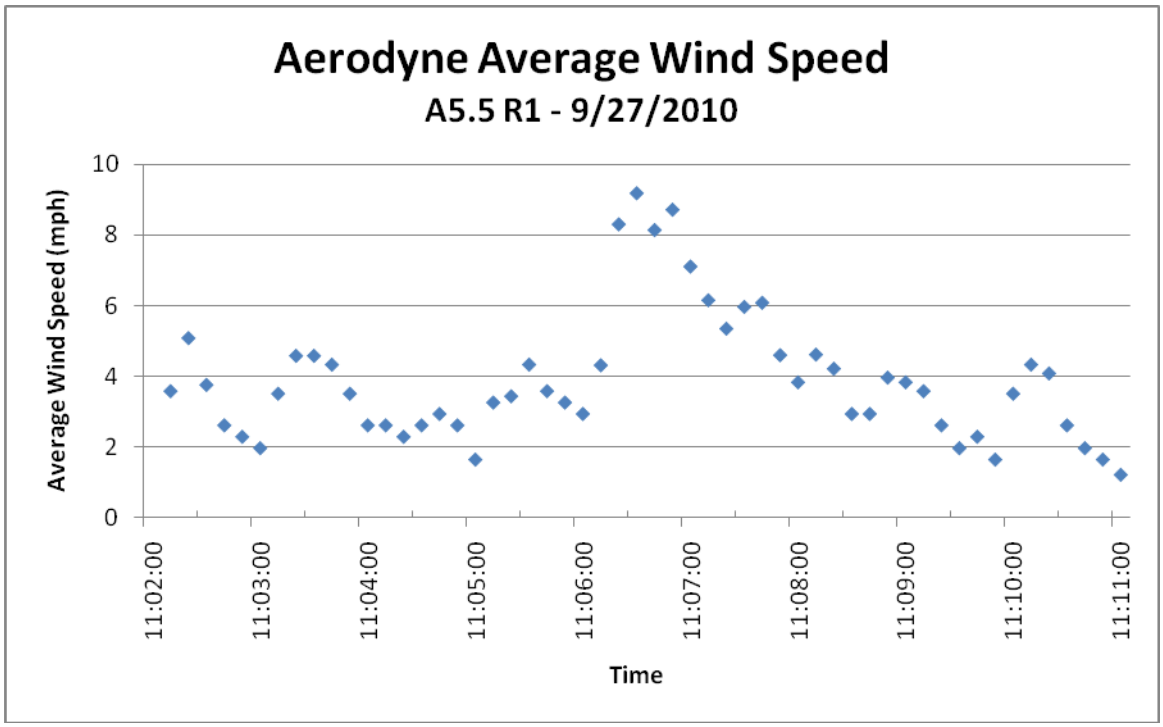


Figure J-95a. Wind Speed vs Time for Air Flare Test A5.5 R1

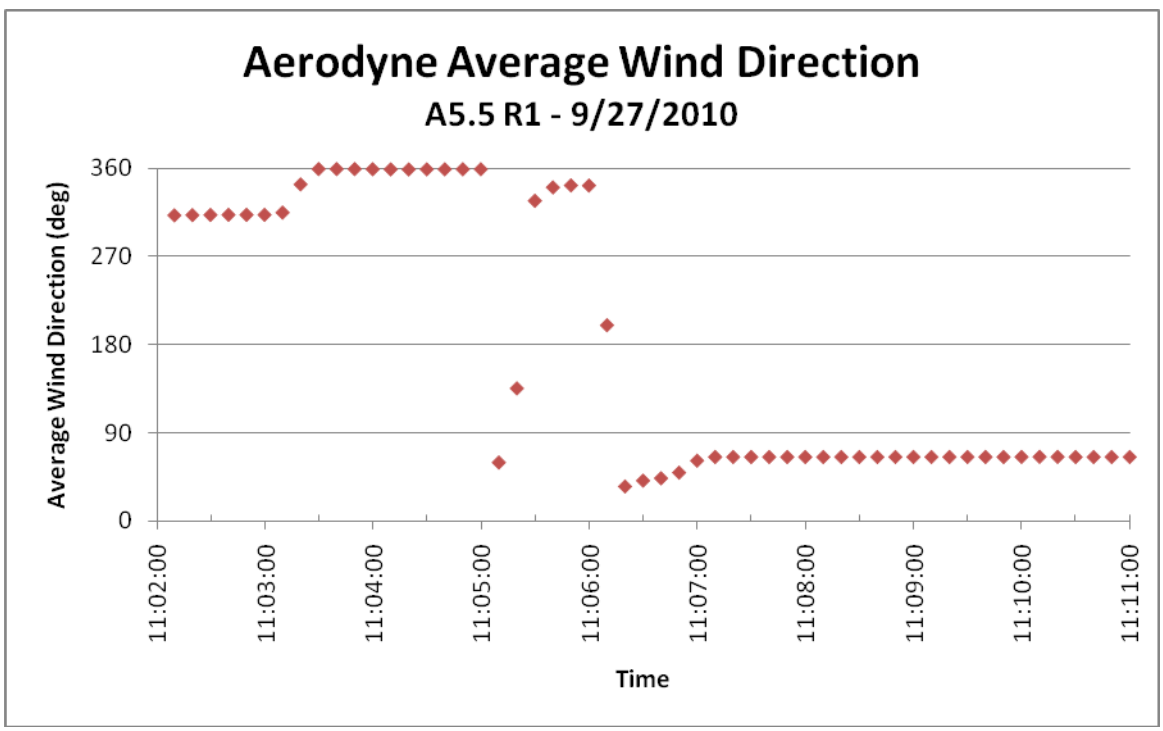


Figure J-95b. Wind Direction vs Time for Air Flare Test A5.5 R1

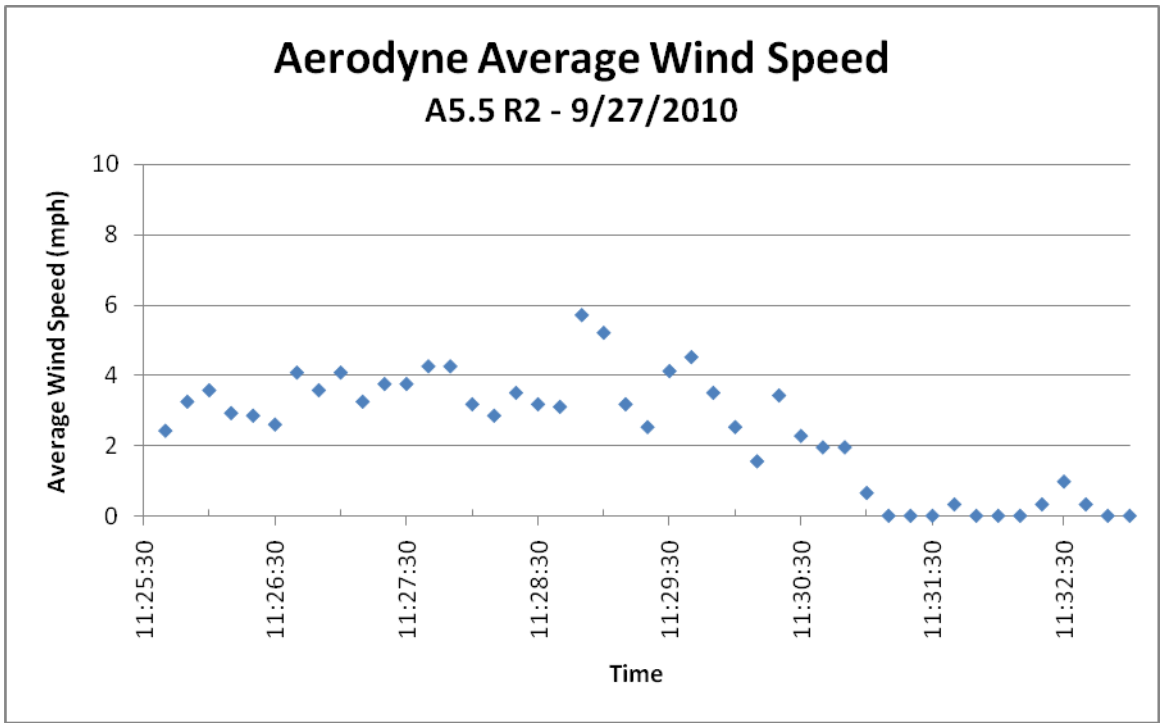


Figure J-96a. Wind Speed vs Time for Air Flare Test A5.5 R2

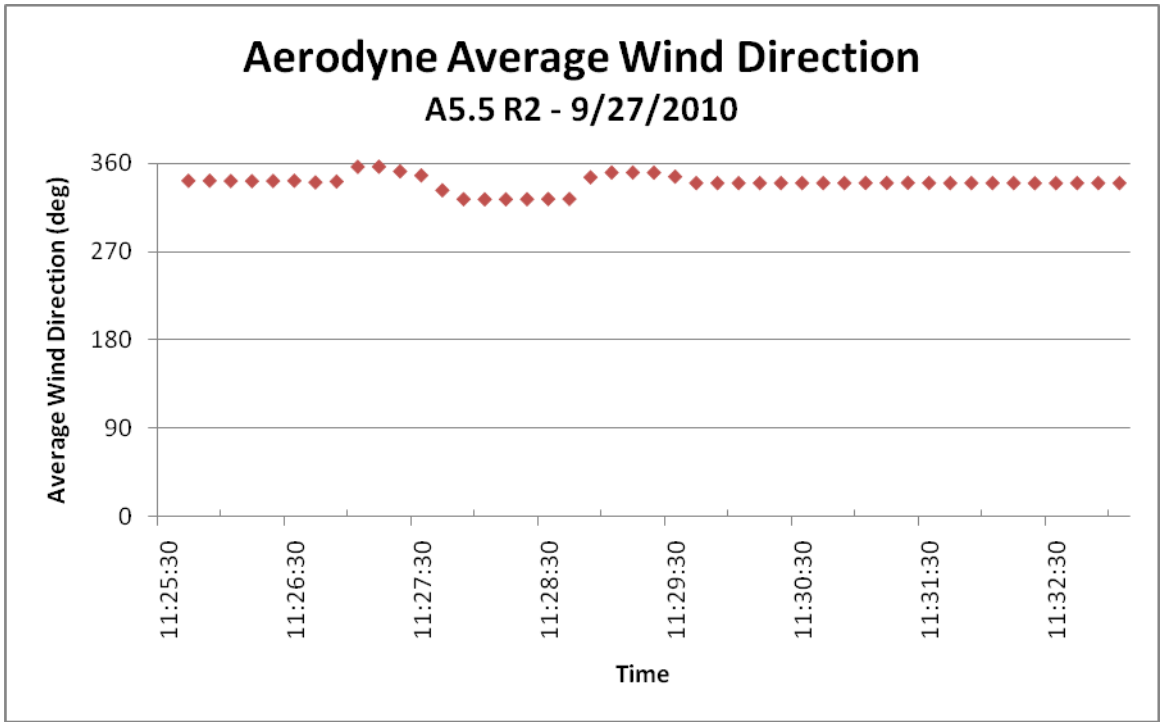


Figure J-96b. Wind Direction vs Time for Air Flare Test A5.5 R2

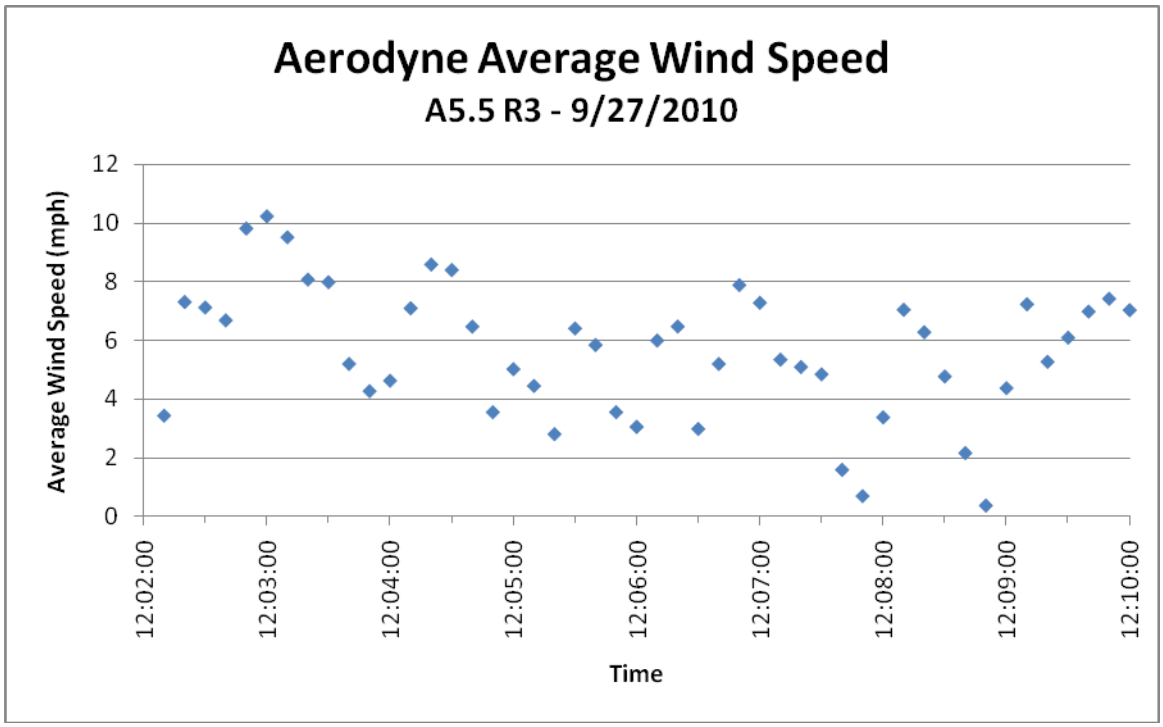


Figure J-97a. Wind Speed vs Time for Air Flare Test A5.5 R3

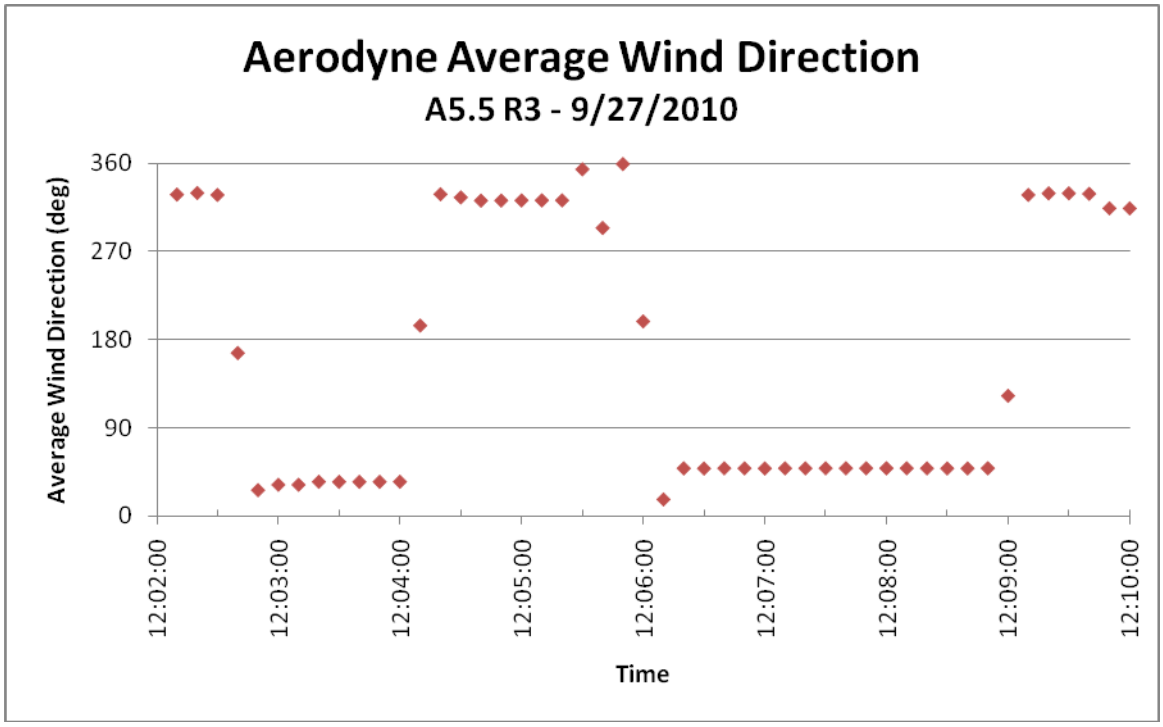


Figure J-97b. Wind Direction vs Time for Air Flare Test A5.5 R3

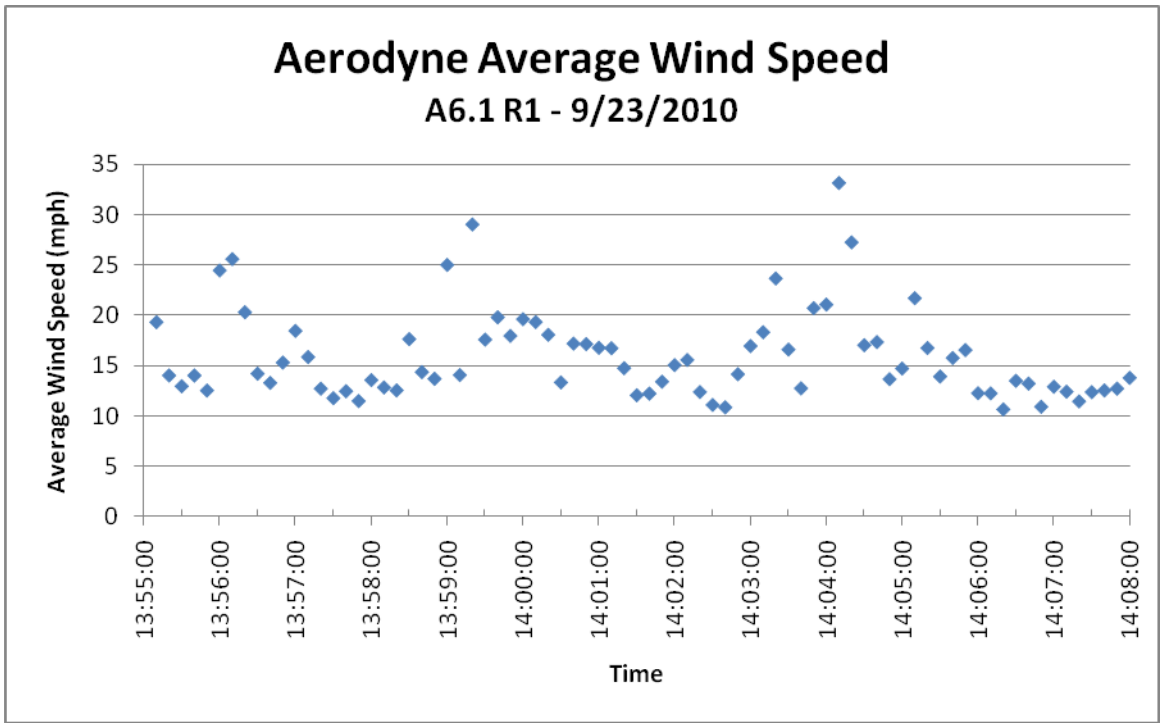


Figure J-98a. Wind Speed vs Time for Air Flare Test A6.1 R1

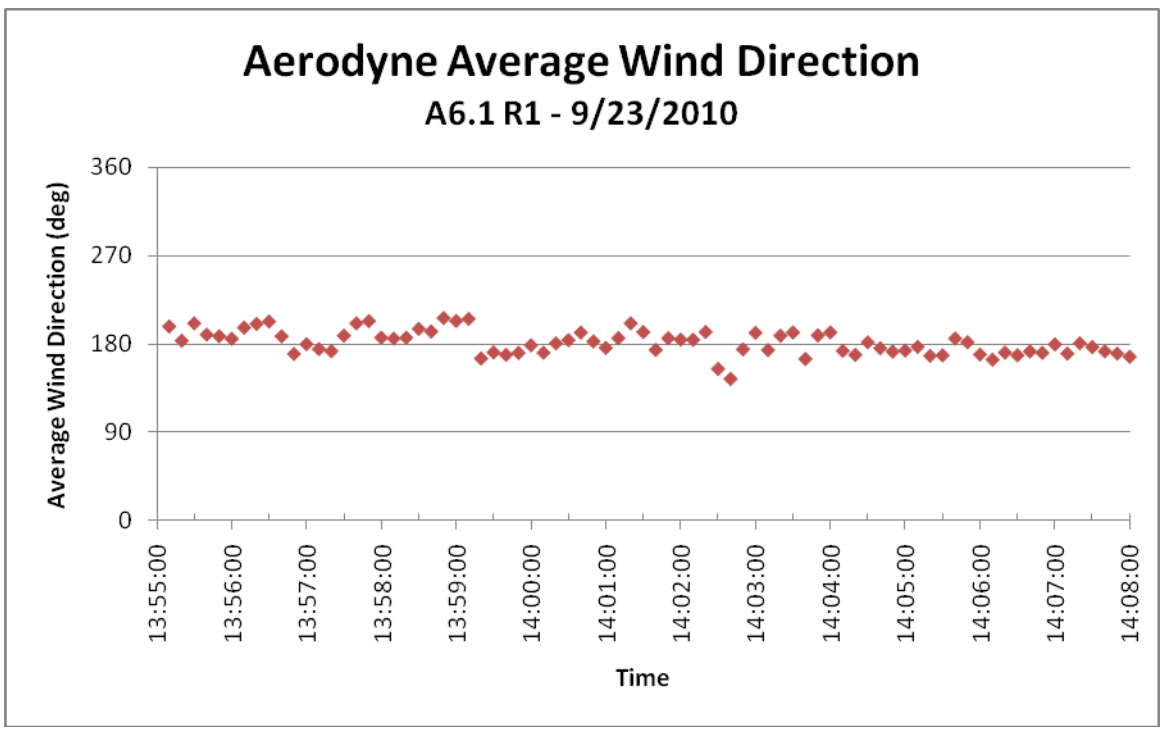
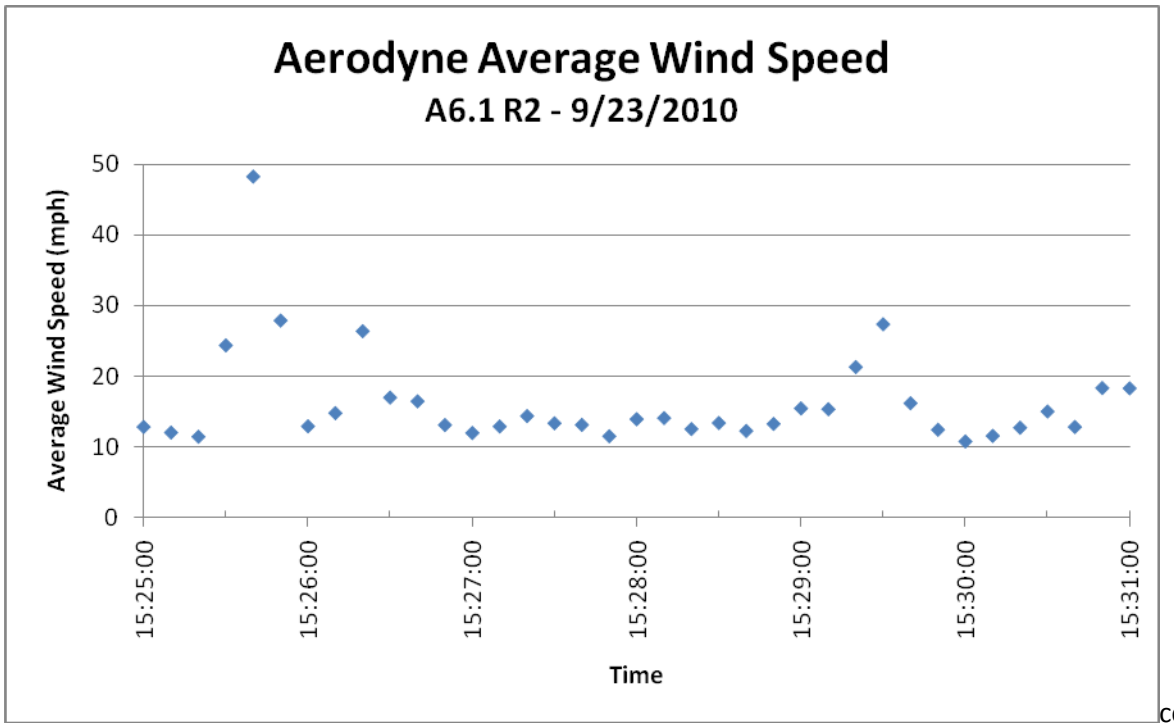


Figure J-98b. Wind Direction vs Time for Air Flare Test A6.1 R1



ccc

Figure J-99a. Wind Speed vs Time for Air Flare Test A6.1 R2

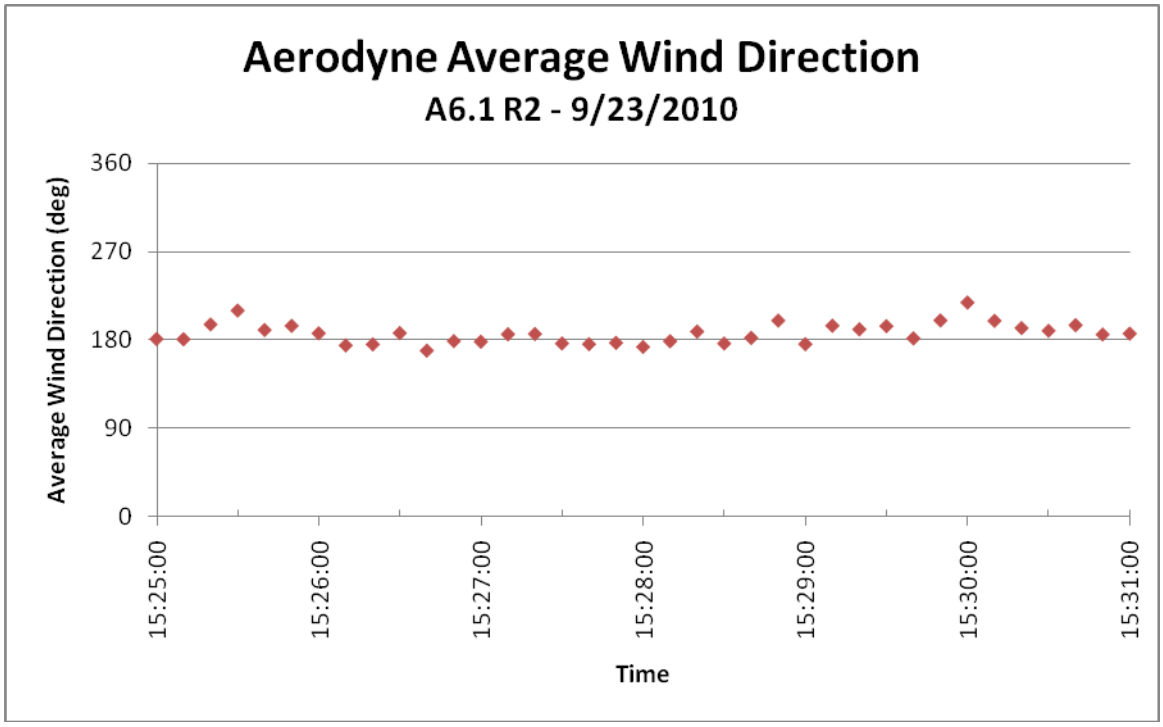


Figure J-99b. Wind Direction vs Time for Air Flare Test A6.1 R2

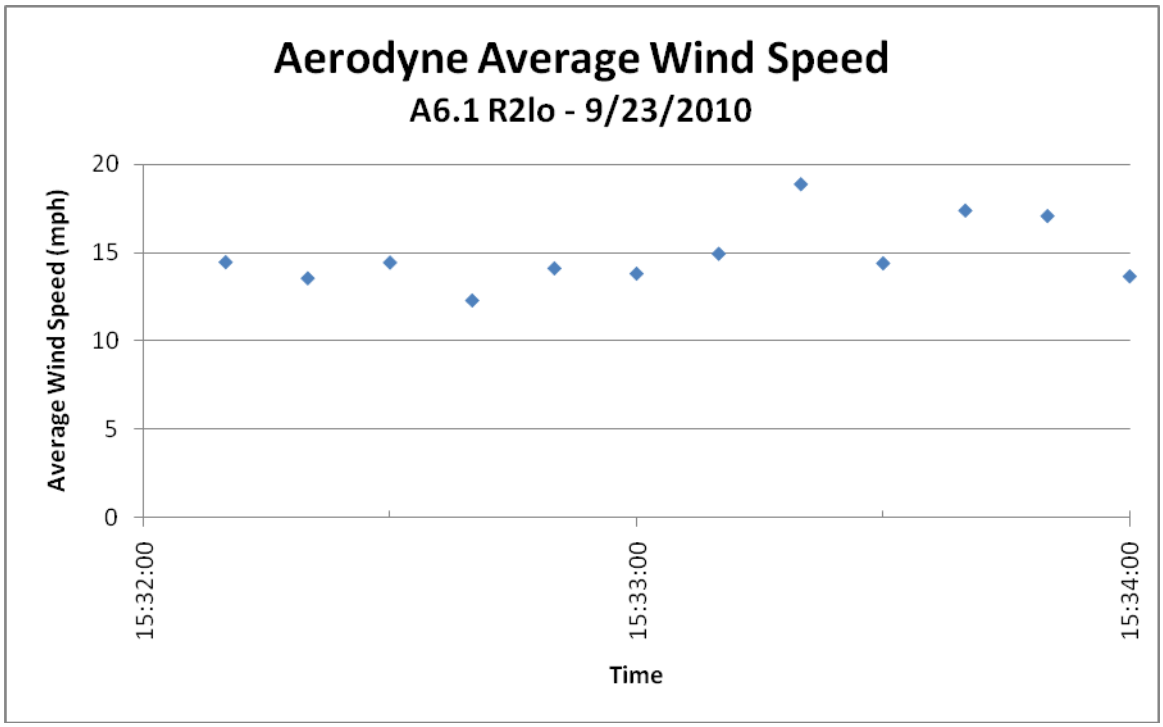


Figure J-100a. Wind Speed vs Time for Air Flare Test A6.1 R2lo

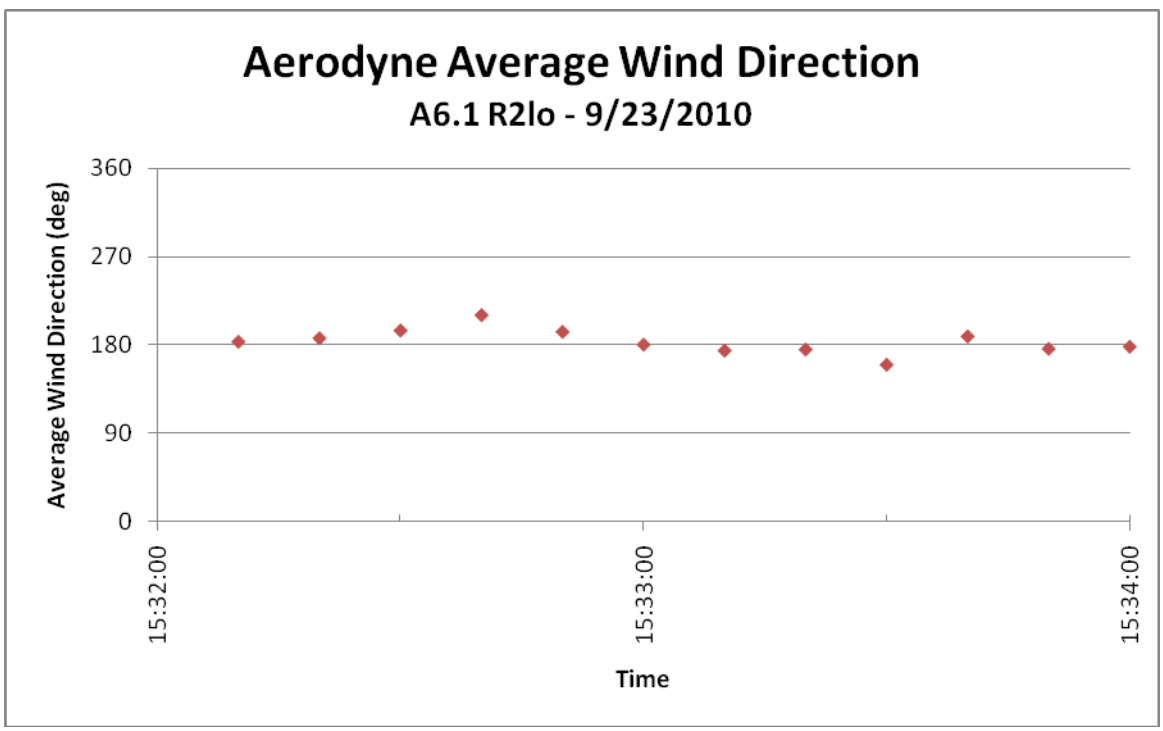


Figure J-100b. Wind Direction vs Time for Air Flare Test A6.1 R2lo

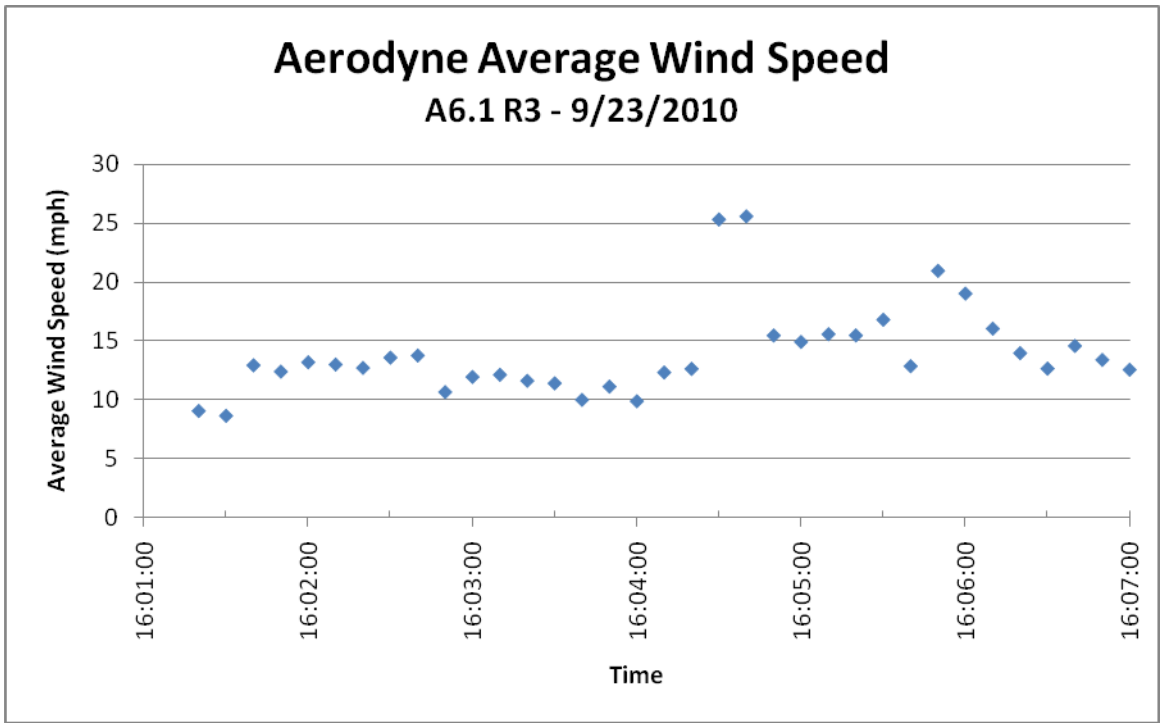


Figure J-101a. Wind Speed vs Time for Air Flare Test A6.1 R3

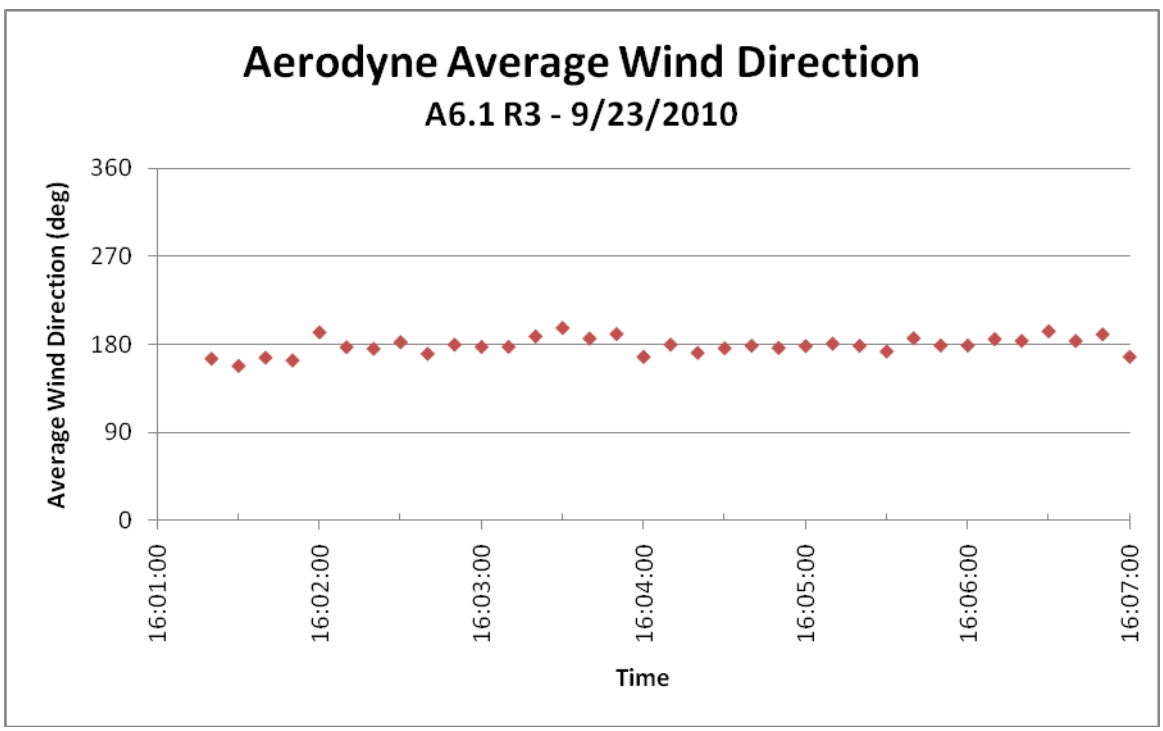


Figure J-101b. Wind Direction vs Time for Air Flare Test A6.1 R3

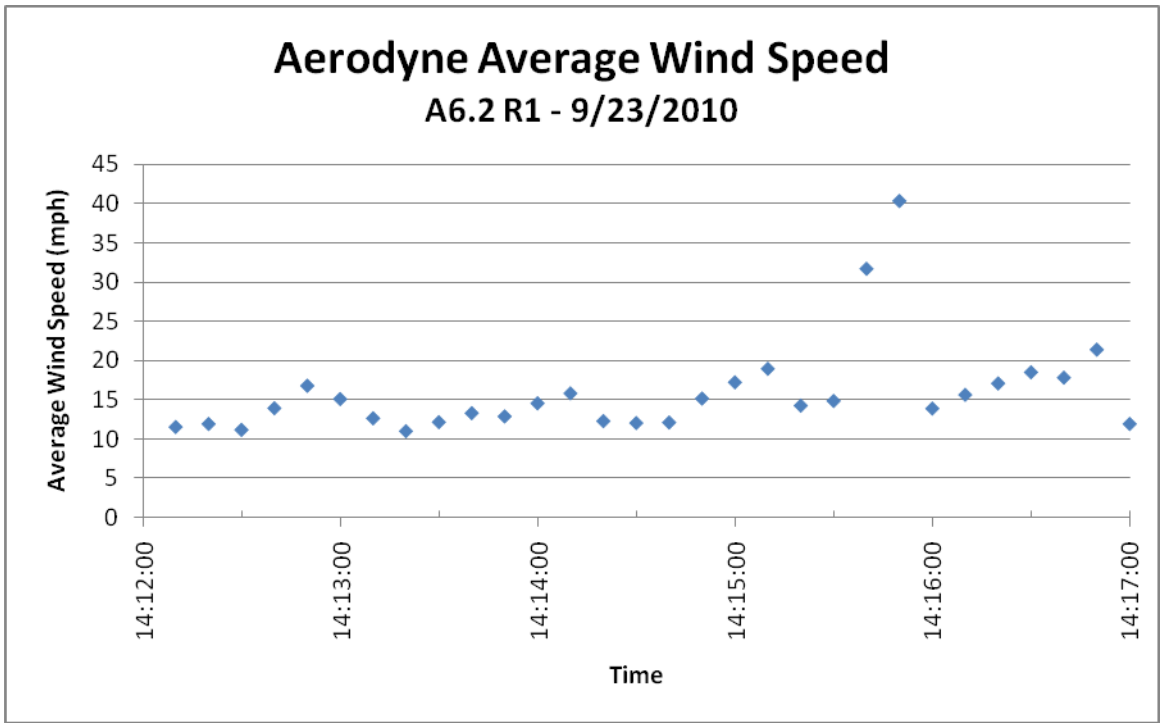


Figure J-102a. Wind Speed vs Time for Air Flare Test A6.2 R1

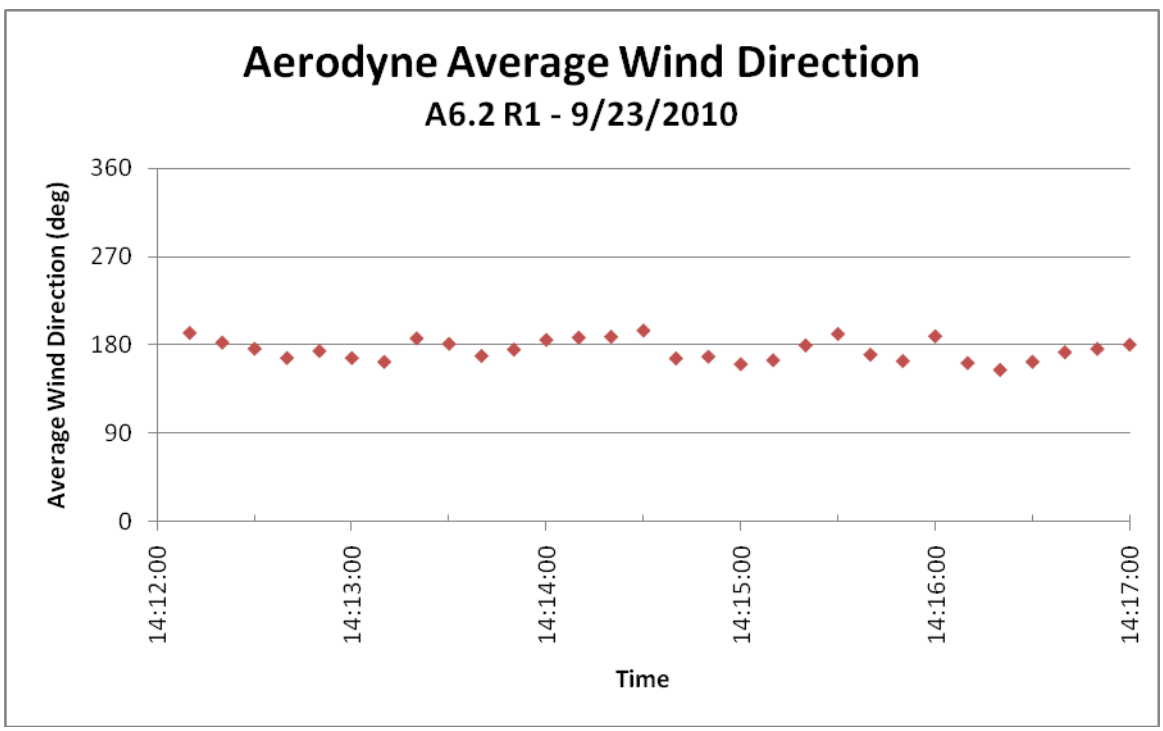


Figure J-102b. Wind Direction vs Time for Air Flare Test A6.2 R1

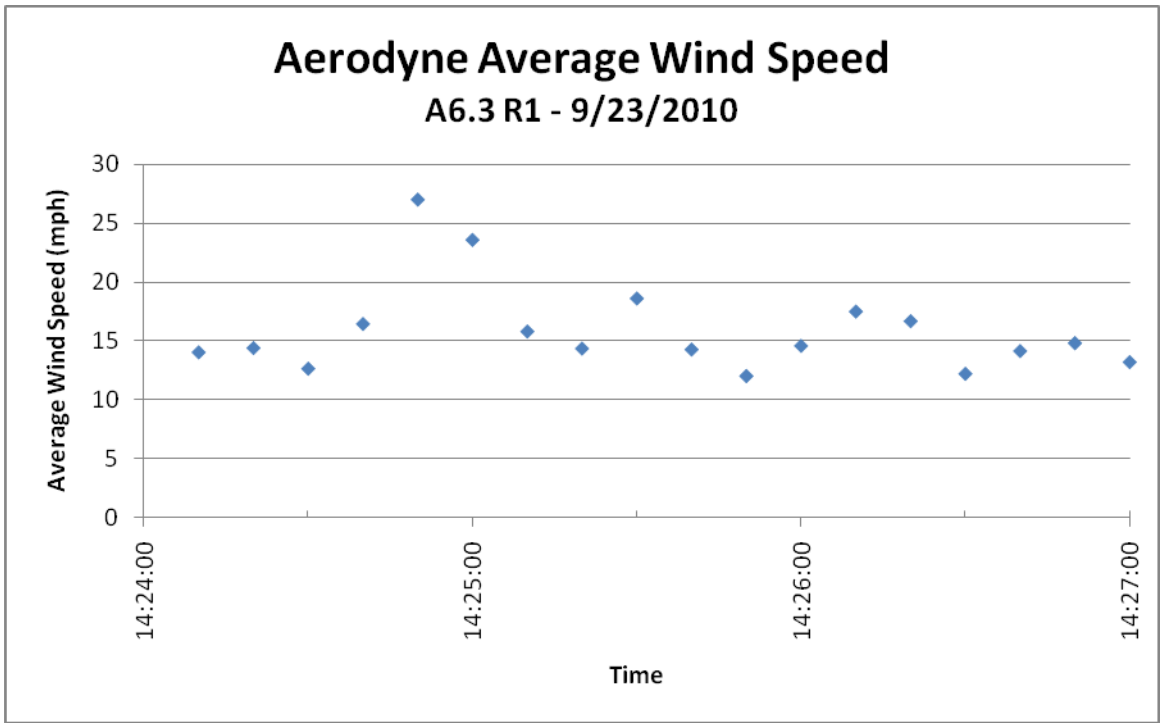


Figure J-103a. Wind Speed vs Time for Air Flare Test A6.3 R1

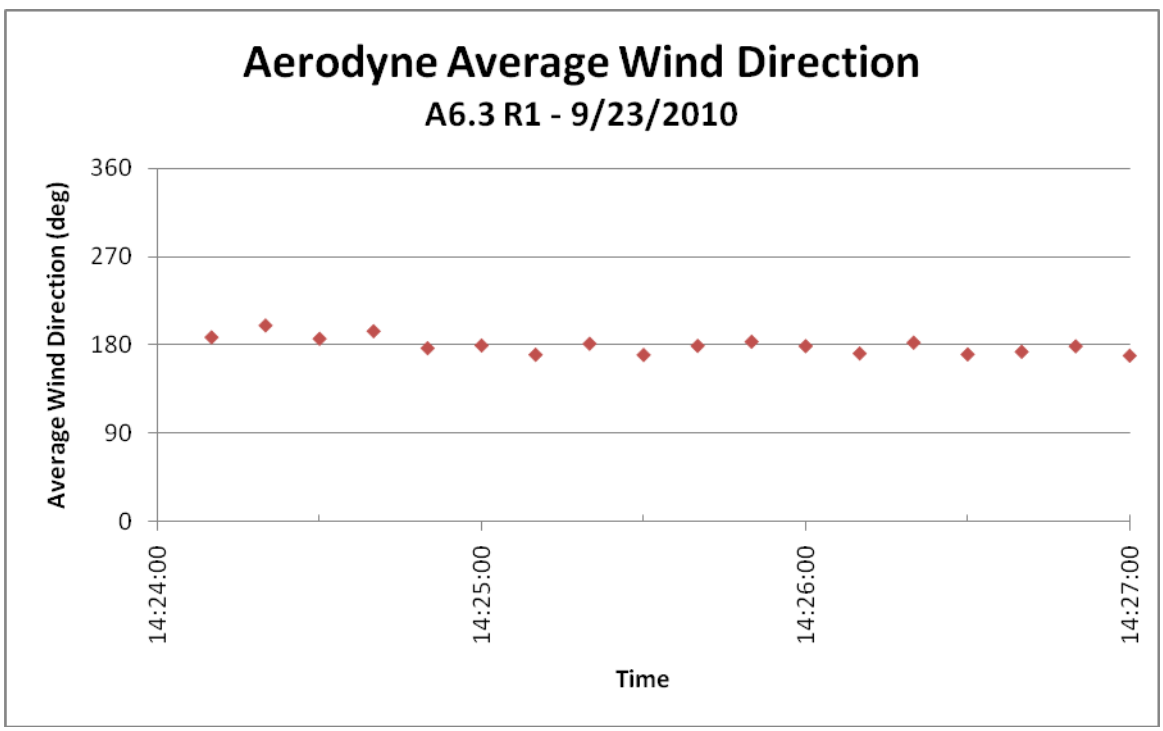


Figure J-103b. Wind Direction vs Time for Air Flare Test A6.3 R1

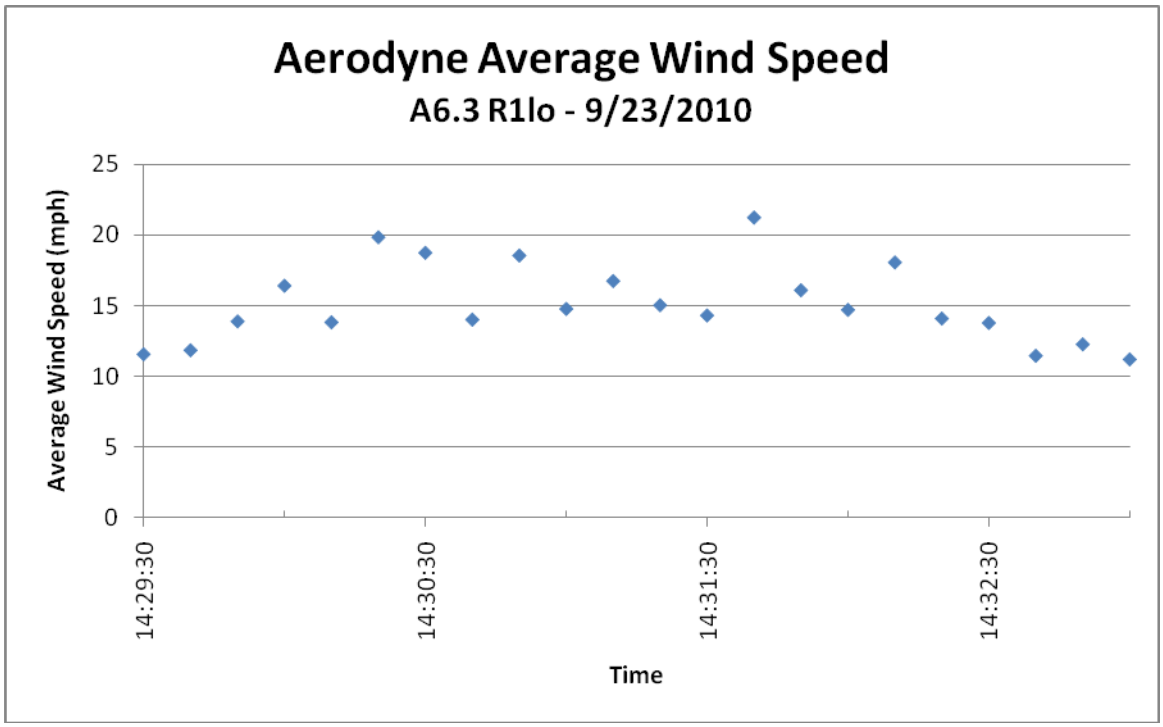


Figure J-104a. Wind Speed vs Time for Air Flare Test A6.3 R1lo

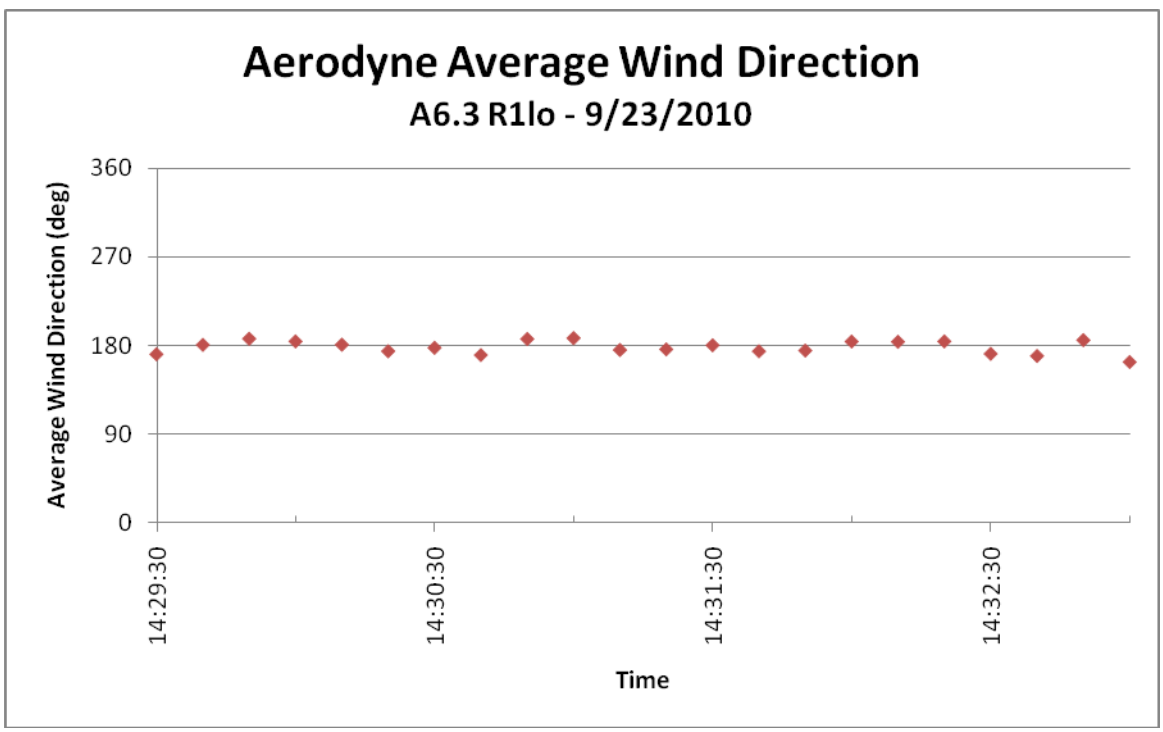


Figure J-104b. Wind Direction vs Time for Air Flare Test A6.3 R1lo

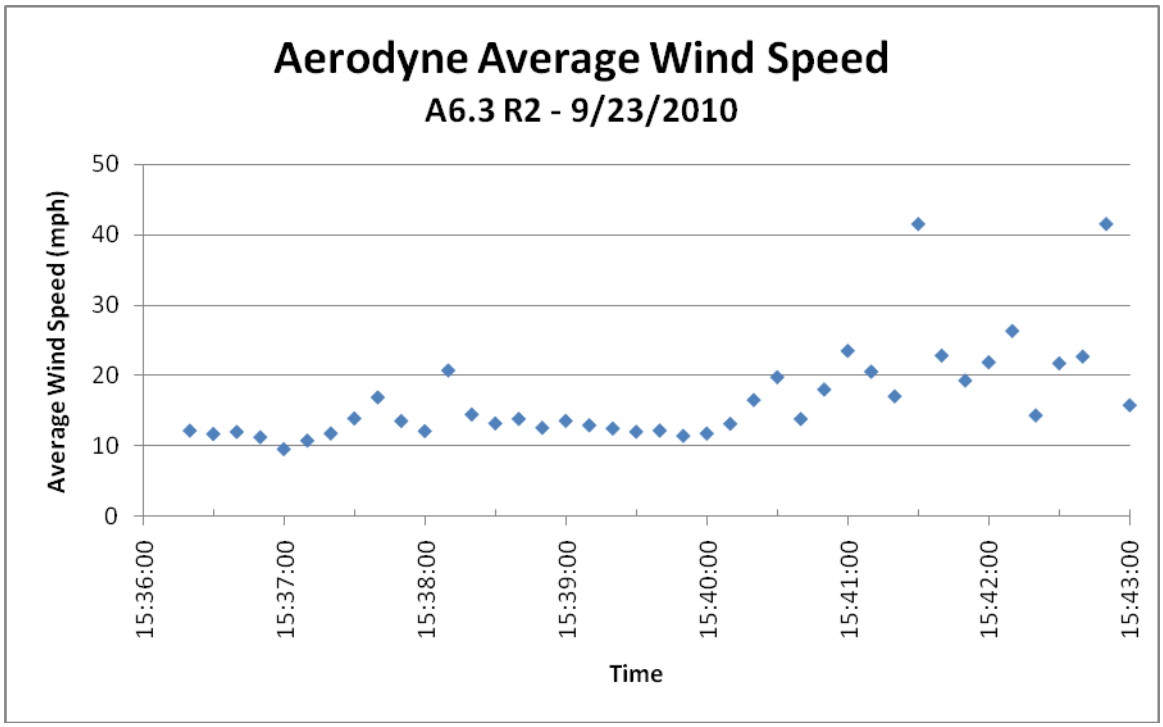


Figure J-105a. Wind Speed vs Time for Air Flare Test A6.3 R2

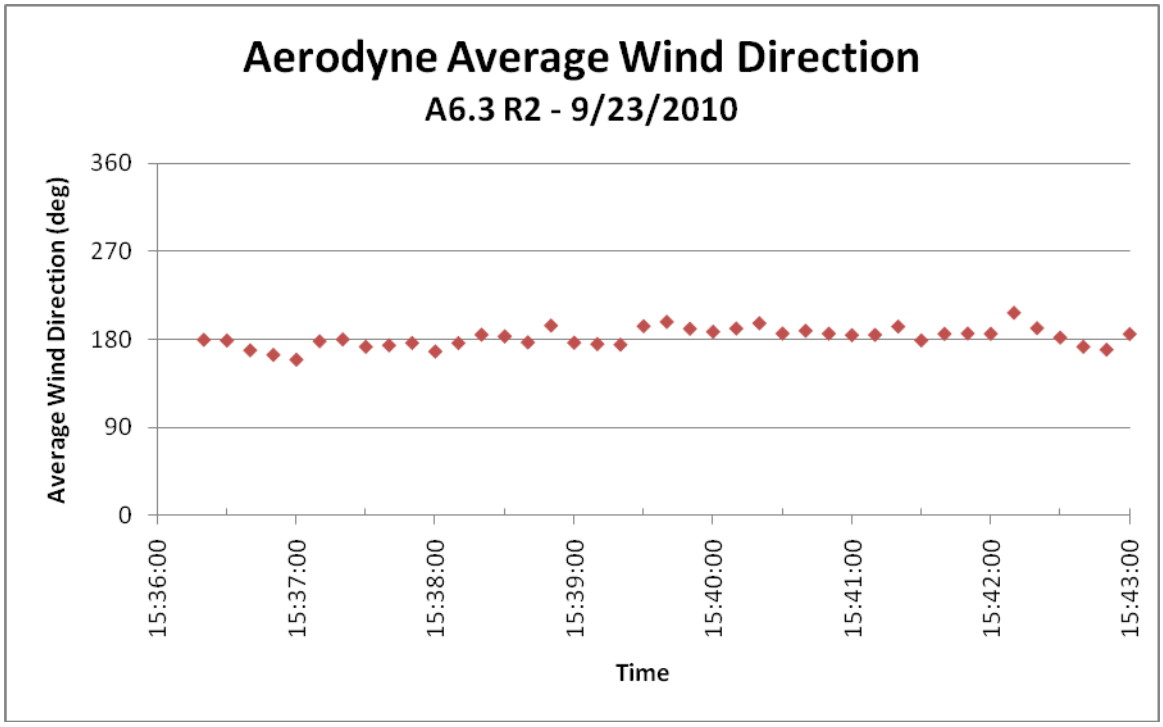


Figure J-105b. Wind Direction vs Time for Air Flare Test A6.3 R2

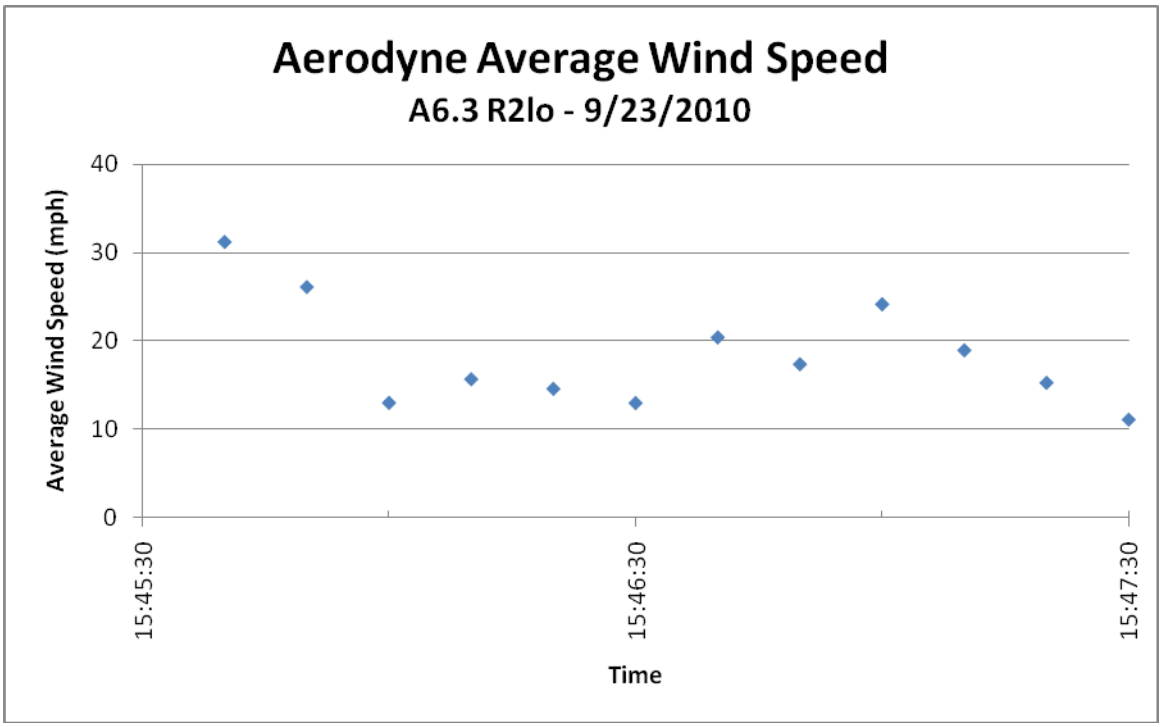


Figure J-106a. Wind Speed vs Time for Air Flare Test A6.3 R2lo

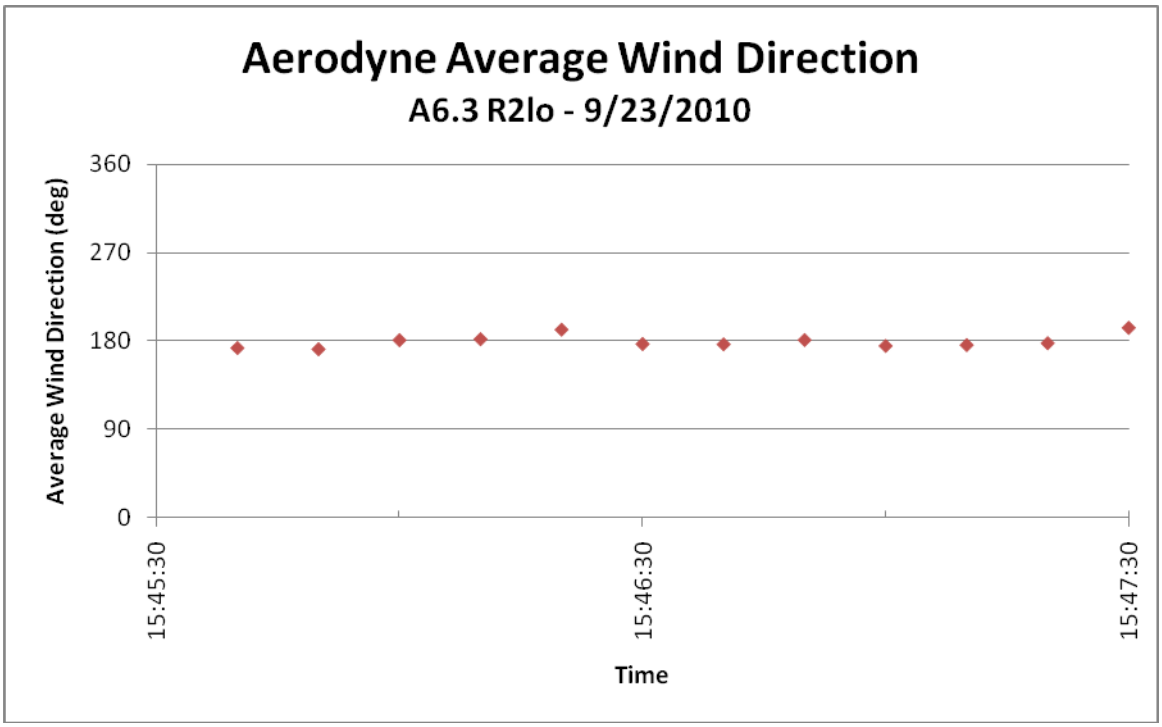


Figure J-106b. Wind Direction vs Time for Air Flare Test A6.3 R2lo

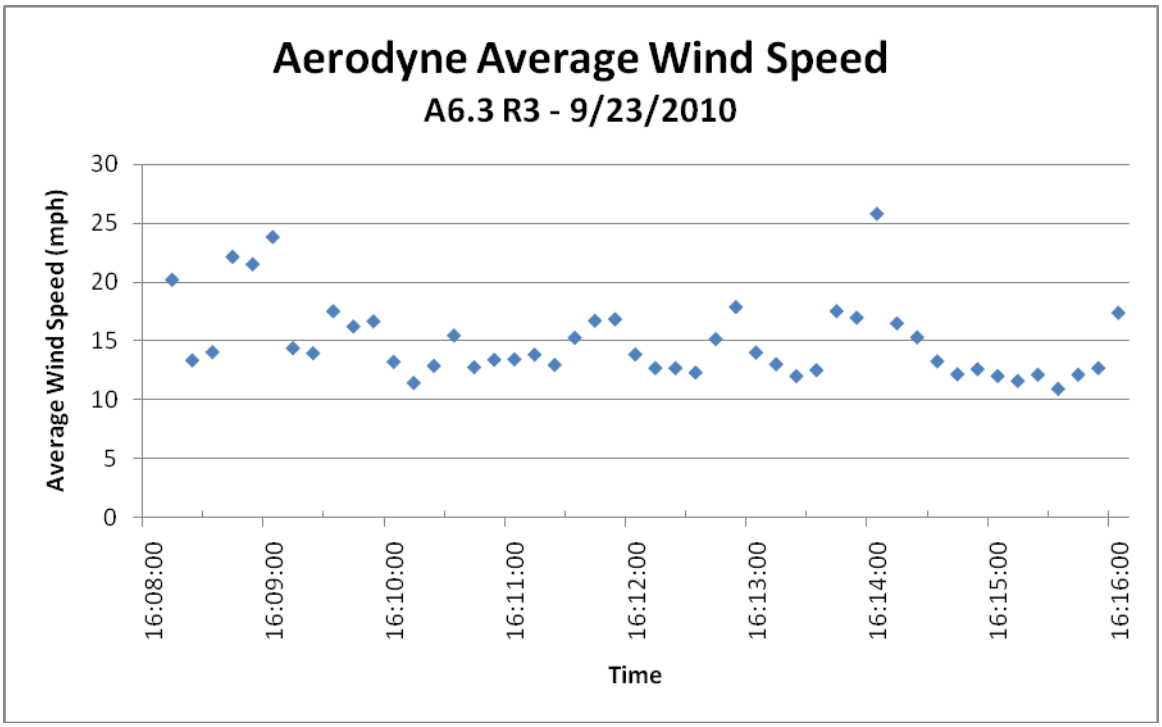


Figure J-107a. Wind Speed vs Time for Air Flare Test A6.3 R3

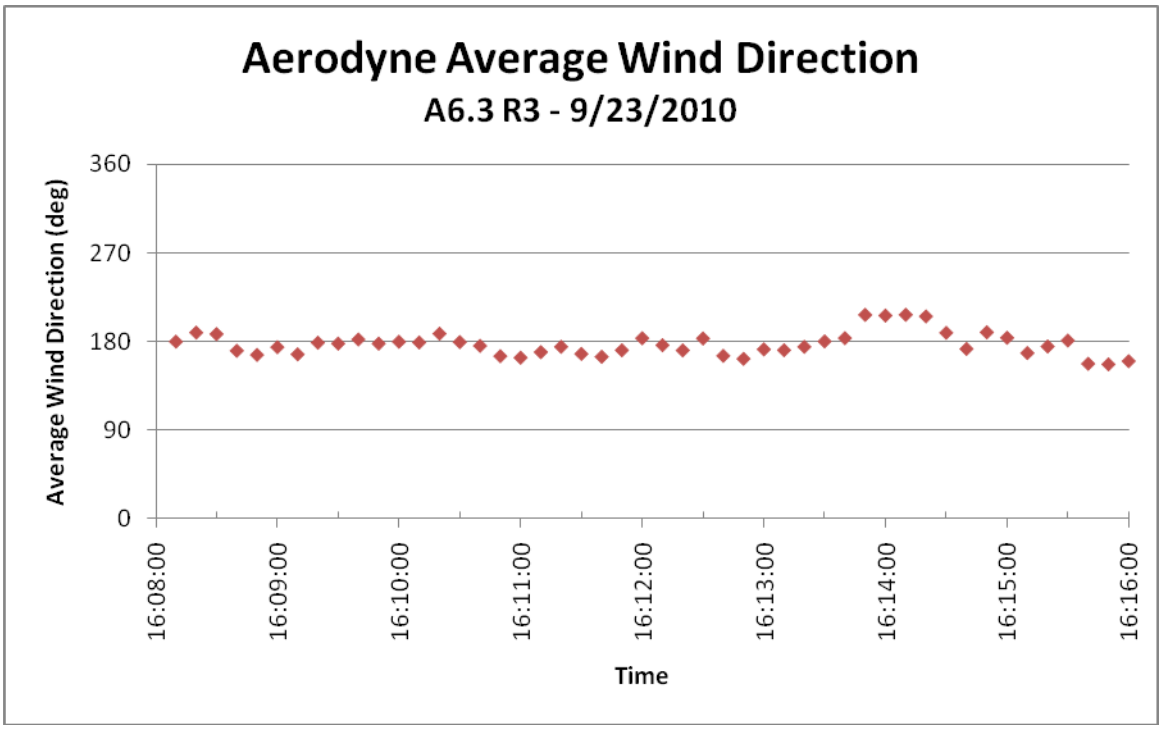


Figure J-107b. Wind Direction vs Time for Air Flare Test A6.3 R3

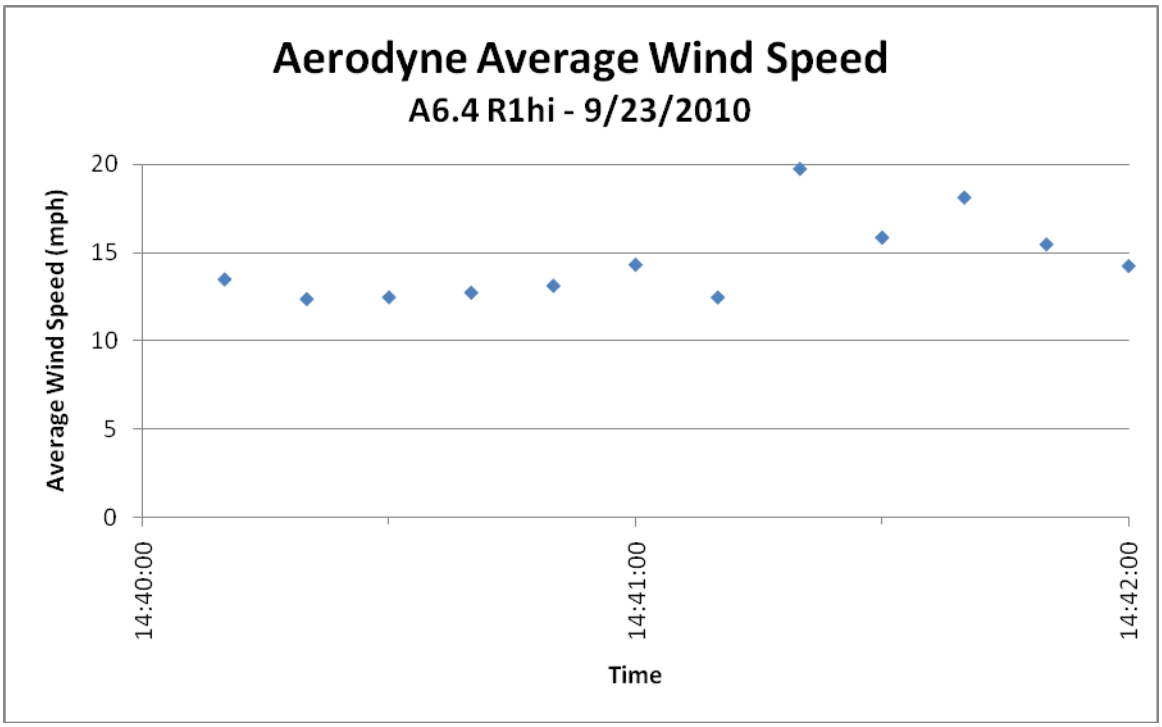


Figure J-108a. Wind Speed vs Time for Air Flare Test A6.4 R1hi

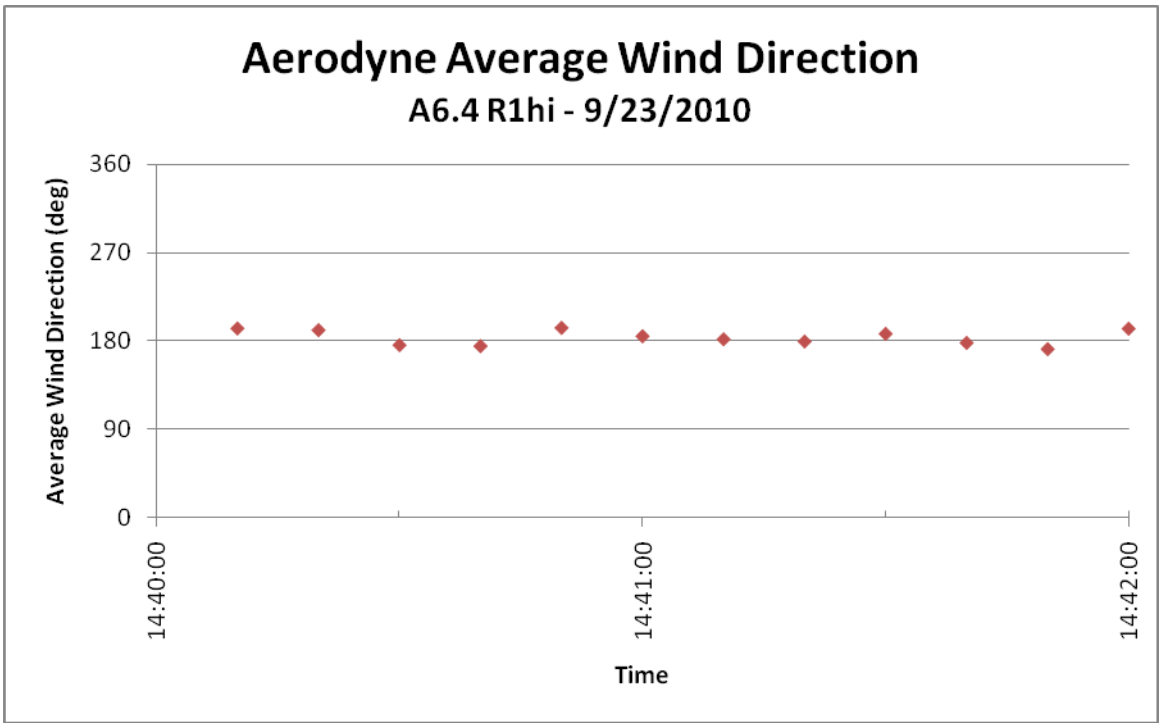


Figure J-108b. Wind Direction vs Time for Air Flare Test A6.4 R1hi

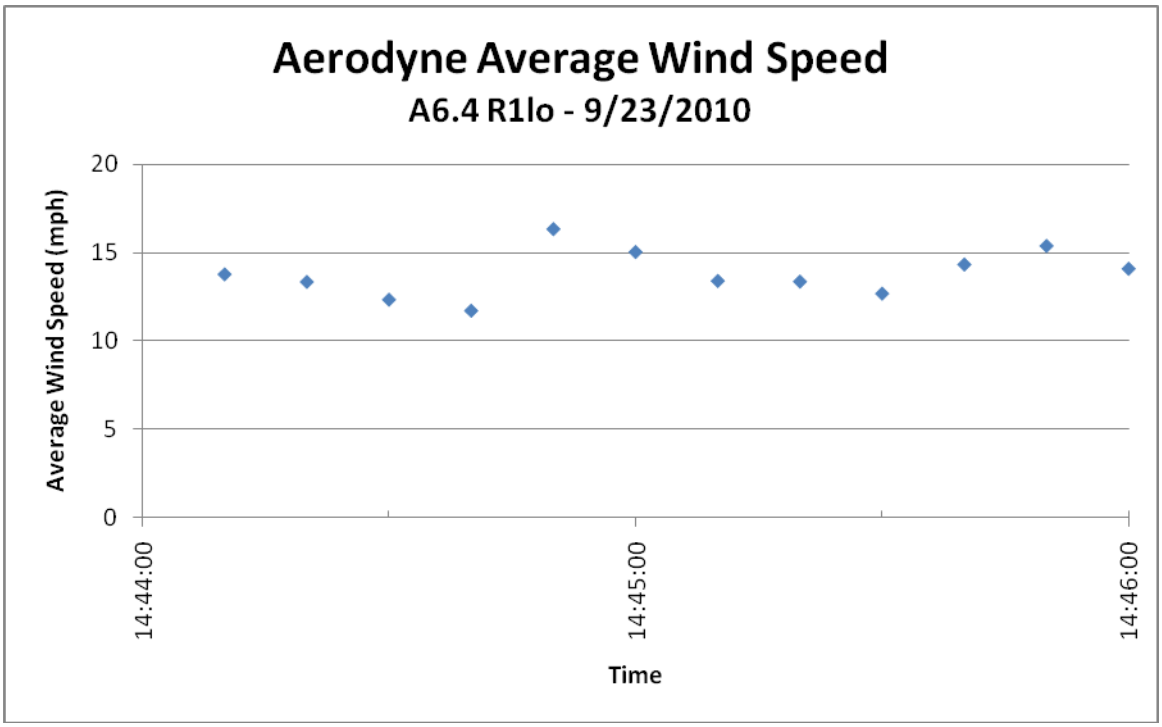


Figure J-109a. Wind Speed vs Time for Air Flare Test A6.4 R1lo

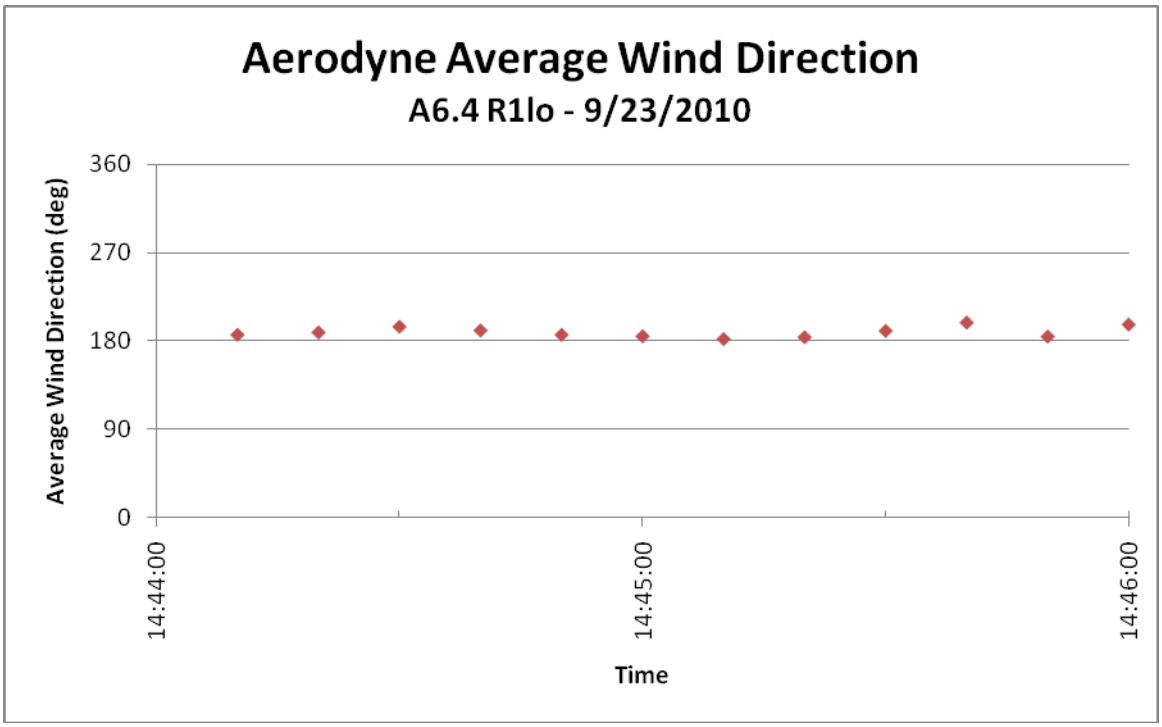


Figure J-109b. Wind Direction vs Time for Air Flare Test A6.4 R1lo

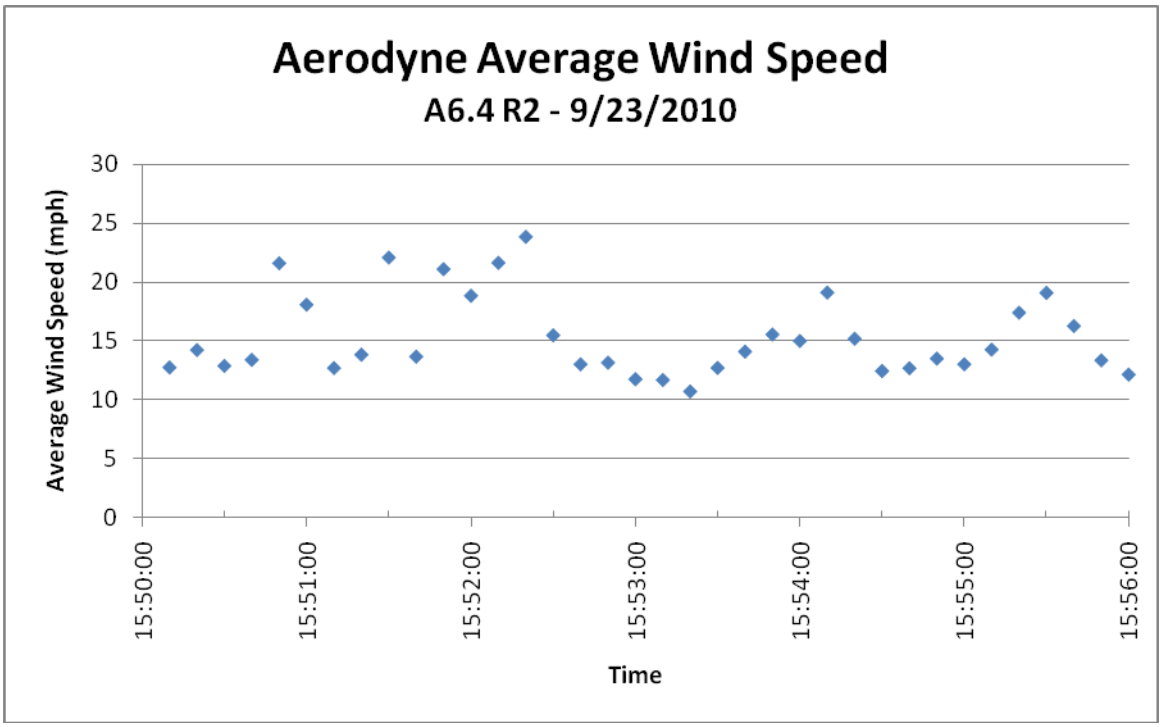


Figure J-110a. Wind Speed vs Time for Air Flare Test A6.4 R2

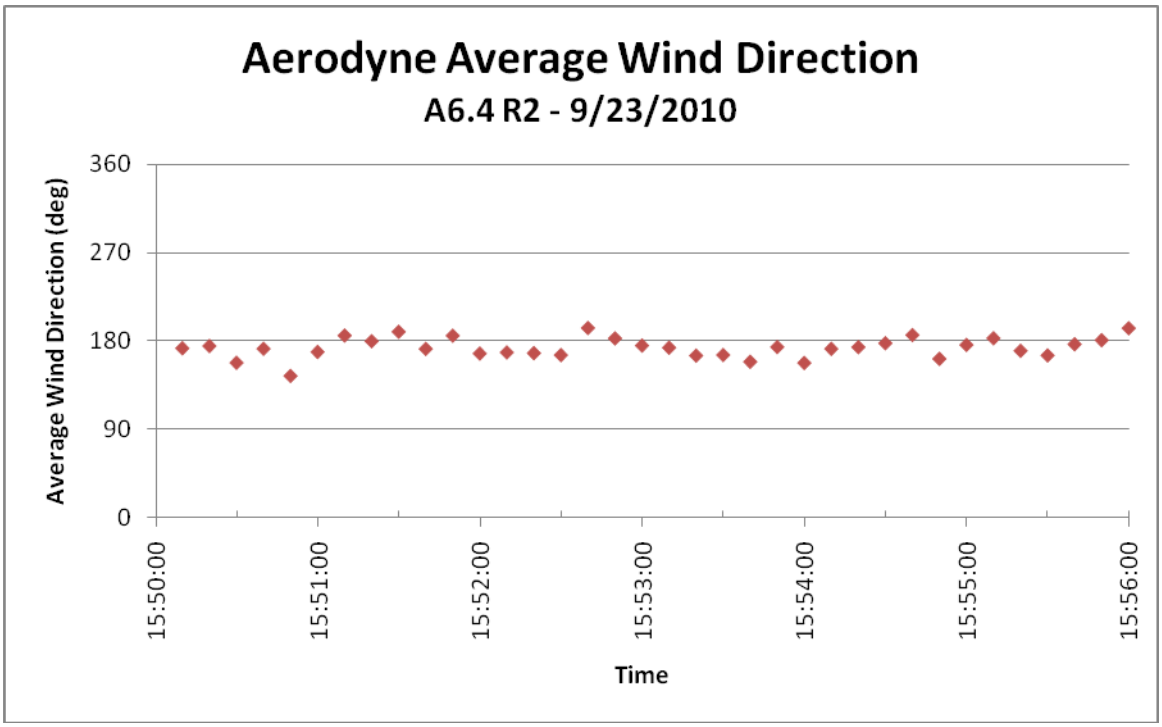


Figure J-110b. Wind Direction vs Time for Air Flare Test A6.4 R2

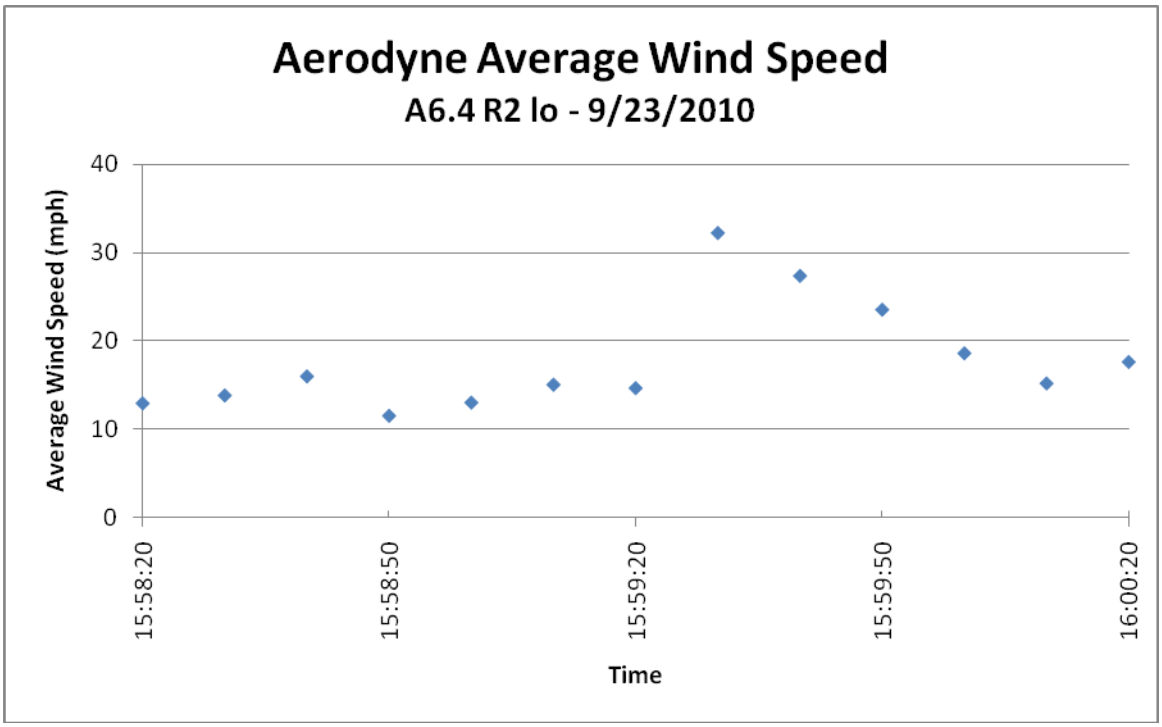


Figure J-111a. Wind Speed vs Time for Air Flare Test A6.4 R2lo

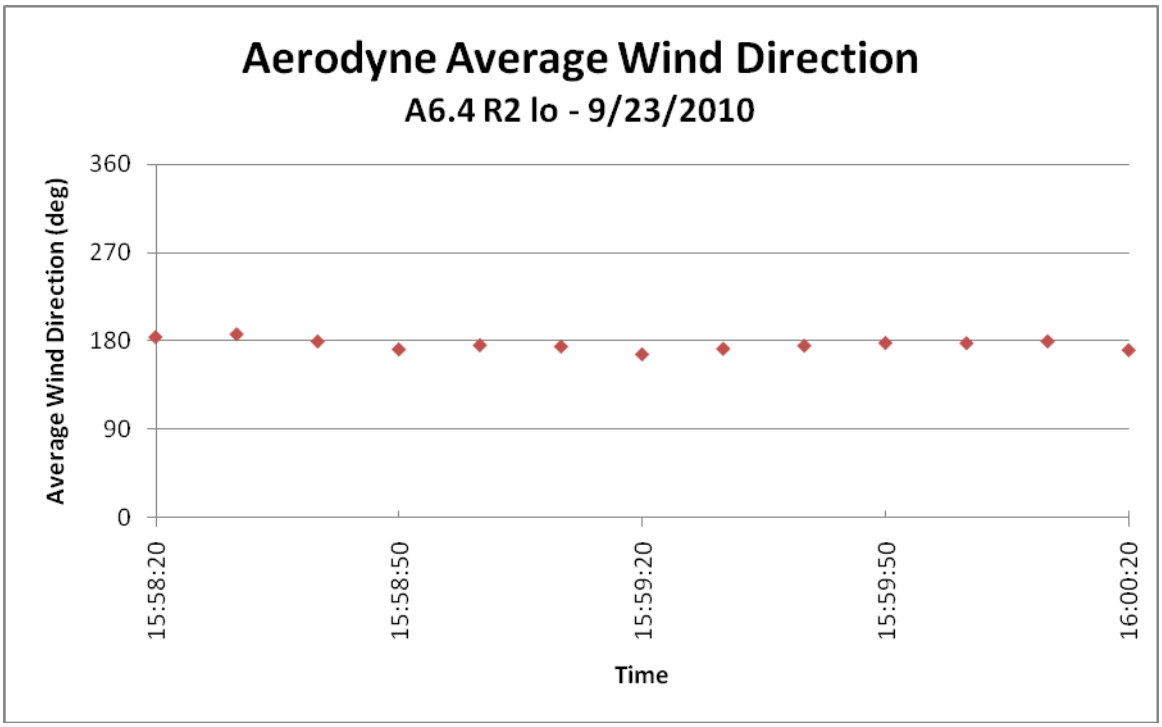


Figure J-111b. Wind Direction vs Time for Air Flare Test A6.4 R2lo

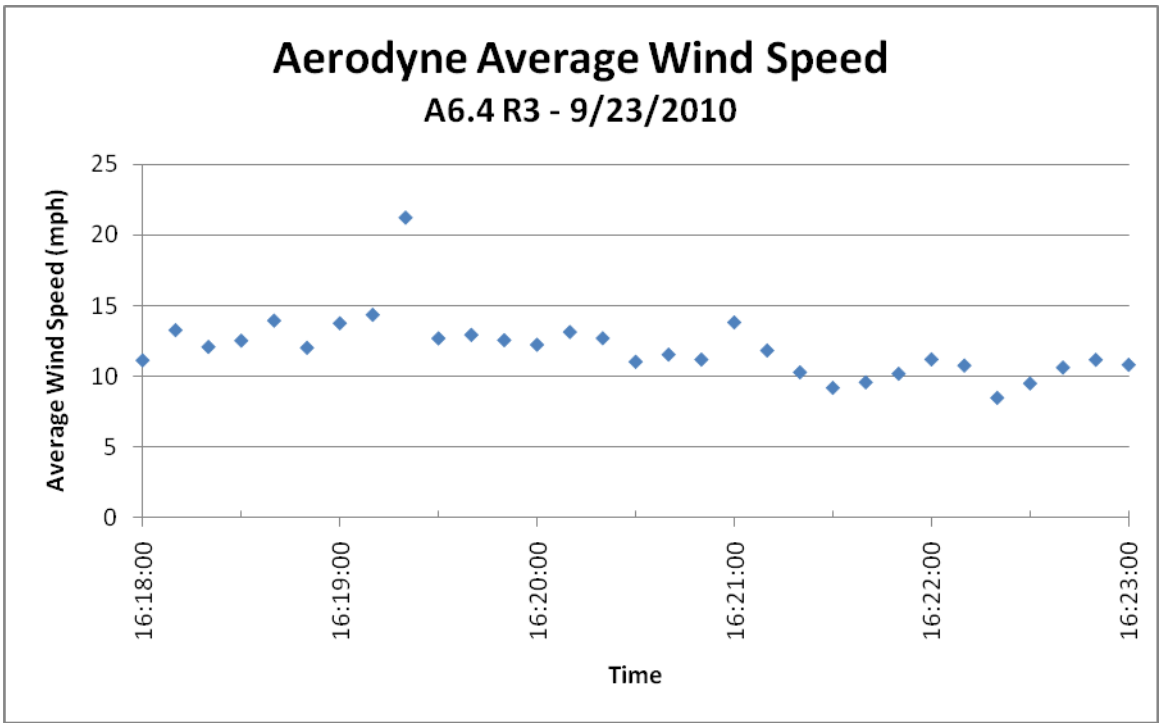


Figure J-112a. Wind Speed vs Time for Air Flare Test A6.4 R3

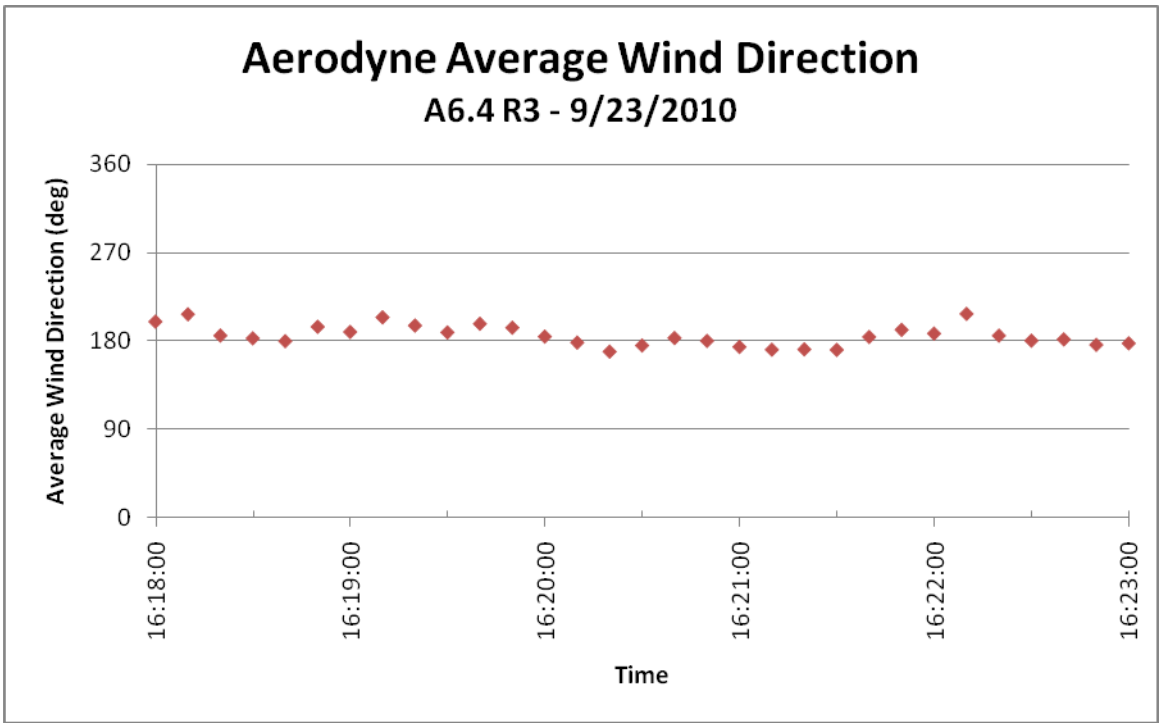


Figure J-112b. Wind Direction vs Time for Air Flare Test A6.4 R3

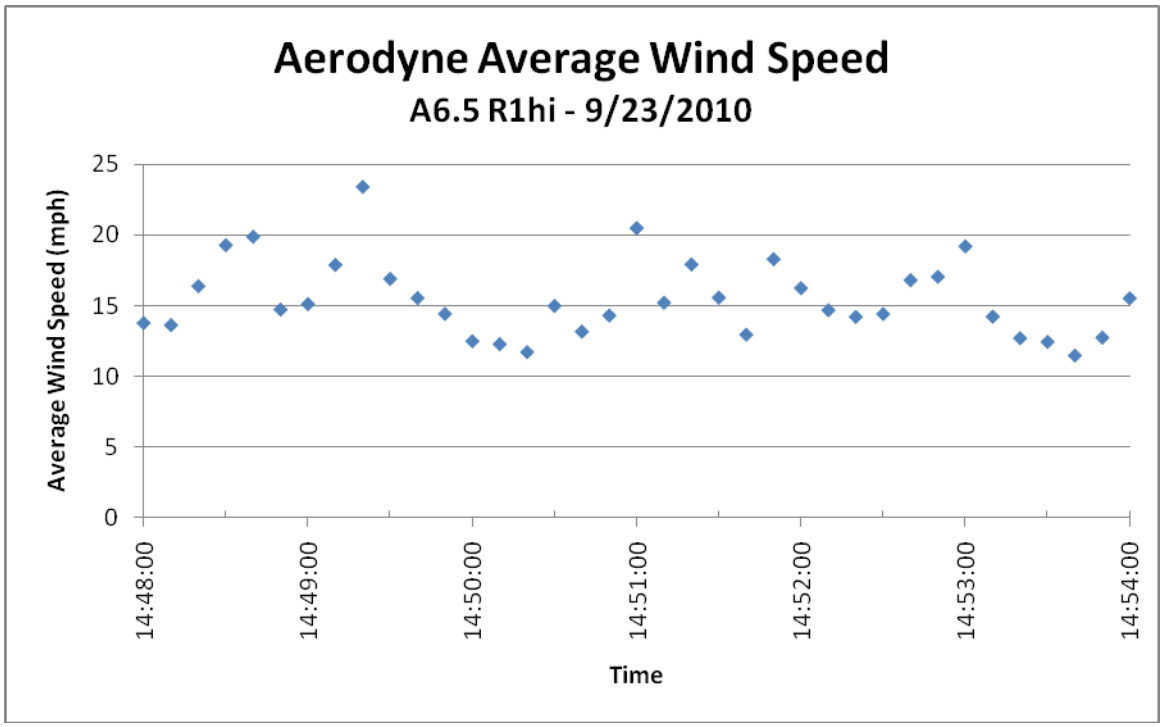


Figure J-113a. Wind Speed vs Time for Air Flare Test A6.5 R1hi

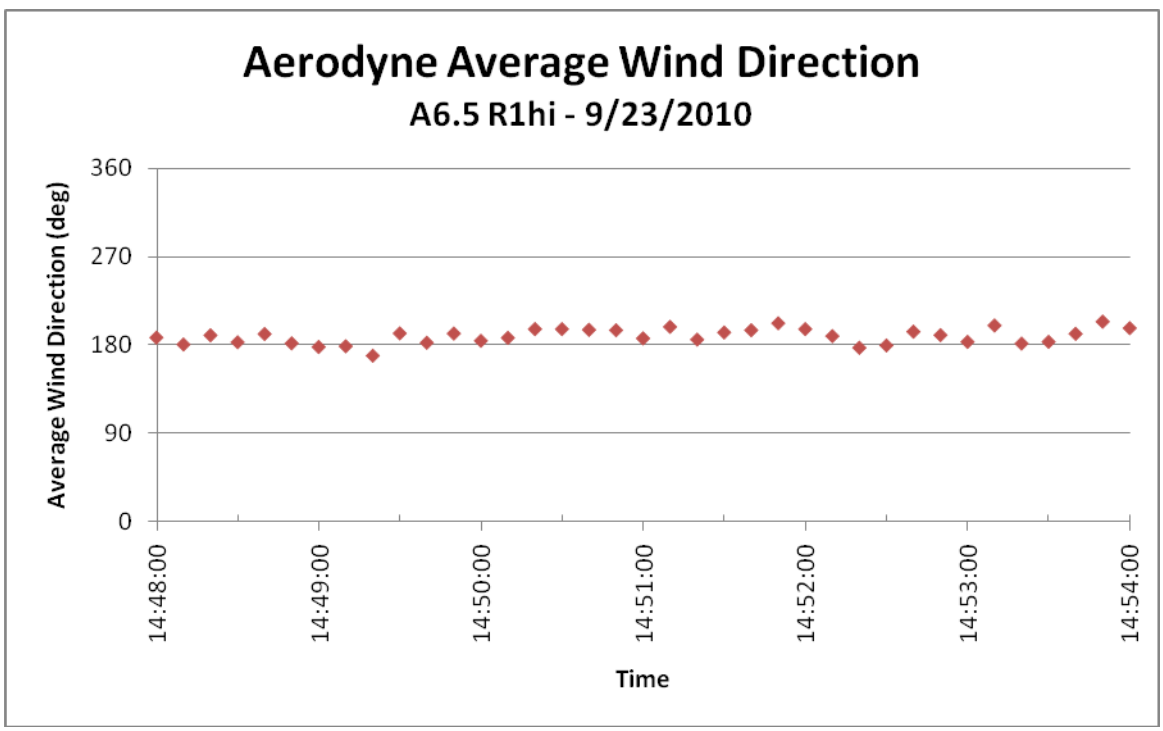


Figure J-113b. Wind Direction vs Time for Air Flare Test A6.5 R1hi

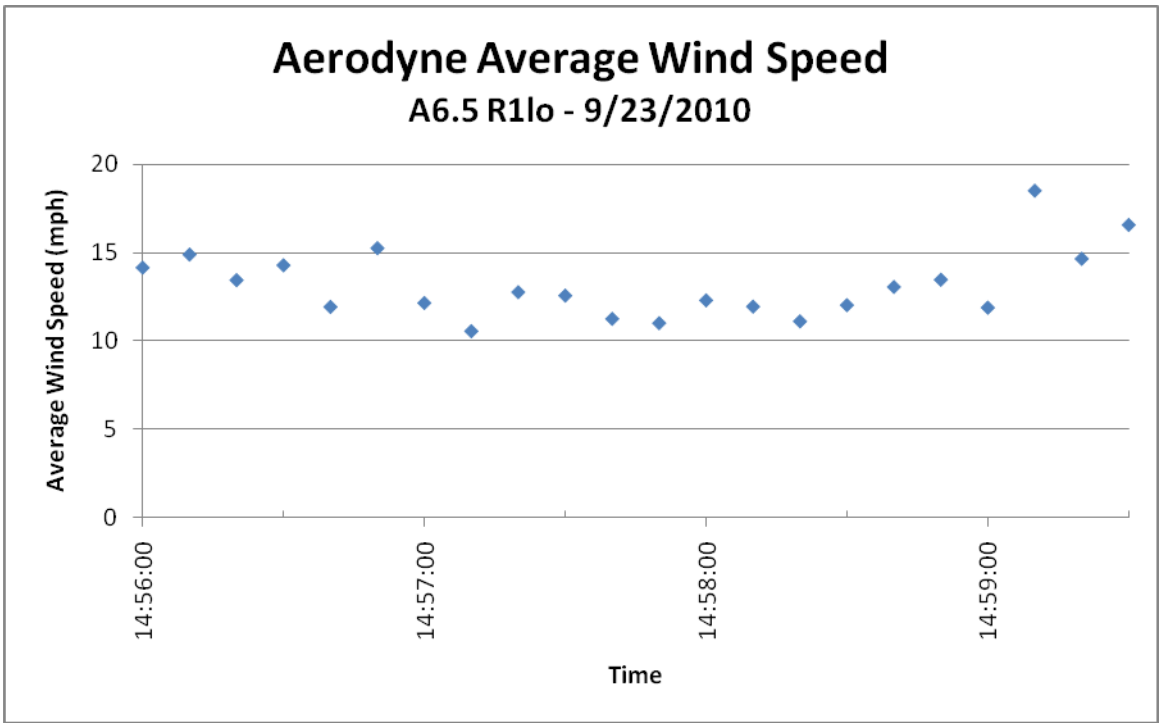


Figure J-114a. Wind Speed vs Time for Air Flare Test A6.5 R1lo

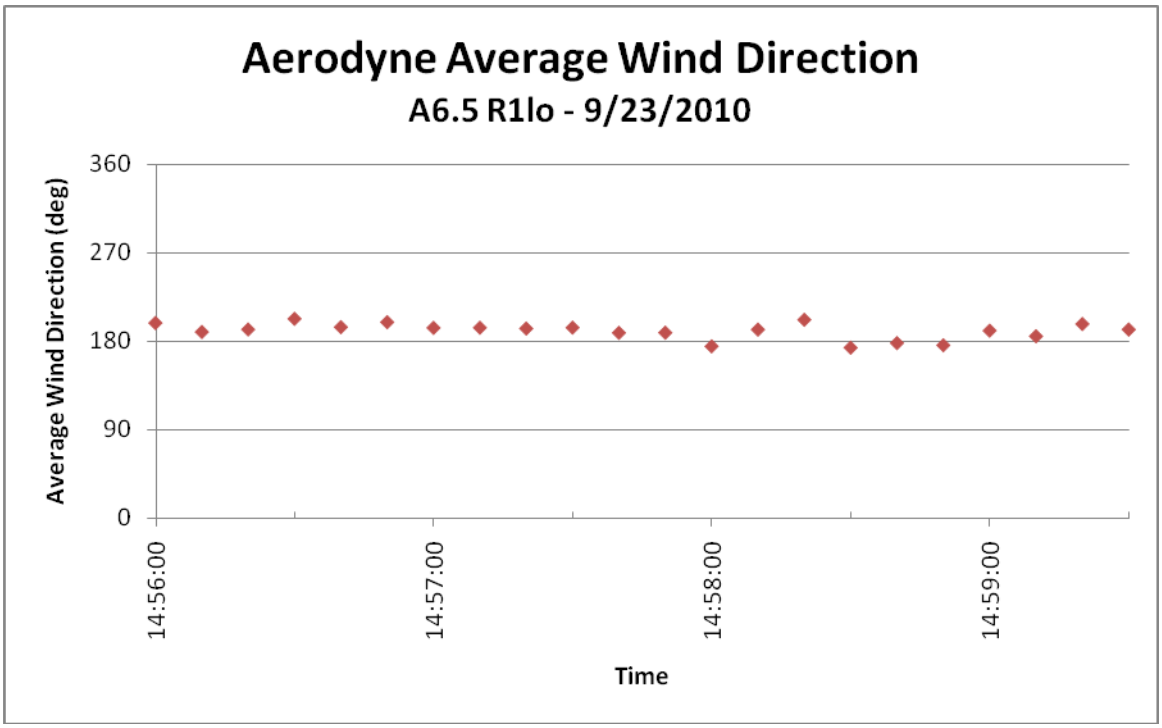


Figure J-114b. Wind Direction vs Time for Air Flare Test A6.5 R1lo

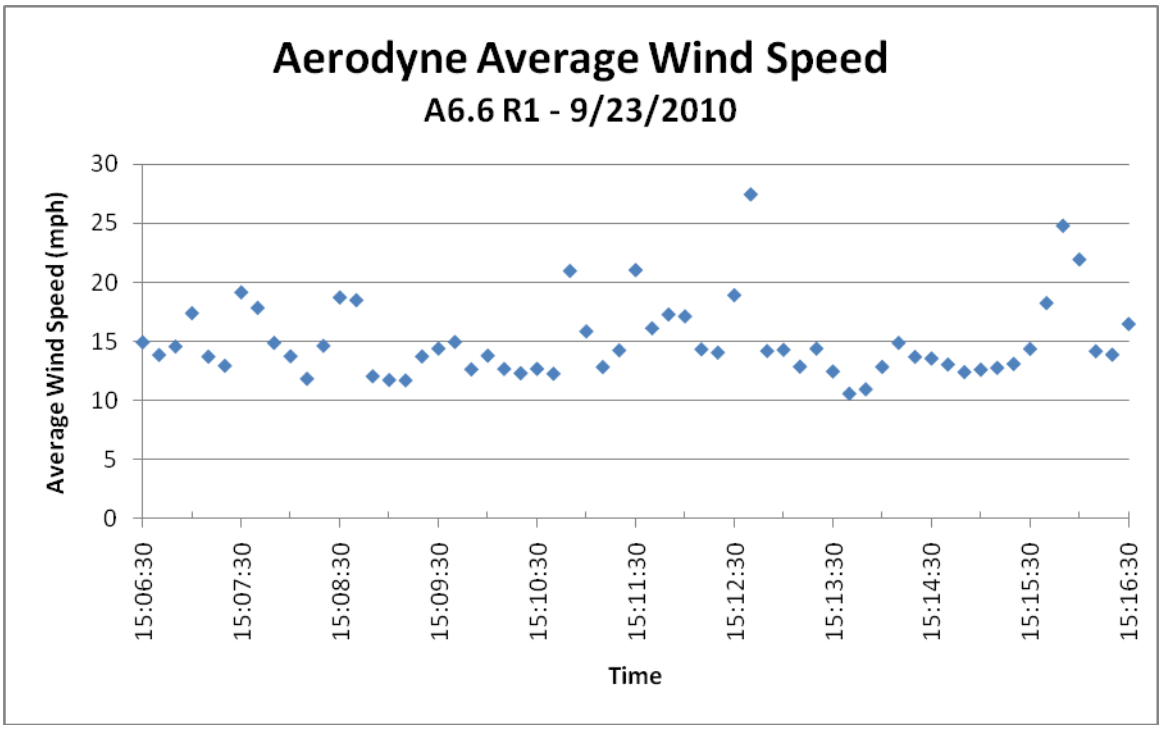


Figure J-115a. Wind Speed vs Time for Air Flare Test A6.6 R1

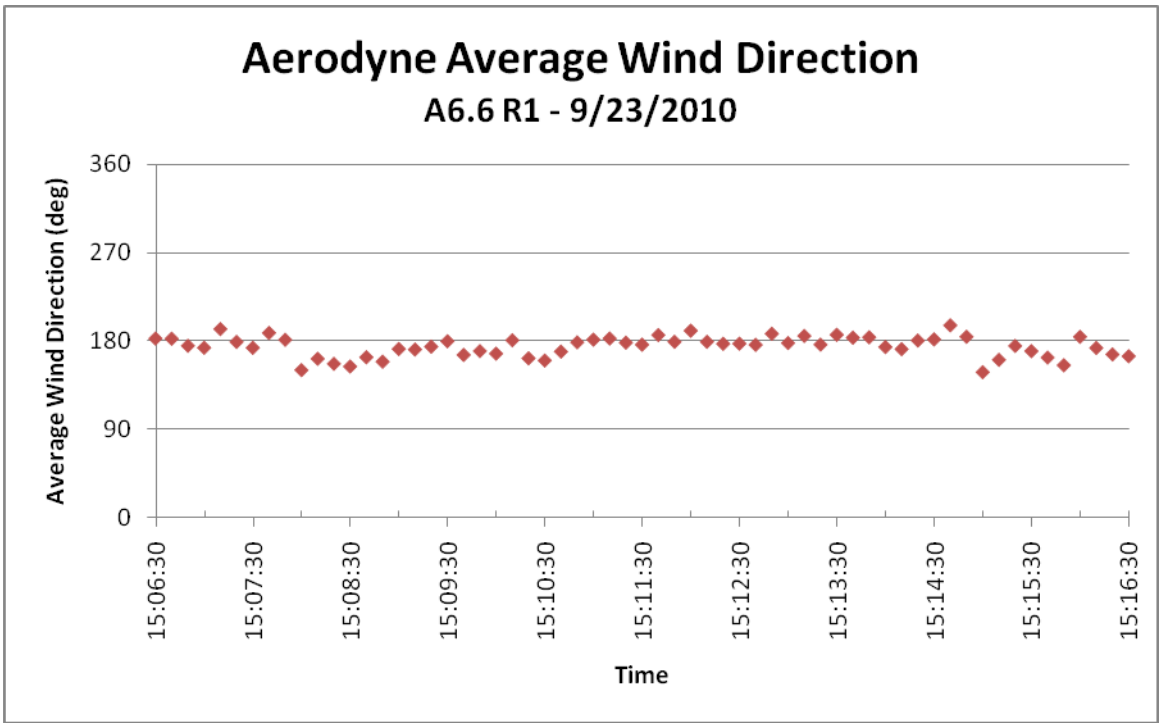


Figure J-115b. Wind Direction vs Time for Air Flare Test A6.6 R1

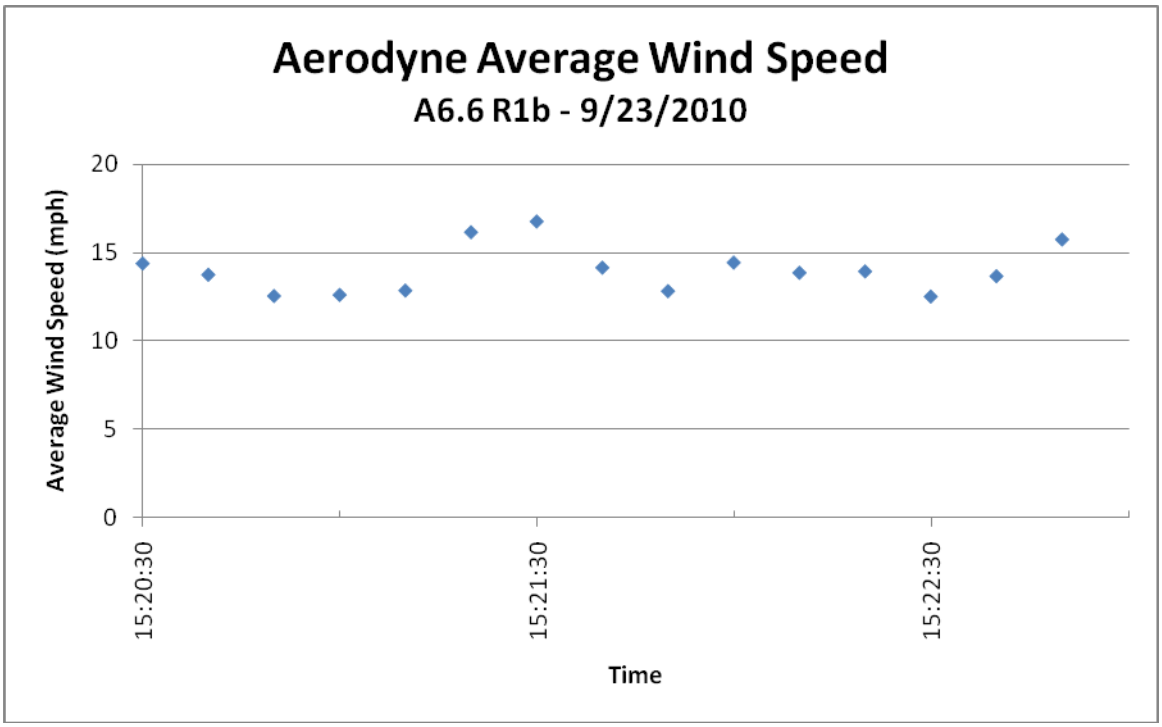


Figure J-116a. Wind Speed vs Time for Air Flare Test A6.6 R1b

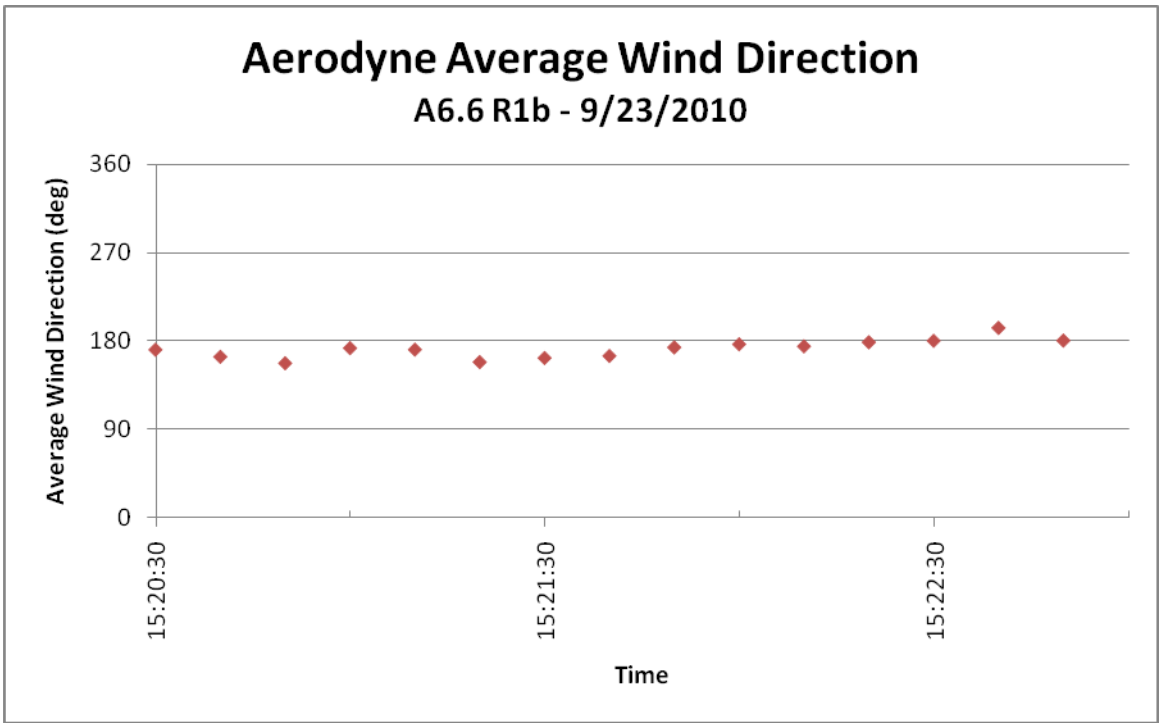


Figure J-116b. Wind Direction vs Time for Air Flare Test A6.6 R1b

Appendix K

Quality Assurance Program and Documentation

Overview of Quality Assurance Program

The quality assurance program for this study consisted of four components: Overall Quality Assurance Coordination (UT Austin), Flare Test System Operation and Instrumentation (John Zink Company, LLC), Extractive Sampling of the Inlet Vent Gas Flow and Flare Plume (Aerodyne Research Incorporated and TRC), and Remote Sensing Technology Measurements fComparison (Industrial Monitor and Control Corporation and Telops).

Methods/ Methodology

UT Austin
UT Austin prepared the Quality Assurance Project Plan (QAPP) for the study and ensured that it was followed during the field tests and analysis of data at UT Austin. During the field tests, UT Austin verified each day that calibrations of instruments or span checks were performed at the intervals specified in the QAPP or entertained exceptions, if necessary. No exceptions to the QAPP were requested during the field tests. In addition, UT Austin ensured that the field tests were performed as specified in the test plan or that the Test Plan Modification Procedure in the QAPP was followed when modifications to the test plan were proposed. There were modifications to the test plan in the field and these modifications were approved and documented (See Test Plan – December 16, 2010) using the Test Plan Modification Procedure. UT Austin also ensured that data capture was coordinated through daily time synchronizations of instrument clocks each morning and time synchronization checks at the end of each day.

John Zink Company, LLC (Zink)
Only Zink personnel assembled, modified or operated equipment associated with the test flares. They also maintained control from receipt through use, of all compressed gases used in flares and for their instrument calibrations, when required. They obtained factory calibrations prior to use and/or calibrated in the field all instruments used at the Zink Test Facility. Once a device was installed in the gas or steam system, the device was calibrated or accuracy verified by Zink instrumentation personnel. If a device was found to be out of specification, the device was replaced with another like device which was calibrated or verified and documentation of the calibration or verification process and results was included in their records/operator logs. Copies of all of these records are found in the John Zink Final Report to UT included in this Appendix.

Flare operating data and measurement data from all instruments used in each test series was recorded each second. Of these data, all data needed by UT Austin to achieve the study objectives or verify quality assurance of data were provided to UT Austin in John Zink's Final Report.

Aerodyne Research Incorporated (ARI)
ARI's primary responsibility was measurement of constituent concentrations in the flare plume. This was achieved using a suite of instrumentation including a Gas Chromatograph/Flame Ionization Detector (GC/FID), Proton Transfer Reaction-Mass Spectrometer (PTR-MS), Gas Chromatograph-Proton Transfer Reaction (GC-PTR), Quantum Cascade Laser (QCL), Aerosol

Mass Spectrometer (AMS), S Orbital and P Orbital-Aerosol Mass Spectrometer (SP-AMS), High Resolution-Aerosol Mass Spectrometer (HR-AMS) and Condensate Particle Counter (CPC).

To calibrate the ARI instruments, ARI would introduce a 100 ppm standard containing methane, ethane propane or propylene into the sampling manifold of the Aerodyne trailer. Each instrument collected a sample of the standard for analysis. Several different concentrations of the standard were used to develop a calibration curve for each instrument. This process occurred at set up and after any major equipment repair or maintenance activity. Additionally, three times per day, before testing began, after lunch before testing resumed and at the end of testing each day, each analysis instrument was challenged with a known concentration of the methane, ethane, propane or propylene standard as a verification of the instrument's performance over the day. This quality control process determined that there was a measurement uncertainty of ± 10% for the GC/FID, PTR-MS, GC-PTR, QCL, AMS, SP-AMS, HR-AMS and CPC measurements.

Carbon Monoxide (CO), Carbon Dioxide (CO_2) and Oxygen (O_2) instruments were calibrated using the same procedures. A 1000 ppm standard containing carbon monoxide, carbon dioxide and oxygen was introduced into the sampling manifold of the Aerodyne trailer; each instrument collected a sample of the standard for analysis. Several different concentrations of the standard were used to develop a calibration curve for each instrument. This process occurred at set up and after any major equipment repair or maintenance activity. Three times per day, before testing began, after lunch before testing resumed and at the end of testing each day, each analysis instrument was challenged with a known concentration of the carbon monoxide, carbon dioxide and oxygen standard as a verification of the instruments performance over the day. This quality control process determined that there was a measurement uncertainty of ± 1% for the CO, CO_2, and O_2 measurements.

ARI was also responsible for measuring wind speed (WS), wind direction (WD), and ambient temperature (T). These sensors were calibrated with factory (Davis Instruments) calibration equipment on the initial field tests set up day. The WS, WD, and T sensors were checked with Davis Instruments wind speed, wind direction and ambient temperature verification equipment before testing began each day and compared to the Tulsa International Airport National Weather Service WS, WD, and T measurements at the end of testing each day. The acceptance criteria for WS of ± 5%, WD of ± 3% and T of ± 0.5° were not exceeded during the field tests. Results of the ARI quality assurance procedures are included in Appendix I

TRC

Gas Chromatograph/Flame Ionization Detector (GC/FID) was calibrated using the same gas standard and procedures as ARI.

A 100 ppm standard containing methane, ethane propane or propylene was introduced into the sampling manifold of the TRC trailer; the GC/FID instrument collected a sample of the standard for analysis. Several different concentrations of the standard were used to develop a calibration curve for each instrument. This process occurred at set up and after any major equipment repair or maintenance activity. Three times per day, before testing began, after lunch before testing resumed and at the end of testing each day, each analysis instrument was challenged with a

known concentration of the methane, ethane, propane or propylene standard as a verification of the instruments performance over the day. This quality control process determined that there was a measurement uncertainty of ± 5% for the GC/FID measurements. A copy of the TRC calibration data are included in this Appendix.

Industrial Monitor and Control Corporation (IMACC)

Both the Active and Passive Fourier transforms infrared spectrometer (FTIR) were calibrated at the IMACC offices in Austin, Texas prior to shipping to Tulsa, Oklahoma. This calibration process involved using a certified compressed gas standard containing carbon monoxide (CO), carbon dioxide (CO_2), and methane (CH_4) at known concentrations. Once the Active and Passive systems were adjusted to match the compound concentration values for each component in the standard, each system was challenged with a variety of known concentrations of CO, CO_2, CH_4, and zero air to prove the calibration was accurate.

Once in the field at the Zink facility, every morning before testing began both the Active and Passive FTIR systems were verified to be producing accurate data. This verification process proved that the instruments were able to reproduce the exact spectra generated during the calibration process in Austin. A copy of the IMACC calibration data is included in this Appendix.

Telops

Acquiring measurements

For every point of a test series, the Hyper-Cam imager is acquiring interferograms in continuous. Acquiring many measurements allows for a better statistical representation of the scene. Blackbody reference measurements are also taken for subsequent radiometric calibration of the data collection.

Interferogram statistical analysis

First, before performing any high-level analysis of the measured hyperspectral data, the calibration of the measurement must take place. This calibration step compensates for the radiometric gain and offset of the instrument. Typically, one will average multiple scene measurement in order to increase the signal to noise ratio. However, due to the turbulent and dynamic nature of the plume in flare scenes, the mean scene is no longer representative of the scene. For such fluctuating scenes, Telops developed an adapted interferogram processing technique based on quantile analysis [RD1].

Radiometric calibration

The blackbody measurements are used to characterise the radiometric gain and offset of the instrument to calibrate a sequence of measurement. The calibrated data is in units of physical radiance [in W/(m2.sr.cm-1)].

A log of the calibrations performed by Telops is included in their final report (Table 3), which is included in this Appendix.

Data Review and Analysis

Once data were collected, quality assurance of the data involved multiple steps. The first step was data review by the technician or field operator for completeness, consistency and proper labeling of the data with measurement performed, test series and time tag information. The next step in the review was for proper conversion of instrument outputs to the desired parameter, i.e., voltage signals to concentrations or pressures, or pressure and temperature to flow rates, etc. The individual contractors performed these first two levels of data review.

UT Austin then performed a third level of data review for completeness and contract compliance. This review included sanity checks of the data, engineering analysis of related parameters, time synchronization and comparison with values of other related process parameters. If UT Austin identified problems in its review, the data would be returned to the contractor for additional review and quality assurance. UT Austin also had a minimum of two people check transfer of contractor data to the UT archive database.

Once these three steps were complete, the first level of data analysis began. In it's simplest form it involved calculating averages of parameters for test periods. More complex statistical analyses, engineering analysis and evaluation of flare performance are included in this final report.

The Project Manager oversees the storage of project data. Original data files submitted by contractors are referred to as source files and are never modified. When a source file's contents are to be used to intentionally create a derivative work, it is then referred to as a processed file. A processed file must be quality assured before it is stored in the project archive files. Copies of source files and processed files are copied when required for routine data analysis. Any file that has been used for data analysis is referred to as a working file. Working files may be at different states of quality assurance so are not added to the project database until they are reviewed and approved by the Project Manager for use as a processed file. All data and project files have been backed-up locally and off-site.

Conclusion

All project participants adhered to the Quality Assurance Project Plan as it applied to their instruments and their measurements met the Data Quality Objectives in Appendix C.

UT Austin ensures quality control of the project files through limited access and review of work performed using source data that are to be added to the project's database.

John Zink Report

Report of Actions and Observations

by

John Zink Company

In Relation to

The Comprehensive Flare Study

Robert Schwartz, P.E, Wes Bussman, Ph.D., Zach Kodesh, P.E.

The University of Texas
Contract: UTA09-000803
Purchase Order: 2011C00168

Testing Conducted - September 2010
Final Report – January 2011

Revision 1

ABSTRACT

The Texas Commission on Environmental Quality (TCEQ) contracted The University of Texas at Austin, Center for Energy and Environmental Resources, to perform a study of flare emissions at turndown fuel flow rates. The University of Texas contracted the John Zink Company to provide testing services to further this study goal. Specifically the John Zink Company made available; a steam assisted flare, an air assisted flare, a sample collector device, fuel, fuel delivery system, fuel metering, instrumentation, and any other items/personnel necessary to operate the flares and maneuver the sample collector device. The John Zink Company also provided electrical power and assistance to the other participants contracted by The University of Texas.

The John Zink Company (JZ) logged the required parameters indicated in the Quality Assurance Project Plan (QAPP). These data logs have been reviewed by JZ and refined to improve understanding and accuracy of the data. The logged data will not be presented in a printed form due to the size of the data files. This report documents the modifications made by JZ to the data logs, results of supporting tests conducted by JZ, and quality control documents.

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Data Log Column Index

Date – Format MM/DD/YYYY
Time – Format HH:MM:SS AM/PM
Point – Format Flare Type (S or A) Test Series (1 to 10) . Point (1 to 5) R run (1 to 4). Example A5.1R1 stands for Air Flare, test series 5, point 1, run 1.
FIT-3312 Propylene Flow (lbs/hr) – Direct measurement
FIT-3306 Nitrogen Flow (lbs/hr) – Direct measurement
FIT-3301 TNG Flow (lbs/hr) – Direct measurement
Total Mixed Fuel Flow (lbs/hr) – Arithmetic summation of propylene, nitrogen, and TNG flows.
Calculated Mixed Fuel LHV (BTU/SCF) – See Description of Calculations section of the QAPP for details.
Mixed Fuel Temp (°F) – Direct measurement
PIT-3317 Pilot Gas Press (psig) – Due to error, no data was logged for this value.
Back Calculated Pilot Gas Pressure (psig) – The pilot gas pressure has been back calculated from the pilot gas flow rate. (See Refinements Made to JZ Data Logs section, item 2 for more details.)
Calculated Pilot Gas Flow (lbs/hr) – See Results of Supporting Experiments section for details.
Corrected Pilot Gas Flow (lbs/hr) – Based on the back calculated pilot gas pressure, the pilot gas flow has been recalculated to correct a slight error in the equation utilized during the testing. (See Refinements Made to JZ Data Logs section, item 3 for more details)
FT-5103 Total Steam Flow to Flare (lbs/hr) – Direct measurement
Median 21s Total Steam Flow (lbs/hr) – The median of a 21 second sample has been utilized to filter out short duration variations in reported flow.
PIT-5104 Center Steam Press (psig) – Direct measurement
Calculated Center Steam Flow (lbs/hr) - See Results of Supporting Experiments section for details.
TE-5105 Center Steam Temp (°F) – Direct measurement
Upper Steam Ring Flow (lbs/hr) – FT-5103 total steam flow minus calculated center steam flow.
Median 21s Upper Steam Ring flow (lbs/hr) – Median 21s total steam flow minus calculated center steam flow.
PIT-5106 Upper Steam Ring Press (psig) – Direct measurement
TE-5107 Upper Steam Ring Temp (°F) – Direct measurement
TE-2103 Sample Temp at Sample Port (°F) – Direct measurement
TE-2104 Sample Device Inlet Temp (°F) – Direct measurement
TE-2105 Sample Device Inlet Temp (°F) – Direct measurement
TE-2106 Sample Device Inlet Temp (°F) – Direct measurement
DPT-2107 Sample Device Pitot dP (Inches w.c.) – Direct measurement
PT-2108 Sample Device Pitot Static (Inches w.c.) – Direct measurement

FT-2102 Air-Assist Flow (SCFM) – Direct measurement
Manual Logged Blower Rotation (%) – 10 to 100% blower rotation. 100% represents 1800 rpm with lower values being proportional. **This column only appears in data files for days that the air assisted flare was utilized. Data will only appear in this column during those tests when the blower pitch was set to 5.**
Corrected and Correlated Air-Assist Flow (SCFM) – Flows from FT-2102 that are less than 20,000 SCFM are corrected from 70° to 68° as the standard temperature. For flows greater than 20,000 SCFM, the rotation verses flow correlation is utilized to determine flow. See Results of Supporting Experiments section for details. **This column only appears in data files for days that the air assisted flare was utilized.**
TE-2101 Air-Assist Temp (°F) – Direct measurement
Ambient Wind Speed (mph) – Direct measurement
Ambient Wind Direction (0=N, 90=E) – Direct measurement
Ambient Temp. (°F) – Direct measurement
Ambient Relative Humidity (%) – Direct measurement
Ambient Barometric Pressure (psia) – Direct measurement
Calculated Steam Flare Exit Velocity (ft/sec) – See Description of Calculations section of QAPP for details.
Calculated Air Flare Exit Velocity (ft/sec) – See Description of Calculations section of QAPP for details.

<u>Acronyms and Abbreviations</u>
BTU = British Thermal Unit
DPT = Differential Pressure Transmitter
°F = Degrees Fahrenheit
FIT = Flow Indicating Transmitter
FT = Flow Transmitter
hr = hours
lbs = pounds
LHV = Lower Heating Value
mph = Miles per Hour
PIT = Pressure Indicating Transmitter
psig = Pounds per Square Inch Gauge
PT = Pressure Transmitter
SCF = Standard Cubic Foot
SCFM = Standard Cubic Feet per Minute
TE = Temperature Element
TNG = Tulsa Natural Gas
w.c. = Water Column

Refinements Made to JZ Data Logs

Note: Any column added to the data log will have a header description that starts with the word "Modified".

Common refinements made to all data files.

1. All columns with "RAW" data, values between 0 and 16383 that represent 4-20 milliamp signals, have been deleted. Only columns with engineering values remain.
2. The pilot gas pressure did not log due to an incorrect tag name in the logging file. The calculated pilot gas flow did log by utilizing the correct tag for pilot pressure in the equation. The pilot pressure value has been back calculated from the flow and is stored in the column titled "Back Calculated Pilot Gas Pressure (psig)".
3. It was found during the pilot gas pressure investigation that the equation utilized to calculate the pilot gas flow was entered into the computer with two errors. The temperature 557 was entered incorrectly into the computer as 577 and the molecular weight of the pilot gas was entered as 17.01 instead of 17.1. The back calculation of pressure was done using the same equation that generated the logged flow value. The pilot flow has been recalculated utilizing the "back calculated pilot gas pressure" and the correct equation. These pilot gas flows are stored in the column titled "Corrected Pilot Gas Flow (lbs/hr)".
4. The steam flow meter would periodically have flow excursions. Based on the consistent upper and center steam pressures, it is unlikely these variations were due to actual changes in flow. Typically these excursions were less than 10 seconds in duration and most likely caused by water droplets on the transducers. To smooth out these flow meter variations, the median of a 21 second sample is utilized. This median is reported at the center (11 seconds) of the 21 second sample. These values are stored in a column titled "Median 21s Total Steam Flow (lbs/hr)".
5. The upper steam ring flow is calculated by subtracting the calculated center steam flow from the total steam flow. A new upper steam ring flow has been calculated using the "Median 21s Total Steam Flow" values. These new upper steam ring flows are stored in a column titled "Median 21s Upper Steam Ring Flow (lbs/hr)".
6. The column titled "Calculated Center Steam Flow" has been changed to include the units, "Calculated Center Steam Flow (lbs/hr)".
7. The test point column entries have been modified to only appear between the start/stop times of a particular point. While transitioning between points, this column will be blank.
8. During some tests the pilots were shut off. Due to the equation utilized to correlate pilot gas flow to pilot gas pressure, a zero pressure will cause the appearance of pilot gas flow. Zeros have been inserted into the Corrected Pilot

Gas Flow column for pilot pressures less than 14 psig. A pressure less than 14 psig indicates the pilots were shut off, but some residual gas was trapped in the pilot gas line causing the pressure transmitter to report something other than zero.

9. Some data logs have point codes without spaces while other logs have point codes with spaces. All spaces have been removed from test point codes.

Refinements made to air flow data from the air flare tests

1. The air flow transmitter (FIT-2107) was spanned 0 to 20,000 SCFM (standard conditions for the manufacturer are 70°F and 14.7 psia). For this style of transmitter the span is not field adjustable. When the blower was set to a blade pitch of 5, it produced more flow than 20,000 SCFM, and the transmitter under reported the flow. Utilizing pitot measurements, a correlation between blower rotation and CFM air flow was developed (see Results of Supporting Experiments section for details). A column has been added to indicate blower rotation titled "Manual Logged Blower Rotation (%)". This column contains the rotation of the blower when the blade pitch was set to 5. A second column has been added titled "Corrected and Correlated Air-Assist Flow (SCFM)". If the flow reported by FIT-2107 is 20,000 SCFM or less, then the value reported by FIT-2107 is adjusted from a standard temperature of 70° to 68°F and input into the "Corrected and Correlated Air-Assist Flow (SCFM)" column using the equation below.

$$SCFM(68°F) = SCFM(70°F)x\frac{(460+68)}{(460+70)}$$

If the flow reported by FIT-2107 is greater than 20,000 SCFM, then the flow will be calculated from the blower rotation correlation equation and adjusted to standard conditions using the equation below. The AirAssistTemp is the temperature of the air in the duct (TE-2101).

$$SCFM = (342.35xBlowerRotation(\%) + 413.48)x\frac{(460+68)}{(460+AirAssistTemp(°F))}x\frac{Barometric\,Pressure(psia)}{14.696}$$

Refinements made to specific data files.

File: 9-22-2010 JZ Refined Log.xls

1. Due to a faulty steam trap, the steam flow meter filled with condensed water causing the flow meter to output a steam flow rate other than zero. Zeros have been entered into the "Median 21s Total Steam Flow (lbs/hr)".

File: 9-23-2010 JZ Refined Log.xls

1. Due to a faulty steam trap, the steam flow meter filled with condensed water causing the flow meter to output a steam flow rate other than zero. Zeros have been entered into the "Median 21s Total Steam Flow (lbs/hr)" column.
2. A slight pressure was registered by the center steam pressure transmitter. This pressure was most likely caused by water trapped in the piping. This small pressure caused the appearance of center steam flow. Zeros have been entered into the "Corrected Center Steam Flow (lbs/hr)" column.

File: 9-27-2010 JZ Refined Log.xls

1. Total steam flow, calculated center steam flow, and upper steam flow were all off during this days testing. The center steam pressure transmitter was shut in causing an indication of pressure and consequently and indication of flow. A column has been added to indicate the center steam flow is zero. (Corrected Center Steam Flow)

RESULTS OF SUPPORTING EXPERIMENTS

SAMPLE COLLECTOR VELOCITY PROFILE TESTS

John Zink Flue Gas Sample Collector
Results of Velocity Distribution Study and Calibration

Overall average

Flow rate (actual ft^3/min)	1963.962
Average velocity (ft/s)	41.677
Average velocity / Centerline velocity	0.890

Vertical multi-point scan (top to bottom)
Scan Number 1

With air flow set at 100% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Scan 1.R1

Data Input

Air Temperature (F)	84.7	
Atm. pressure (psia)	14.28	
Static pressure in collector (in WC)	-1.65	(if below atmospheric pressure type "-")
Motive air pressure upstream (psig)	70	
Motive air pressure downstream (psig)	60	

Results

Density air (lbm/ft^3)		0.0705						
Point #	Location (inch)	Pitot tube dP (in WC)	Velocity (ft/s)	Cell CL from wall (in)	Avg. V in cell (ft/s)	Pipe CL to Cell CL (in)	Area of cell (ft2)	Vol. Flow of cell (ft3/s)
0 (wall)	0.00	0.000	0.00	0.125	16.87	5.875	0.064	0.541
1	0.25	0.240	33.75	0.825	38.66	5.175	0.260	5.019
2	1.40	0.400	43.57	1.805	44.50	4.195	0.148	3.299
3	2.21	0.435	45.43	3.175	45.82	2.825	0.238	5.450
4	4.14	0.450	46.21	5.07	46.47	0.93	0.075	1.754
5 (centerline)	6.00	0.460	46.72	6.93	46.59	0.93	0.075	1.758
6	7.86	0.455	46.47	8.825	46.21	2.825	0.238	5.497
7	9.79	0.445	45.95	10.195	45.56	4.195	0.148	3.378
8	10.60	0.430	45.17	11.075	43.96	5.075	0.210	4.624
9	11.55	0.385	42.74	11.775	21.37	5.775	0.113	1.212
10 (wall)	12.00	0.000	0.00				Flow rate (actual ft^3/s)	32.531
							Flow rate (actual ft^3/min)	1951.830
							Average velocity (ft/s)	41.419
							Average velocity / Centerline velocity	0.887

Scan 1.R2

Data Input

Air Temperature (F)	84.7	
Atm. pressure (psia)	14.28	
Static pressure in collector (in WC)	-1.65	(if below atmospheric pressure type "-")
Motive air pressure upstream (psig)	70	
Motive air pressure downstream (psig)	60	

Results

Density air (lbm/ft^3)		0.0705						
Point #	Location (inch)	Pitot tube dP (in WC)	Velocity (ft/s)	Cell CL from wall (in)	Avg. V in cell (ft/s)	Pipe CL to Cell CL (in)	Area of cell (ft2)	Vol. Flow of cell (ft3/s)
0 (wall)	0.00	0.000	0.00	0.125	17.22	5.875	0.064	0.552
1	0.25	0.250	34.44	0.825	39.28	5.175	0.260	5.099
2	1.40	0.410	44.11	1.805	44.90	4.195	0.148	3.329
3	2.21	0.440	45.69	3.175	46.08	2.825	0.238	5.481
4	4.14	0.455	46.47	5.07	46.72	0.93	0.075	1.763
5 (centerline)	6.00	0.465	46.97	6.93	46.59	0.93	0.075	1.758
6	7.86	0.450	46.21	8.825	46.21	2.825	0.238	5.497
7	9.79	0.450	46.21	10.195	45.95	4.195	0.148	3.407
8	10.60	0.440	45.69	11.075	44.22	5.075	0.210	4.651
9	11.55	0.385	42.74	11.775	21.37	5.775	0.113	1.212
10 (wall)	12.00	0.000	0.00				Flow rate (actual ft^3/s)	32.748
							Flow rate (actual ft^3/min)	1964.904
							Average velocity (ft/s)	41.697
							Average velocity / Centerline velocity	0.888

John Zink LLC
Date of test: September 14, 2010
Test Team: Wes Bussman, Cliff Pugh, Garrett Spaulding
Rev 1
Scan 1 Page 1 of 2

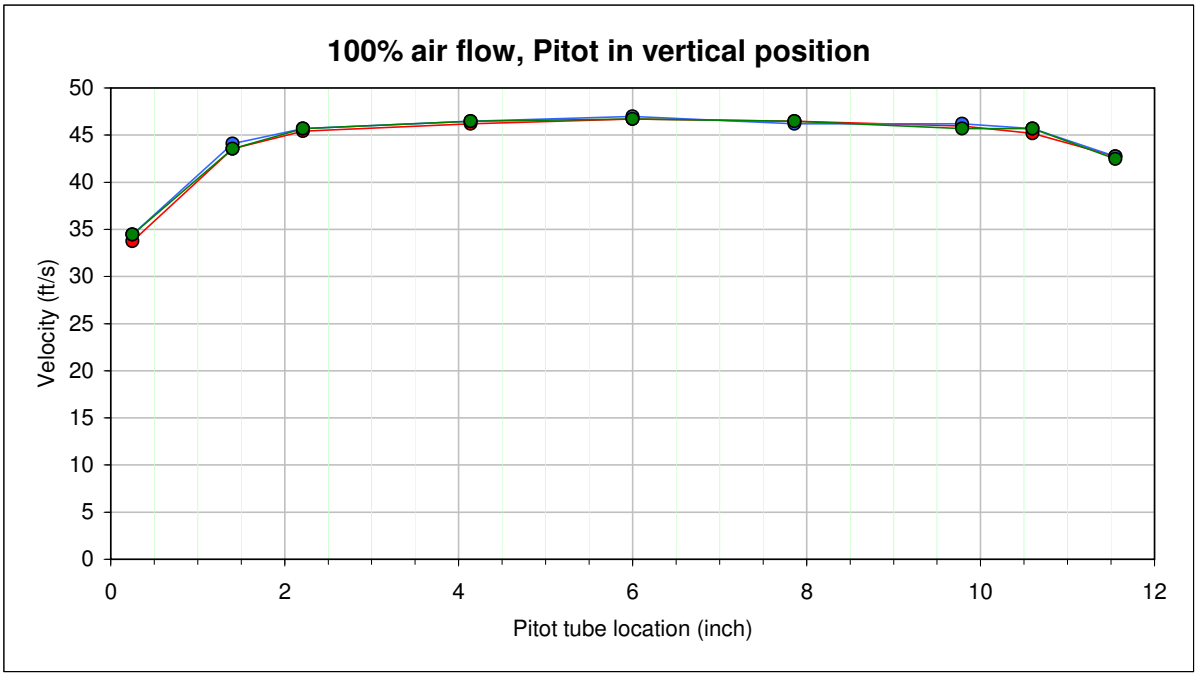
Scan 1.R3

Data Input

Air Temperature (F)	84.7	
Atm. pressure (psia)	14.28	
Static pressure in collector (in WC)	-1.65	(if below atmospheric pressure type "-")
Motive air pressure upstream (psig)	70	
Motive air pressure downstream (psig)	60	

Results

Density air (lbm/ft^3)		0.0705						
Point #	Location (inch)	Pitot tube dP (in WC)	Velocity (ft/s)	Cell CL from wall (in)	Avg. V in cell (ft/s)	Pipe CL to Cell CL (in)	Area of cell (ft2)	Vol. Flow of cell (ft3/s)
0 (wall)	0.00	0.000	0.00	0.125	17.22	5.875	0.064	0.552
1	0.25	0.250	34.44	0.825	39.01	5.175	0.260	5.064
2	1.40	0.400	43.57	1.805	44.63	4.195	0.148	3.309
3	2.21	0.440	45.69	3.175	46.08	2.825	0.238	5.481
4	4.14	0.455	46.47	5.07	46.59	0.93	0.075	1.758
5 (centerline)	6.00	0.460	46.72	6.93	46.59	0.93	0.075	1.758
6	7.86	0.455	46.47	8.825	46.08	2.825	0.238	5.481
7	9.79	0.440	45.69	10.195	45.69	4.195	0.148	3.387
8	10.60	0.440	45.69	11.075	44.08	5.075	0.210	4.636
9	11.55	0.380	42.46	11.775	21.23	5.775	0.113	1.204
10 (wall)	12.00	0.000	0.00	Flow rate (actual ft^3/s)				32.631
				Flow rate (actual ft^3/min)				1957.879
				Average velocity (ft/s)				41.548
				Average velocity / Centerline velocity				0.889



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Date of test: September 14, 2010
Test Team: Wes Bussman, Cliff Pugh, Garrett Spaulding
Rev 1
Scan 1 Page 2 of 2

Horizontal multi-point scan (side to side)
Scan Number 2

With air flow set at 100% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Scan 2.R1

Data Input

Air Temperature (F)	84.7	
Atm. pressure (psia)	14.28	
Static pressure in collector (in WC)	-1.65	(if below atmospheric pressure type "-")
Motive air pressure upstream (psig)	70	
Motive air pressure downstream (psig)	60	

Results

Density air (lbm/ft^3)		0.0705						
Point #	Location (inch)	Pitot tube dP (in WC)	Velocity (ft/s)	Cell CL from wall (in)	Avg. V in cell (ft/s)	Pipe CL to Cell CL (in)	Area of cell (ft2)	Vol. Flow of cell (ft3/s)
0 (wall)	0.00	0.000	0.00	0.125	17.73	5.875	0.064	0.568
1	0.25	0.265	35.46	0.825	40.05	5.175	0.260	5.200
2	1.40	0.420	44.64	1.805	45.43	4.195	0.148	3.368
3	2.21	0.450	46.21	3.175	46.47	2.825	0.238	5.527
4	4.14	0.460	46.72	5.07	46.72	0.93	0.075	1.763
5 (centerline)	6.00	0.460	46.72	6.93	46.72	0.93	0.075	1.763
6	7.86	0.460	46.72	8.825	46.21	2.825	0.238	5.496
7	9.79	0.440	45.69	10.195	45.17	4.195	0.148	3.348
8	10.60	0.420	44.64	11.075	43.27	5.075	0.210	4.552
9	11.55	0.370	41.90	11.775	20.95	5.775	0.113	1.188
10 (wall)	12.00	0.000	0.00				Flow rate (actual ft^3/s)	32.773
							Flow rate (actual ft^3/min)	1966.409
							Average velocity (ft/s)	41.729
							Average velocity / Centerline velocity	0.893

Scan 2.R2

Data Input

Air Temperature (F)	84.7	
Atm. pressure (psia)	14.28	
Static pressure in collector (in WC)	-1.65	(if below atmospheric pressure type "-")
Motive air pressure upstream (psig)	70	
Motive air pressure downstream (psig)	60	

Results

Density air (lbm/ft^3)		0.0705						
Point #	Location (inch)	Pitot tube dP (in WC)	Velocity (ft/s)	Cell CL from wall (in)	Avg. V in cell (ft/s)	Pipe CL to Cell CL (in)	Area of cell (ft2)	Vol. Flow of cell (ft3/s)
0 (wall)	0.00	0.000	0.00	0.125	17.90	5.875	0.064	0.573
1	0.25	0.270	35.79	0.825	40.35	5.175	0.260	5.239
2	1.40	0.425	44.91	1.805	45.69	4.195	0.148	3.387
3	2.21	0.455	46.47	3.175	46.72	2.825	0.238	5.557
4	4.14	0.465	46.97	5.07	46.97	0.93	0.075	1.773
5 (centerline)	6.00	0.465	46.97	6.93	46.85	0.93	0.075	1.768
6	7.86	0.460	46.72	8.825	46.21	2.825	0.238	5.496
7	9.79	0.440	45.69	10.195	45.17	4.195	0.148	3.348
8	10.60	0.420	44.64	11.075	43.13	5.075	0.210	4.537
9	11.55	0.365	41.62	11.775	20.81	5.775	0.113	1.180
10 (wall)	12.00	0.000	0.00				Flow rate (actual ft^3/s)	32.859
							Flow rate (actual ft^3/min)	1971.514
							Average velocity (ft/s)	41.837
							Average velocity / Centerline velocity	0.891

John Zink LLC
Date of test: September 14, 2010
Test Team: Wes Bussman, Cliff Pugh, Garrett Spaulding
Rev 1
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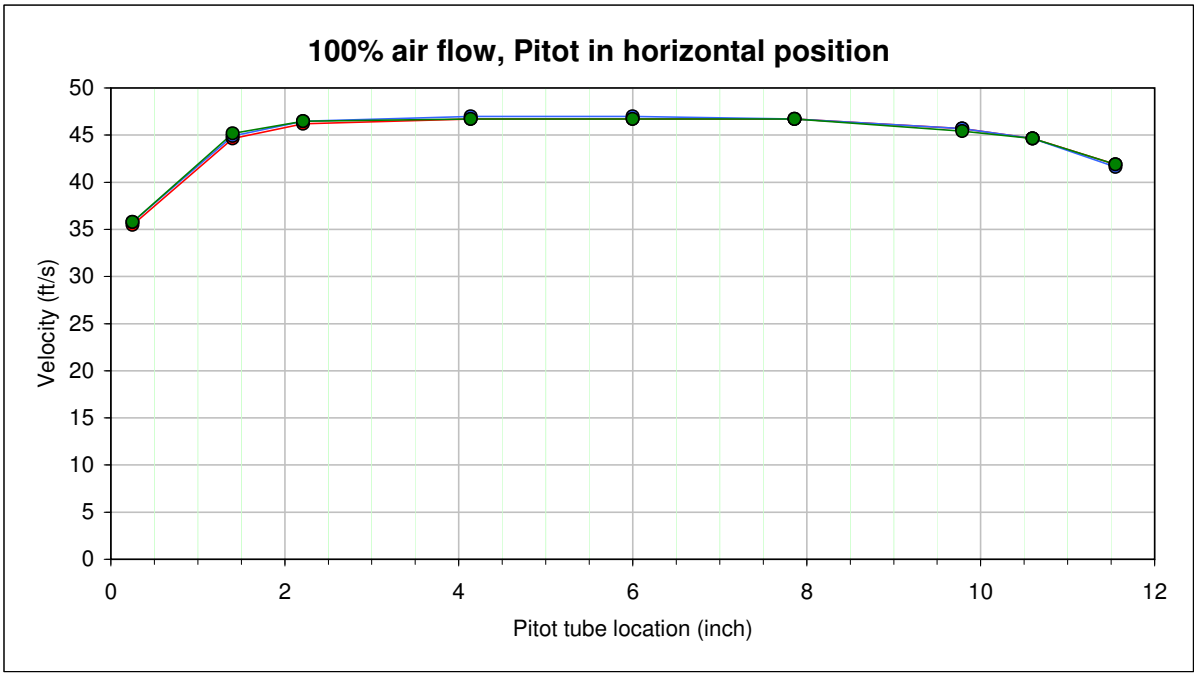
Scan 2.R3

Data Input

Air Temperature (F)	84.7	
Atm. pressure (psia)	14.28	
Static pressure in collector (in WC)	-1.65	(if below atmospheric pressure type "-")
Motive air pressure upstream (psig)	70	
Motive air pressure downstream (psig)	60	

Results

Density air (lbm/ft^3)		0.0705						
Point #	Location (inch)	Pitot tube dP (in WC)	Velocity (ft/s)	Cell CL from wall (in)	Avg. V in cell (ft/s)	Pipe CL to Cell CL (in)	Area of cell (ft2)	Vol. Flow of cell (ft3/s)
0 (wall)	0.00	0.000	0.00	0.125	17.90	5.875	0.064	0.573
1	0.25	0.270	35.79	0.825	40.48	5.175	0.260	5.256
2	1.40	0.430	45.17	1.805	45.82	4.195	0.148	3.397
3	2.21	0.455	46.47	3.175	46.59	2.825	0.238	5.542
4	4.14	0.460	46.72	5.07	46.72	0.93	0.075	1.763
5 (centerline)	6.00	0.460	46.72	6.93	46.72	0.93	0.075	1.763
6	7.86	0.460	46.72	8.825	46.08	2.825	0.238	5.481
7	9.79	0.435	45.43	10.195	45.04	4.195	0.148	3.339
8	10.60	0.420	44.64	11.075	43.27	5.075	0.210	4.552
9	11.55	0.370	41.90	11.775	20.95	5.775	0.113	1.188
10 (wall)	12.00	0.000	0.00	Flow rate (actual ft^3/s)				32.854
				Flow rate (actual ft^3/min)				1971.234
				Average velocity (ft/s)				41.831
				Average velocity / Centerline velocity				0.895



John Zink LLC
Date of test: September 14, 2010
Test Team: Wes Bussman, Cliff Pugh, Garrett Spaulding
Rev 1
Scan 2 Page 2 of 2

John Zink Flue Gas Sample Collector
Results of Velocity Distribution Study and Calibration

Overall average

Flow rate (actual ft^3/min)	1419.593
Average velocity (ft/s)	30.125
Average velocity / Centerline velocity	0.883

Vertical multi-point scan (top to bottom)
Scan Number 3

With air flow set at 60% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Scan 3.R1

Data Input

Air Temperature (F)	84	
Atm. pressure (psia)	14.28	
Static pressure in collector (in WC)	-0.88	(if below atmospheric pressure type "-")
Motive air pressure upstream (psig)	37.5	
Motive air pressure downstream (psig)	30	

Results

Density air (lbm/ft^3)		0.0708						
Point #	Location (inch)	Pitot tube dP (in WC)	Velocity (ft/s)	Cell CL from wall (in)	Avg. V in cell (ft/s)	Pipe CL to Cell CL (in)	Area of cell (ft2)	Vol. Flow of cell (ft3/s)
0 (wall)	0.00	0.000	0.00	0.125	12.40	5.875	0.064	0.397
1	0.25	0.130	24.80	0.825	28.16	5.175	0.260	3.656
2	1.40	0.210	31.52	1.805	32.25	4.195	0.148	2.391
3	2.21	0.230	32.98	3.175	33.34	2.825	0.238	3.966
4	4.14	0.240	33.69	5.07	33.87	0.93	0.075	1.278
5 (centerline)	6.00	0.245	34.04	6.93	34.04	0.93	0.075	1.285
6	7.86	0.245	34.04	8.825	33.87	2.825	0.238	4.028
7	9.79	0.240	33.69	10.195	33.52	4.195	0.148	2.485
8	10.60	0.235	33.34	11.075	31.66	5.075	0.210	3.330
9	11.55	0.190	29.98	11.775	14.99	5.775	0.113	0.850
10 (wall)	12.00	0.000	0.00				Flow rate (actual ft^3/s)	23.665
							Flow rate (actual ft^3/min)	1419.898
							Average velocity (ft/s)	30.131
							Average velocity / Centerline velocity	0.885

Scan 3.R2

Data Input

Air Temperature (F)	84	
Atm. pressure (psia)	14.28	
Static pressure in collector (in WC)	-0.88	(if below atmospheric pressure type "-")
Motive air pressure upstream (psig)	37.5	
Motive air pressure downstream (psig)	30	

Results

Density air (lbm/ft^3)		0.0708						
Point #	Location (inch)	Pitot tube dP (in WC)	Velocity (ft/s)	Cell CL from wall (in)	Avg. V in cell (ft/s)	Pipe CL to Cell CL (in)	Area of cell (ft2)	Vol. Flow of cell (ft3/s)
0 (wall)	0.00	0.000	0.00	0.125	12.40	5.875	0.064	0.397
1	0.25	0.130	24.80	0.825	27.97	5.175	0.260	3.631
2	1.40	0.205	31.14	1.805	32.06	4.195	0.148	2.377
3	2.21	0.230	32.98	3.175	33.51	2.825	0.238	3.986
4	4.14	0.245	34.04	5.07	34.21	0.93	0.075	1.291
5 (centerline)	6.00	0.250	34.39	6.93	34.04	0.93	0.075	1.285
6	7.86	0.240	33.69	8.825	33.69	2.825	0.238	4.008
7	9.79	0.240	33.69	10.195	33.34	4.195	0.148	2.471
8	10.60	0.230	32.98	11.075	31.68	5.075	0.210	3.332
9	11.55	0.195	30.37	11.775	15.19	5.775	0.113	0.861
10 (wall)	12.00	0.000	0.00				Flow rate (actual ft^3/s)	23.639
							Flow rate (actual ft^3/min)	1418.356
							Average velocity (ft/s)	30.098
							Average velocity / Centerline velocity	0.875

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Date of test: September 10, 2010
Test Team: Wes Bussman, Cliff Pugh, Garrett Spaulding
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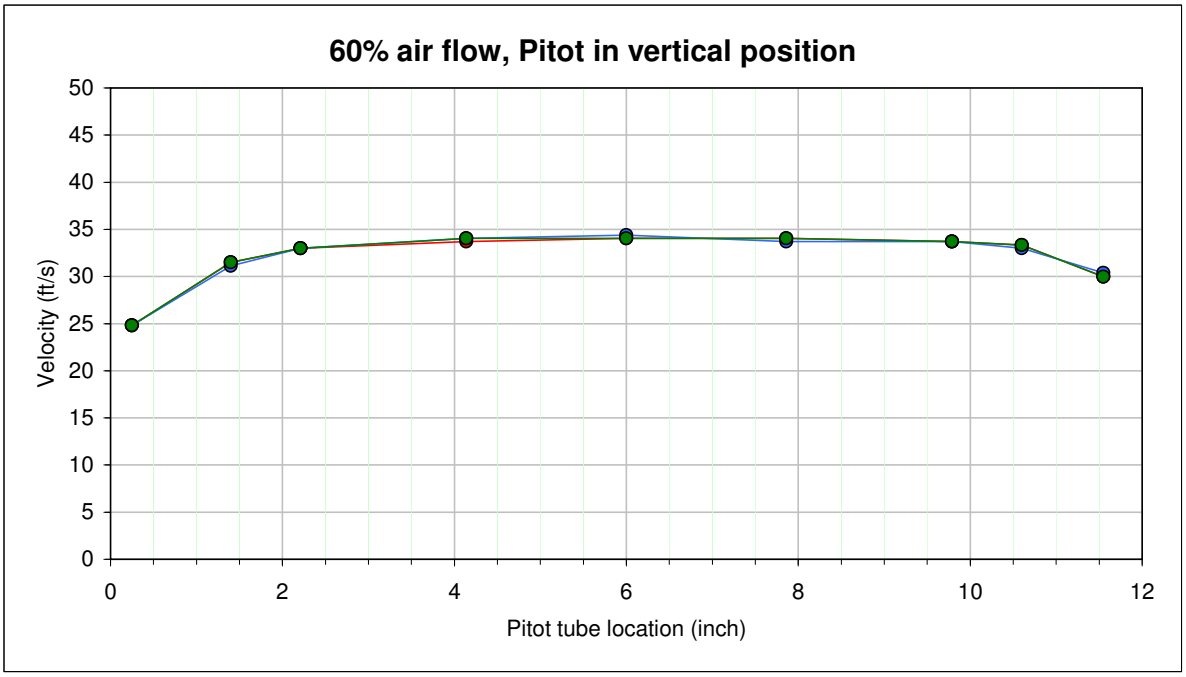
Scan 3.R3

Data Input

Air Temperature (F)	84	
Atm. pressure (psia)	14.28	
Static pressure in collector (in WC)	-0.88	(if below atmospheric pressure type "-")
Motive air pressure upstream (psig)	37.5	
Motive air pressure downstream (psig)	30	

Results

Density air (lbm/ft^3)		0.0708						
Point #	Location (inch)	Pitot tube dP (in WC)	Velocity (ft/s)	Cell CL from wall (in)	Avg. V in cell (ft/s)	Pipe CL to Cell CL (in)	Area of cell (ft2)	Vol. Flow of cell (ft3/s)
0 (wall)	0.00	0.000	0.00	0.125	12.40	5.875	0.064	0.397
1	0.25	0.130	24.80	0.825	28.16	5.175	0.260	3.656
2	1.40	0.210	31.52	1.805	32.25	4.195	0.148	2.391
3	2.21	0.230	32.98	3.175	33.51	2.825	0.238	3.986
4	4.14	0.245	34.04	5.07	34.04	0.93	0.075	1.285
5 (centerline)	6.00	0.245	34.04	6.93	34.04	0.93	0.075	1.285
6	7.86	0.245	34.04	8.825	33.87	2.825	0.238	4.028
7	9.79	0.240	33.69	10.195	33.52	4.195	0.148	2.485
8	10.60	0.235	33.34	11.075	31.66	5.075	0.210	3.330
9	11.55	0.190	29.98	11.775	14.99	5.775	0.113	0.850
10 (wall)	12.00	0.000	0.00	Flow rate (actual ft^3/s)				23.692
		0		Flow rate (actual ft^3/min)				1421.539
				Average velocity (ft/s)				30.166
				Average velocity / Centerline velocity				0.886



John Zink LLC
Date of test: September 10, 2010
Test Team: Wes Bussman, Cliff Pugh, Garrett Spaulding
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Scan 3 Page 2 of 2

Horizontal multi-point scan (side to side)
Scan Number 4

With air flow set at 60% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Scan 4.R1

Data Input

Air Temperature (F)	84	
Atm. pressure (psia)	14.28	
Static pressure in collector (in WC)	-0.88	(if below atmospheric pressure type "-")
Motive air pressure upstream (psig)	37.5	
Motive air pressure downstream (psig)	30	

Results

Density air (lbm/ft^3)		0.0708						
Point #	Location (inch)	Pitot tube dP (in WC)	Velocity (ft/s)	Cell CL from wall (in)	Avg. V in cell (ft/s)	Pipe CL to Cell CL (in)	Area of cell (ft2)	Vol. Flow of cell (ft3/s)
0 (wall)	0.00	0.000	0.00	0.125	12.40	5.875	0.064	0.397
1	0.25	0.130	24.80	0.825	28.16	5.175	0.260	3.656
2	1.40	0.210	31.52	1.805	32.60	4.195	0.148	2.417
3	2.21	0.240	33.69	3.175	33.87	2.825	0.238	4.028
4	4.14	0.245	34.04	5.07	34.04	0.93	0.075	1.285
5 (centerline)	6.00	0.245	34.04	6.93	34.04	0.93	0.075	1.285
6	7.86	0.245	34.04	8.825	33.69	2.825	0.238	4.007
7	9.79	0.235	33.34	10.195	32.80	4.195	0.148	2.431
8	10.60	0.220	32.26	11.075	30.92	5.075	0.210	3.252
9	11.55	0.185	29.58	11.775	14.79	5.775	0.113	0.839
10 (wall)	12.00	0.000	0.00				Flow rate (actual ft^3/s)	23.598
							Flow rate (actual ft^3/min)	1415.858
							Average velocity (ft/s)	30.045
							Average velocity / Centerline velocity	0.883

Scan 4.R2

Data Input

Air Temperature (F)	84	
Atm. pressure (psia)	14.28	
Static pressure in collector (in WC)	-0.88	(if below atmospheric pressure type "-")
Motive air pressure upstream (psig)	37.5	
Motive air pressure downstream (psig)	30	

Results

Density air (lbm/ft^3)		0.0708						
Point #	Location (inch)	Pitot tube dP (in WC)	Velocity (ft/s)	Cell CL from wall (in)	Avg. V in cell (ft/s)	Pipe CL to Cell CL (in)	Area of cell (ft2)	Vol. Flow of cell (ft3/s)
0 (wall)	0.00	0.000	0.00	0.125	12.87	5.875	0.064	0.412
1	0.25	0.140	25.73	0.825	29.00	5.175	0.260	3.765
2	1.40	0.220	32.26	1.805	32.98	4.195	0.148	2.445
3	2.21	0.240	33.69	3.175	33.69	2.825	0.238	4.008
4	4.14	0.240	33.69	5.07	33.87	0.93	0.075	1.278
5 (centerline)	6.00	0.245	34.04	6.93	33.87	0.93	0.075	1.278
6	7.86	0.240	33.69	8.825	33.52	2.825	0.238	3.987
7	9.79	0.235	33.34	10.195	32.98	4.195	0.148	2.445
8	10.60	0.225	32.62	11.075	31.10	5.075	0.210	3.271
9	11.55	0.185	29.58	11.775	14.79	5.775	0.113	0.839
10 (wall)	12.00	0.000	0.00				Flow rate (actual ft^3/s)	23.727
							Flow rate (actual ft^3/min)	1423.621
							Average velocity (ft/s)	30.210
							Average velocity / Centerline velocity	0.887

John Zink LLC
Date of test: September 10, 2010
Test Team: Wes Bussman, Cliff Pugh, Garrett Spaulding
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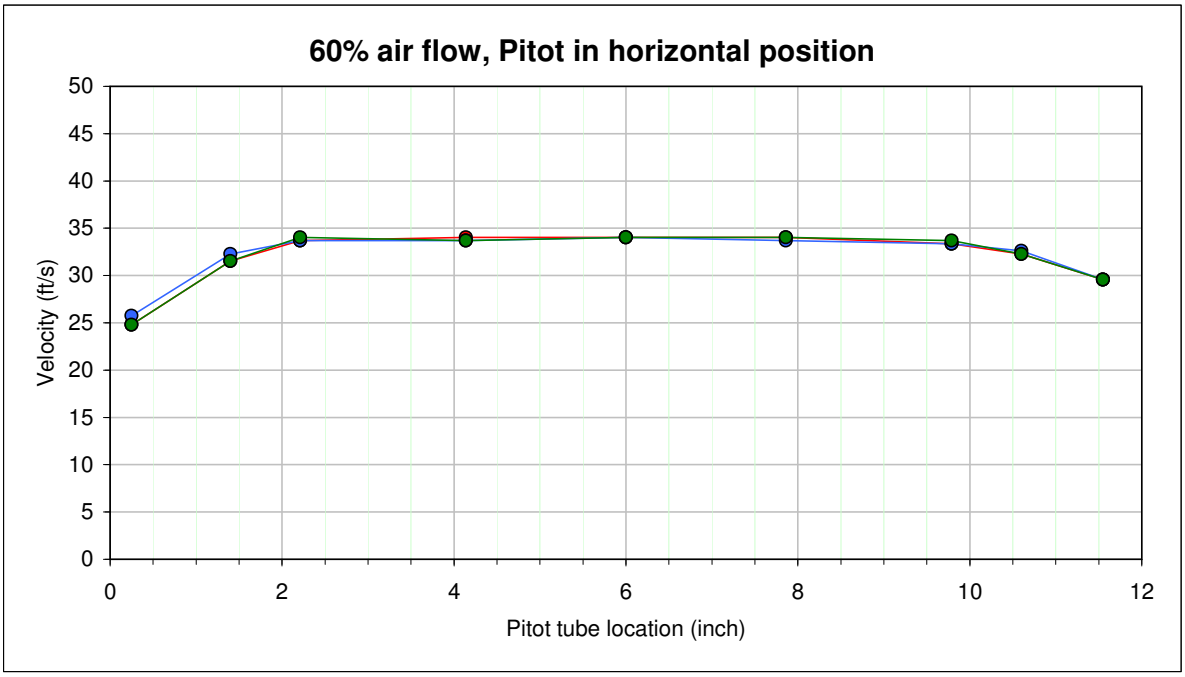
Scan 4.R3

Data Input

Air Temperature (F)	84	
Atm. pressure (psia)	14.28	
Static pressure in collector (in WC)	-0.88	(if below atmospheric pressure type "-")
Motive air pressure upstream (psig)	37.5	
Motive air pressure downstream (psig)	30	

Results

Density air (lbm/ft^3)		0.0708						
Point #	Location (inch)	Pitot tube dP (in WC)	Velocity (ft/s)	Cell CL from wall (in)	Avg. V in cell (ft/s)	Pipe CL to Cell CL (in)	Area of cell (ft2)	Vol. Flow of cell (ft3/s)
0 (wall)	0.00	0.000	0.00	0.125	12.40	5.875	0.064	0.397
1	0.25	0.130	24.80	0.825	28.16	5.175	0.260	3.656
2	1.40	0.210	31.52	1.805	32.78	4.195	0.148	2.430
3	2.21	0.245	34.04	3.175	33.87	2.825	0.238	4.028
4	4.14	0.240	33.69	5.07	33.87	0.93	0.075	1.278
5 (centerline)	6.00	0.245	34.04	6.93	34.04	0.93	0.075	1.285
6	7.86	0.245	34.04	8.825	33.87	2.825	0.238	4.028
7	9.79	0.240	33.69	10.195	32.98	4.195	0.148	2.445
8	10.60	0.220	32.26	11.075	30.92	5.075	0.210	3.252
9	11.55	0.185	29.58	11.775	14.79	5.775	0.113	0.839
10 (wall)	12.00	0.000	0.00				Flow rate (actual ft^3/s)	23.638
							Flow rate (actual ft^3/min)	1418.283
							Average velocity (ft/s)	30.097
							Average velocity / Centerline velocity	0.884



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Test Team: Wes Bussman, Cliff Pugh, Garrett Spaulding
Rev 1
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SAMPLE COLLECTOR HOMOGENEITY TESTS

John Zink Flue Gas Sample Collector
Results of Homogeneity Testing

CO2 Injection Location 1
Vertical multi-point scan (top to bottom)
Scan Number 8

With air flow set at 60% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Upstream air P (psig)	36
Downstream air P (psig)	30
Amb T (F)	81
Abm P (psia)	14.28

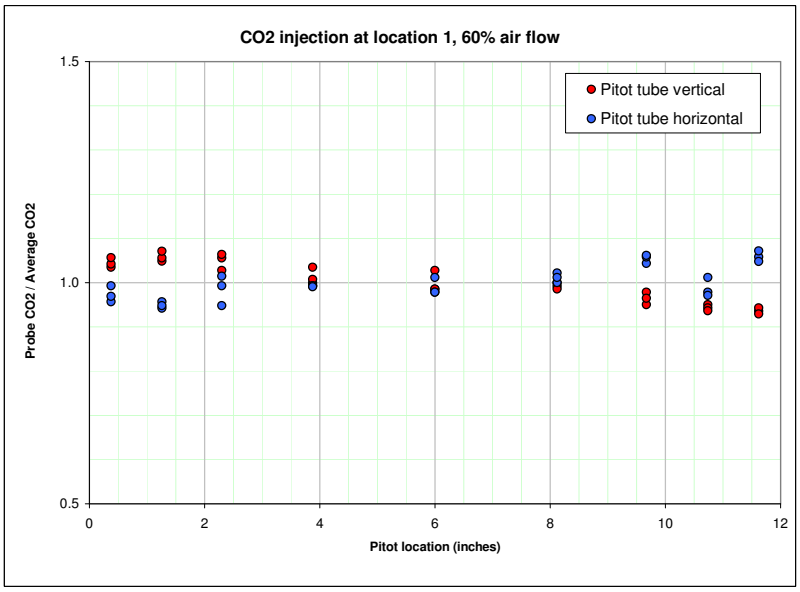
	Pitot	Run #1				Run #2				Run #3			
Data Point #	Location (inch)	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2
1	0.38	2270	800	1470	1.034	2250	780	1470	1.042	2270	780	1490	1.057
2	1.26	2270	780	1490	1.048	2250	760	1490	1.056	2270	760	1510	1.071
3	2.30	2220	760	1460	1.027	2250	760	1490	1.056	2250	750	1500	1.064
4	3.88	2250	780	1470	1.034	2220	810	1410	0.999	2220	800	1420	1.007
5 (centerline)	6.00	2220	760	1460	1.027	2190	800	1390	0.985	2190	800	1390	0.986
6	8.12	2190	780	1410	0.992	2190	780	1410	0.999	2190	800	1390	0.986
7	9.67	2130	780	1350	0.950	2160	780	1380	0.978	2160	800	1360	0.965
8	10.74	2160	810	1350	0.950	2160	830	1330	0.943	2130	810	1320	0.936
9	11.62	2130	800	1330	0.936	2130	800	1330	0.943	2110	800	1310	0.929
			average	1421				1411				1410	

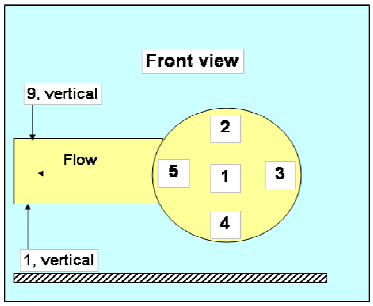
CO2 Injection Location 1
Horizontal multi-point scan (side to side)
Scan Number 8

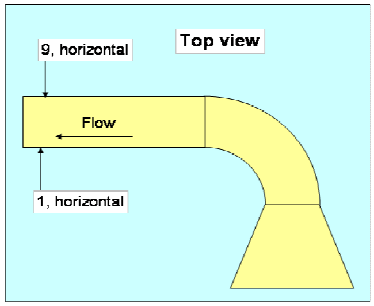
With air flow set at 60% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Upstream air P (psig)	36
Downstream air P (psig)	30
Amb T (F)	81
Abm P (psia)	14.28

	Pitot	Run #1				Run #2				Run #3			
Data Point #	Location (inch)	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2
1	0.38	2110	780	1330	0.957	2180	800	1380	0.993	2160	800	1360	0.969
2	1.26	2130	800	1330	0.957	2110	800	1310	0.942	2130	800	1330	0.948
3	2.30	2190	780	1410	1.014	2160	780	1380	0.993	2130	800	1330	0.948
4	3.88	2160	780	1380	0.993	2160	780	1380	0.993	2190	800	1390	0.990
5 (centerline)	6.00	2160	800	1360	0.978	2160	800	1360	0.978	2220	800	1420	1.012
6	8.12	2220	800	1420	1.022	2190	800	1390	1.000	2220	800	1420	1.012
7	9.67	2250	800	1450	1.043	2250	780	1470	1.058	2270	780	1490	1.062
8	10.74	2190	830	1360	0.978	2160	810	1350	0.971	2220	800	1420	1.012
9	11.62	2270	800	1470	1.058	2270	780	1490	1.072	2250	780	1470	1.048
			average	1390				1390				1403	







John Zink LLC
Date of test: September 10, 2010
Test Team: Wes Bussman, Cliff Pugh, Garrett Spaulding
Rev 0
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John Zink Flue Gas Sample Collector
Results of Homogeneity Testing

CO2 Injection Location 2
Vertical multi-point scan (top to bottom)
Scan Number 9

With air flow set at 60% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Upstream air P (psig)	36
Downstream air P (psig)	30
Amb T (F)	81
Abm P (psia)	14.28

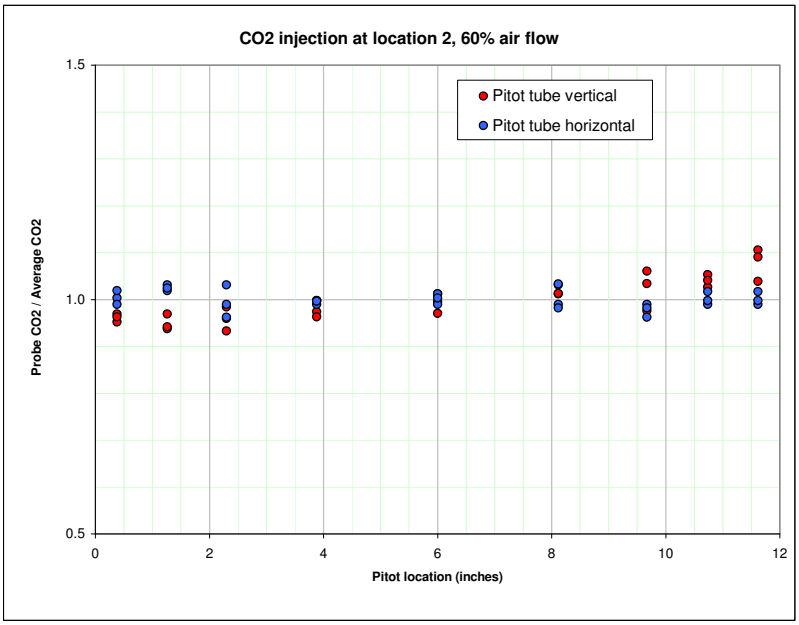
Data Point #	Pitot Location (inch)	Run #1 Probe CO2 (ppm)	Run #1 Amb CO2 (ppm)	Run #1 Probe CO2 - Amb CO2	Run #1 Probe CO2 Avg CO2	Run #2 Probe CO2 (ppm)	Run #2 Amb CO2 (ppm)	Run #2 Probe CO2 - Amb CO2	Run #2 Probe CO2 Avg CO2	Run #3 Probe CO2 (ppm)	Run #3 Amb CO2 (ppm)	Run #3 Probe CO2 - Amb CO2	Run #3 Probe CO2 Avg CO2
1	0.38	2080	730	1350	0.969	2050	730	1320	0.952	2080	720	1360	0.963
2	1.26	2050	700	1350	0.969	2020	720	1300	0.938	2050	720	1330	0.942
3	2.30	2020	720	1300	0.933	2050	720	1330	0.959	2110	720	1390	0.984
4	3.88	2110	720	1390	0.998	2080	730	1350	0.974	2080	720	1360	0.963
5 (centerline)	6.00	2130	720	1410	1.012	2110	730	1380	0.995	2110	740	1370	0.970
6	8.12	2130	720	1410	1.012	2160	730	1430	1.031	2160	730	1430	1.013
7	9.67	2060	700	1360	0.976	2220	750	1470	1.060	2190	730	1460	1.034
8	10.74	2160	730	1430	1.026	2190	730	1460	1.053	2200	730	1470	1.041
9	11.62	2270	730	1540	1.105	2190	750	1440	1.038	2270	730	1540	1.090
			average	1393				1387				1412	

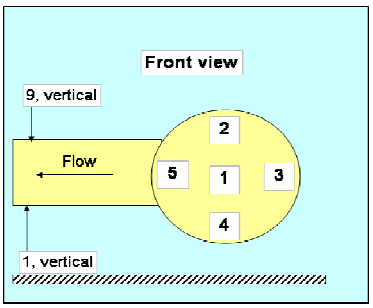
CO2 Injection Location 2
Horizontal multi-point scan (side to side)
Scan Number 9

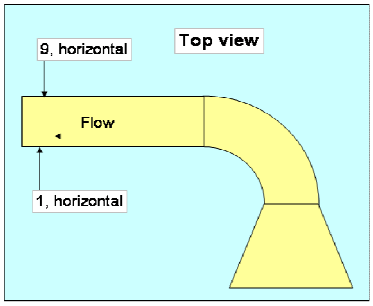
With air flow set at 60% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Upstream air P (psig)	36
Downstream air P (psig)	30
Amb T (F)	81
Abm P (psia)	14.28

Data Point #	Pitot Location (inch)	Run #1 Probe CO2 (ppm)	Run #1 Amb CO2 (ppm)	Run #1 Probe CO2 - Amb CO2	Run #1 Probe CO2 Avg CO2	Run #2 Probe CO2 (ppm)	Run #2 Amb CO2 (ppm)	Run #2 Probe CO2 - Amb CO2	Run #2 Probe CO2 Avg CO2	Run #3 Probe CO2 (ppm)	Run #3 Amb CO2 (ppm)	Run #3 Probe CO2 - Amb CO2	Run #3 Probe CO2 Avg CO2
1	0.38	2100	670	1430	1.003	2130	690	1440	1.019	2110	690	1420	0.989
2	1.26	2160	690	1470	1.031	2130	690	1440	1.019	2160	690	1470	1.024
3	2.30	2160	690	1470	1.031	2060	700	1360	0.962	2110	690	1420	0.989
4	3.88	2110	700	1410	0.989	2130	720	1410	0.998	2130	700	1430	0.996
5 (centerline)	6.00	2110	700	1410	0.989	2130	700	1430	1.012	2160	720	1440	1.003
6	8.12	2130	720	1410	0.989	2130	670	1460	1.033	2110	700	1410	0.982
7	9.67	2110	700	1410	0.989	2080	720	1360	0.962	2110	700	1410	0.982
8	10.74	2110	700	1410	0.989	2130	720	1410	0.998	2160	700	1460	1.017
9	11.62	2130	720	1410	0.989	2130	720	1410	0.998	2160	700	1460	1.017
			average	1426				1413				1436	







John Zink LLC
Date of test: September 10, 2010
Test Team: Wes Bussman, Cliff Pugh, Garrett Spaulding
Rev 1
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John Zink Flue Gas Sample Collector
Results of Homogeneity Testing

CO2 Injection Location 3
Vertical multi-point scan (top to bottom)
Scan Number 10

With air flow set at 60% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Upstream air P (psig)	36
Downstream air P (psig)	30
Amb T (F)	79
Abm P (psia)	14.4

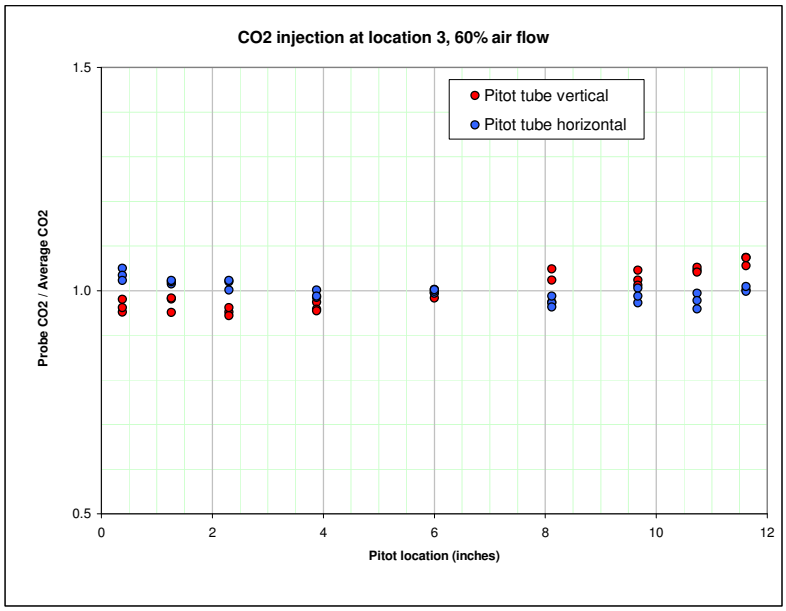
	Pitot	Run #1				Run #2				Run #3			
Data Point #	Location (inch)	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2
1	0.38	2130	810	1320	0.952	2160	800	1360	0.980	2130	800	1330	0.961
2	1.26	2160	800	1360	0.981	2130	810	1320	0.951	2160	800	1360	0.983
3	2.30	2130	810	1320	0.952	2110	800	1310	0.944	2110	780	1330	0.961
4	3.88	2160	810	1350	0.974	2130	800	1330	0.958	2130	810	1320	0.954
5 (centerline)	6.00	2190	800	1390	1.002	2160	780	1380	0.994	2160	800	1360	0.983
6	8.12	2160	810	1350	0.974	2220	800	1420	1.023	2250	800	1450	1.048
7	9.67	2250	800	1450	1.046	2220	800	1420	1.023	2200	800	1400	1.012
8	10.74	2250	800	1450	1.046	2270	810	1460	1.052	2250	810	1440	1.041
9	11.62	2300	810	1490	1.075	2300	810	1490	1.074	2270	810	1460	1.055
			average	1387				1388				1383	

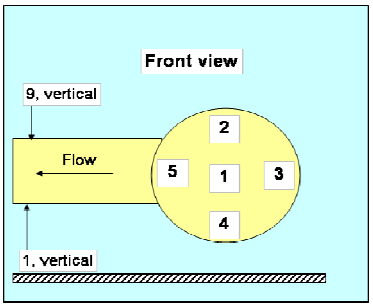
CO2 Injection Location 3
Horizontal multi-point scan (side to side)
Scan Number 10

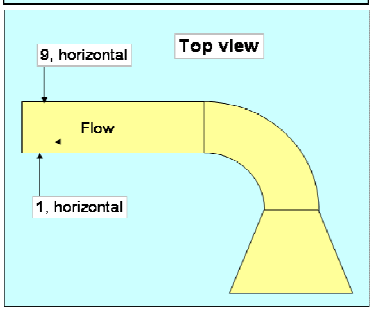
With air flow set at 60% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Upstream air P (psig)	36
Downstream air P (psig)	30
Amb T (F)	79
Abm P (psia)	14.4

	Pitot	Run #1				Run #2				Run #3			
Data Point #	Location (inch)	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2
1	0.38	2300	810	1490	1.050	2270	810	1460	1.034	2250	810	1440	1.023
2	1.26	2250	810	1440	1.015	2250	810	1440	1.020	2250	810	1440	1.023
3	2.30	2250	830	1420	1.001	2250	810	1440	1.020	2250	810	1440	1.023
4	3.88	2220	800	1420	1.001	2190	800	1390	0.984	2190	800	1390	0.987
5 (centerline)	6.00	2220	810	1410	0.994	2220	810	1410	0.998	2220	810	1410	1.002
6	8.12	2190	810	1380	0.973	2160	800	1360	0.963	2190	800	1390	0.987
7	9.67	2190	810	1380	0.973	2220	800	1420	1.006	2190	800	1390	0.987
8	10.74	2220	810	1410	0.994	2190	810	1380	0.977	2160	810	1350	0.959
9	11.62	2220	800	1420	1.001	2220	810	1410	0.998	2220	800	1420	1.009
			average	1419				1412				1408	







John Zink LLC
Date of test: September 10, 2010
Test Team: Wes Bussman, Cliff Pugh, Garrett Spaulding
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John Zink Flue Gas Sample Collector
Results of Homogeneity Testing

CO2 Injection Location 4
Vertical multi-point scan (top to bottom)
Scan Number 11

With air flow set at 60% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Upstream air P (psig)	36
Downstream air P (psig)	30
Amb T (F)	80
Abm P (psia)	14.3

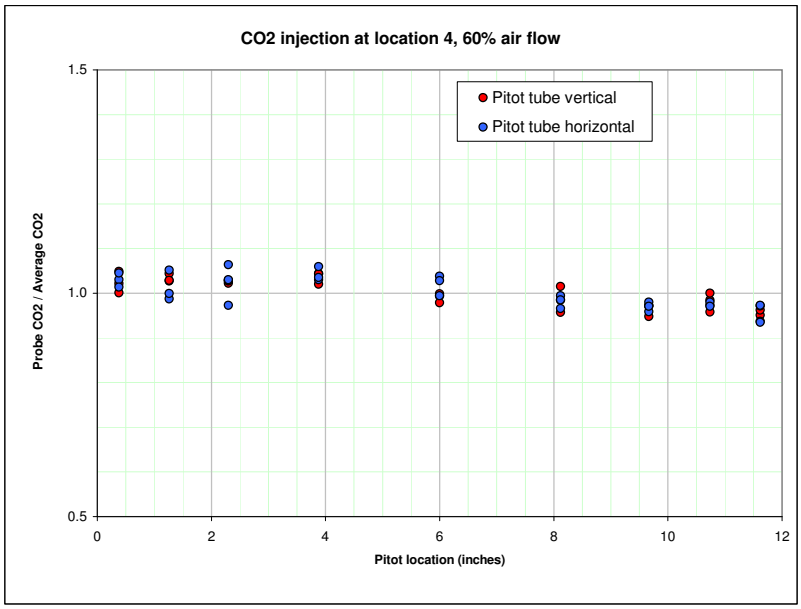
	Pitot	Run #1				Run #2				Run #3			
Data Point #	Location (inch)	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2
1	0.38	2000	610	1390	1.001	2080	630	1450	1.049	2080	660	1420	1.022
2	1.26	2080	630	1450	1.044	2050	630	1420	1.027	2060	630	1430	1.029
3	2.30	2050	630	1420	1.022	2050	630	1420	1.027	2060	630	1430	1.029
4	3.88	2050	600	1450	1.044	2020	610	1410	1.020	2050	600	1450	1.043
5 (centerline)	6.00	2020	640	1380	0.994	2020	640	1380	0.998	2000	640	1360	0.978
6	8.12	2020	610	1410	1.015	2000	640	1360	0.984	1970	640	1330	0.957
7	9.67	1970	620	1350	0.972	1940	630	1310	0.948	1960	610	1350	0.971
8	10.74	1970	640	1330	0.958	2000	640	1360	0.984	2020	630	1390	1.000
9	11.62	1940	620	1320	0.950	1970	640	1330	0.962	1970	620	1350	0.971
			average	1389				1382				1390	

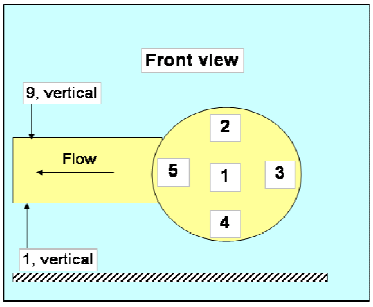
CO2 Injection Location 4
Horizontal multi-point scan (side to side)
Scan Number 11

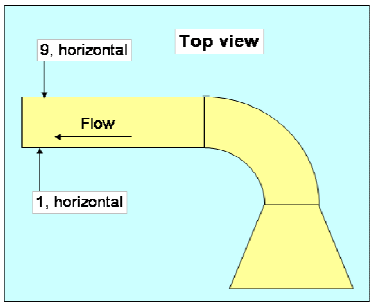
With air flow set at 60% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Upstream air P (psig)	36
Downstream air P (psig)	30
Amb T (F)	80
Abm P (psia)	14.3

	Pitot	Run #1				Run #2				Run #3			
Data Point #	Location (inch)	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2
1	0.38	2050	610	1440	1.030	2080	630	1450	1.045	2050	630	1420	1.013
2	1.26	2110	640	1470	1.052	2000	630	1370	0.987	2050	650	1400	0.999
3	2.30	2080	640	1440	1.030	2010	660	1350	0.973	2130	640	1490	1.063
4	3.88	2080	640	1440	1.030	2110	640	1470	1.059	2110	660	1450	1.035
5 (centerline)	6.00	2050	660	1390	0.994	2080	640	1440	1.038	2080	640	1440	1.028
6	8.12	2050	660	1390	0.994	2000	660	1340	0.966	2050	670	1380	0.985
7	9.67	2000	660	1340	0.959	2020	660	1360	0.980	2000	640	1360	0.971
8	10.74	2020	660	1360	0.973	2000	640	1360	0.980	2020	660	1360	0.971
9	11.62	2000	690	1310	0.937	2020	670	1350	0.973	2000	690	1310	0.935
			average	1398				1388				1401	







John Zink LLC
Date of test: September 10, 2010
Test Team: Wes Bussman, Cliff Pugh, Garrett Spaulding
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John Zink Flue Gas Sample Collector
Results of Homogeneity Testing

CO2 Injection Location 5
Vertical multi-point scan (top to bottom)
Scan Number 12

With air flow set at 60% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Upstream air P (psig)	36
Downstream air P (psig)	30
Amb T (F)	80
Abm P (psia)	14.3

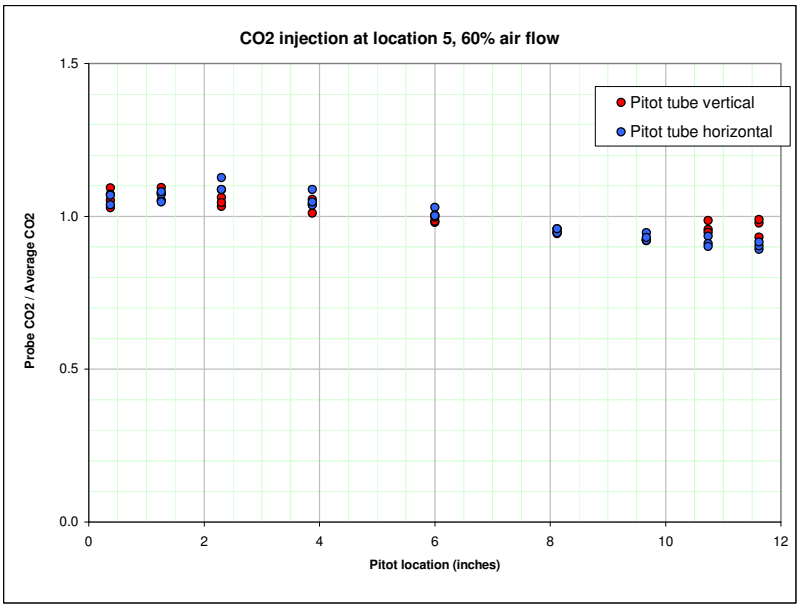
	Pitot	Run #1				Run #2				Run #3			
Data Point #	Location (inch)	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2
1	0.38	2270	770	1500	1.027	2300	760	1540	1.052	2330	750	1580	1.093
2	1.26	2330	760	1570	1.075	2360	760	1600	1.093	2300	780	1520	1.051
3	2.30	2300	750	1550	1.062	2270	760	1510	1.032	2270	760	1510	1.045
4	3.88	2270	730	1540	1.055	2250	730	1520	1.039	2220	760	1460	1.010
5 (centerline)	6.00	2190	760	1430	0.979	2190	750	1440	0.984	2190	750	1440	0.996
6	8.12	2160	760	1400	0.959	2130	750	1380	0.943	2130	760	1370	0.948
7	9.67	2110	760	1350	0.925	2080	730	1350	0.923	2080	750	1330	0.920
8	10.74	2190	750	1440	0.986	2160	760	1400	0.957	2130	760	1370	0.948
9	11.62	2110	750	1360	0.932	2190	760	1430	0.977	2190	760	1430	0.989
			average	1460				1463				1446	

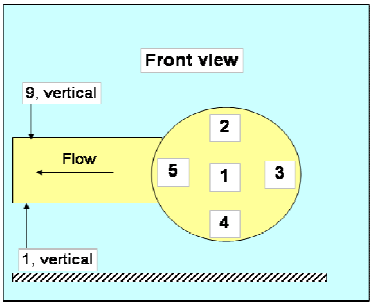
CO2 Injection Location 5
Horizontal multi-point scan (side to side)
Scan Number 12

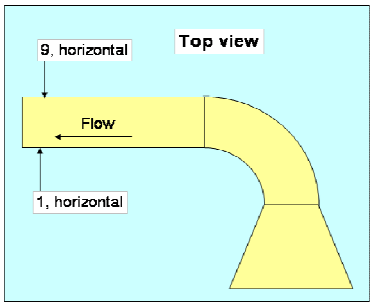
With air flow set at 60% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Upstream air P (psig)	36
Downstream air P (psig)	30
Amb T (F)	80
Abm P (psia)	14.3

	Pitot	Run #1				Run #2				Run #3			
Data Point #	Location (inch)	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2
1	0.38	2250	760	1490	1.072	2250	760	1490	1.069	2200	750	1450	1.037
2	1.26	2250	760	1490	1.072	2220	760	1460	1.047	2270	760	1510	1.080
3	2.30	2270	760	1510	1.086	2330	760	1570	1.126	2300	780	1520	1.087
4	3.88	2220	780	1440	1.036	2220	760	1460	1.047	2270	750	1520	1.087
5 (centerline)	6.00	2190	760	1430	1.029	2160	760	1400	1.004	2160	760	1400	1.002
6	8.12	2110	780	1330	0.957	2080	760	1320	0.947	2100	760	1340	0.959
7	9.67	2080	800	1280	0.921	2100	780	1320	0.947	2080	780	1300	0.930
8	10.74	2080	780	1300	0.935	2050	780	1270	0.911	2020	760	1260	0.901
9	11.62	2020	780	1240	0.892	2020	760	1260	0.904	2040	760	1280	0.916
			average	1390				1394				1398	







John Zink LLC
Date of test: September 10, 2010
Test Team: Wes Bussman, Cliff Pugh, Garrett Spaulding
Rev 1
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John Zink Flue Gas Sample Collector
Results of Homogeneity Testing

CO2 Injection Location 1
Vertical multi-point scan (top to bottom)
Scan Number 3

With air flow set at 100% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Upstream air P (psig)	70
Downstream air P (psig)	60
Amb T (F)	73
Abm P (psia)	14.38

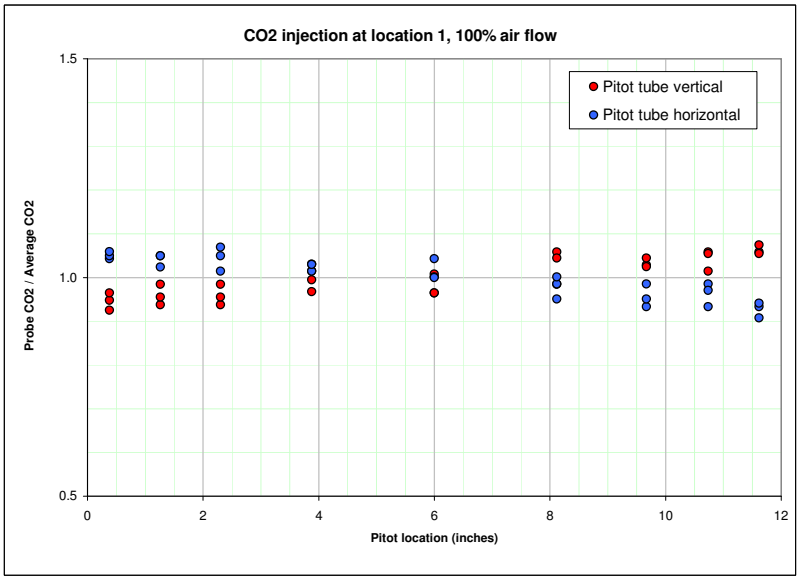
	Pitot	Run #1				Run #2				Run #3			
Data Point #	Location (inch)	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2
1	0.38	1630	690	940	0.947	1660	690	970	0.965	1630	700	930	0.925
2	1.26	1630	700	930	0.937	1660	700	960	0.955	1690	700	990	0.985
3	2.30	1630	700	930	0.937	1690	700	990	0.985	1660	700	960	0.955
4	3.88	1660	700	960	0.968	1690	690	1000	0.994	1690	670	1020	1.014
5 (centerline)	6.00	1690	690	1000	1.008	1660	690	970	0.965	1660	690	970	0.965
6	8.12	1720	670	1050	1.058	1720	670	1050	1.044	1690	700	990	0.985
7	9.67	1720	700	1020	1.028	1750	720	1030	1.024	1770	720	1050	1.044
8	10.74	1770	720	1050	1.058	1720	700	1020	1.014	1750	690	1060	1.054
9	11.62	1750	700	1050	1.058	1750	690	1060	1.054	1770	690	1080	1.074
			average	992				1006				1006	

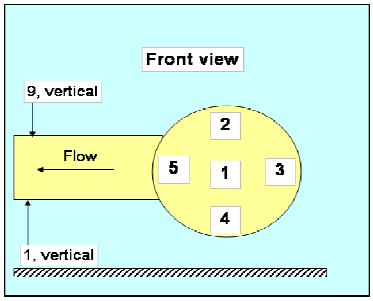
CO2 Injection Location 1
Horizontal multi-point scan (side to side)
Scan Number 3

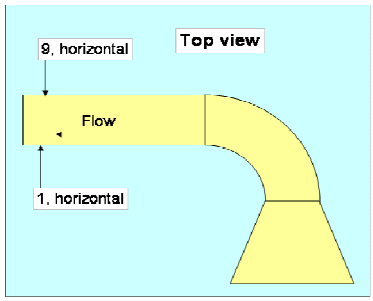
With air flow set at 100% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Upstream air P (psig)	70
Downstream air P (psig)	60
Amb T (F)	73
Abm P (psia)	14.38

	Pitot	Run #1				Run #2				Run #3			
Data Point #	Location (inch)	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2
1	0.38	1770	690	1080	1.043	1750	670	1080	1.050	1770	690	1080	1.059
2	1.26	1750	690	1060	1.024	1770	690	1080	1.050	1770	700	1070	1.049
3	2.30	1720	670	1050	1.014	1770	670	1100	1.069	1770	700	1070	1.049
4	3.88	1720	670	1050	1.014	1750	690	1060	1.030	1720	670	1050	1.029
5 (centerline)	6.00	1750	670	1080	1.043	1720	690	1030	1.001	1720	700	1020	1.000
6	8.12	1690	670	1020	0.985	1720	690	1030	1.001	1660	690	970	0.951
7	9.67	1690	670	1020	0.985	1660	700	960	0.933	1660	690	970	0.951
8	10.74	1690	670	1020	0.985	1630	670	960	0.933	1660	670	990	0.971
9	11.62	1630	690	940	0.908	1630	670	960	0.933	1660	700	960	0.941
			average	1036				1029				1020	







John Zink LLC
Date of test: September 14, 2010
Test Team: Wes Bussman, Cliff Pugh, Garrett Spaulding
Rev 1
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John Zink Flue Gas Sample Collector
Results of Homogeneity Testing

CO2 Injection Location 2
Vertical multi-point scan (top to bottom)
Scan Number 4

With air flow set at 100% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Upstream air P (psig)	70
Downstream air P (psig)	60
Amb T (F)	73
Abm P (psia)	14.38

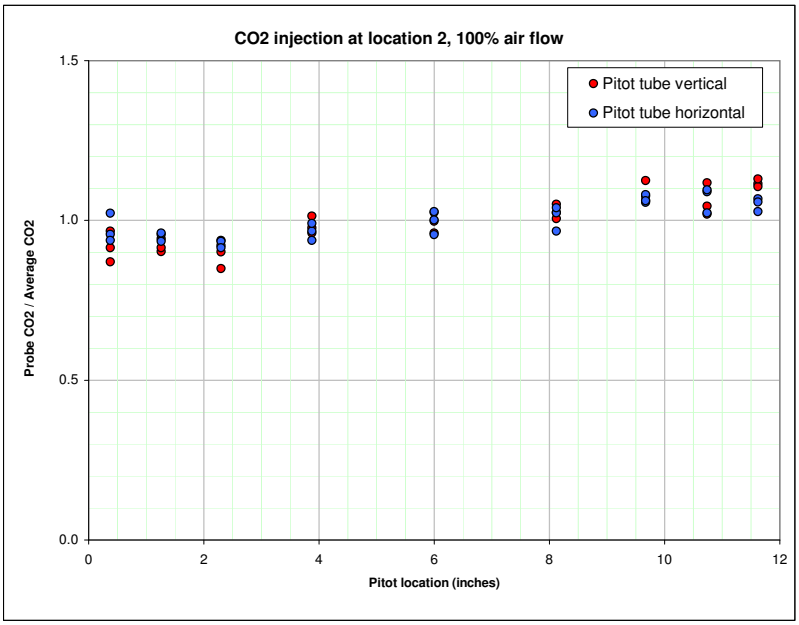
Data Point #	Pitot Location (inch)	Run #1 Probe CO2 (ppm)	Run #1 Amb CO2 (ppm)	Run #1 Probe CO2 - Amb CO2	Run #1 Probe CO2 Avg CO2	Run #2 Probe CO2 (ppm)	Run #2 Amb CO2 (ppm)	Run #2 Probe CO2 - Amb CO2	Run #2 Probe CO2 Avg CO2	Run #3 Probe CO2 (ppm)	Run #3 Amb CO2 (ppm)	Run #3 Probe CO2 - Amb CO2	Run #3 Probe CO2 Avg CO2
1	0.38	1610	700	910	0.966	1520	670	850	0.870	1500	690	810	0.915
2	1.26	1550	700	850	0.902	1610	690	920	0.942	1500	690	810	0.915
3	2.30	1580	780	800	0.849	1580	700	880	0.901	1500	670	830	0.937
4	3.88	1610	690	920	0.976	1660	670	990	1.014	1520	670	850	0.960
5 (centerline)	6.00	1610	670	940	0.998	1690	690	1000	1.024	1520	670	850	0.960
6	8.12	1690	700	990	1.051	1690	690	1000	1.024	1580	690	890	1.005
7	9.67	1750	690	1060	1.125	1720	670	1050	1.075	1630	690	940	1.061
8	10.74	1660	700	960	1.019	1690	670	1020	1.044	1660	670	990	1.118
9	11.62	1720	670	1050	1.114	1750	670	1080	1.106	1690	690	1000	1.129
			average	942				977				886	

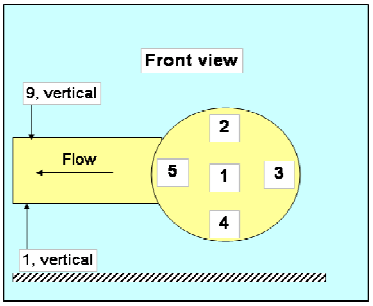
CO2 Injection Location 2
Horizontal multi-point scan (side to side)
Scan Number 4

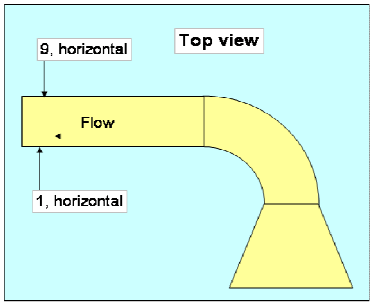
With air flow set at 100% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Upstream air P (psig)	70
Downstream air P (psig)	60
Amb T (F)	73
Abm P (psia)	14.38

Data Point #	Pitot Location (inch)	Run #1 Probe CO2 (ppm)	Run #1 Amb CO2 (ppm)	Run #1 Probe CO2 - Amb CO2	Run #1 Probe CO2 Avg CO2	Run #2 Probe CO2 (ppm)	Run #2 Amb CO2 (ppm)	Run #2 Probe CO2 - Amb CO2	Run #2 Probe CO2 Avg CO2	Run #3 Probe CO2 (ppm)	Run #3 Amb CO2 (ppm)	Run #3 Probe CO2 - Amb CO2	Run #3 Probe CO2 Avg CO2
1	0.38	1580	670	910	1.022	1520	670	850	0.956	1500	670	830	0.937
2	1.26	1520	670	850	0.955	1500	670	830	0.934	1520	670	850	0.960
3	2.30	1520	700	820	0.921	1520	690	830	0.934	1500	690	810	0.915
4	3.88	1550	690	860	0.966	1550	670	880	0.990	1520	690	830	0.937
5 (centerline)	6.00	1520	670	850	0.955	1580	690	890	1.001	1580	670	910	1.028
6	8.12	1550	690	860	0.966	1580	670	910	1.024	1610	690	920	1.039
7	9.67	1610	670	940	1.056	1630	670	960	1.080	1610	670	940	1.061
8	10.74	1630	660	970	1.090	1580	670	910	1.024	1630	660	970	1.095
9	11.62	1610	660	950	1.067	1610	670	940	1.058	1580	670	910	1.028
			average	890				889				886	







John Zink LLC
Date of test: September 14, 2010
Test Team: Wes Bussman, Cliff Pugh, Garrett Spaulding
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John Zink Flue Gas Sample Collector
Results of Homogeneity Testing

CO2 Injection Location 3
Vertical multi-point scan (top to bottom)
Scan Number 5

With air flow set at 100% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Upstream air P (psig)	70
Downstream air P (psig)	60
Amb T (F)	73
Abm P (psia)	14.38

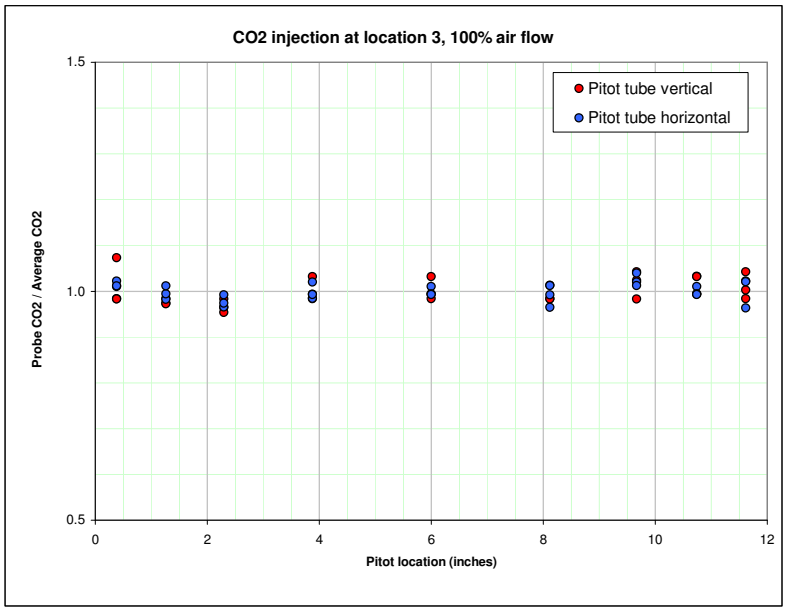
	Pitot	Run #1				Run #2				Run #3			
Data Point #	Location (inch)	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2
1	0.38	1550	550	1000	0.984	1610	530	1080	1.073	1550	550	1000	0.983
2	1.26	1520	520	1000	0.984	1530	550	980	0.974	1550	560	990	0.973
3	2.30	1500	520	980	0.964	1520	560	960	0.954	1550	550	1000	0.983
4	3.88	1520	520	1000	0.984	1550	550	1000	0.993	1580	530	1050	1.032
5 (centerline)	6.00	1550	550	1000	0.984	1550	550	1000	0.993	1610	560	1050	1.032
6	8.12	1550	550	1000	0.984	1580	560	1020	1.013	1550	550	1000	0.983
7	9.67	1610	550	1060	1.043	1610	580	1030	1.023	1580	580	1000	0.983
8	10.74	1580	530	1050	1.033	1580	580	1000	0.993	1610	560	1050	1.032
9	11.62	1610	550	1060	1.043	1550	560	990	0.983	1580	560	1020	1.002
			average	1017				1007				1018	

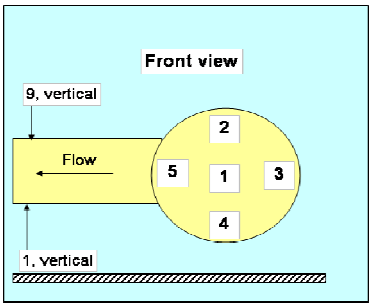
CO2 Injection Location 3
Horizontal multi-point scan (side to side)
Scan Number 5

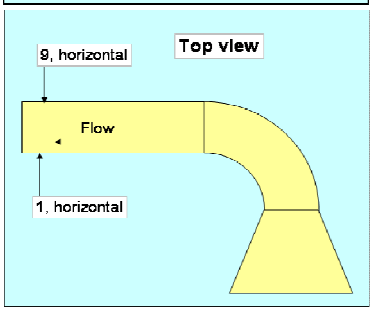
With air flow set at 100% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Upstream air P (psig)	70
Downstream air P (psig)	60
Amb T (F)	73
Abm P (psia)	14.38

	Pitot	Run #1				Run #2				Run #3			
Data Point #	Location (inch)	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2
1	0.38	1550	470	1080	1.010	1580	490	1090	1.022	1580	500	1080	1.011
2	1.26	1520	470	1050	0.982	1550	490	1060	0.994	1580	500	1080	1.011
3	2.30	1550	490	1060	0.992	1520	490	1030	0.966	1550	510	1040	0.974
4	3.88	1550	460	1090	1.020	1550	500	1050	0.984	1550	490	1060	0.993
5 (centerline)	6.00	1550	470	1080	1.010	1580	520	1060	0.994	1580	520	1060	0.993
6	8.12	1550	490	1060	0.992	1580	500	1080	1.013	1550	520	1030	0.965
7	9.67	1580	490	1090	1.020	1580	500	1080	1.013	1610	500	1110	1.040
8	10.74	1550	470	1080	1.010	1550	490	1060	0.994	1580	520	1060	0.993
9	11.62	1520	490	1030	0.964	1580	490	1090	1.022	1610	520	1090	1.021
			average	1069				1067				1068	







John Zink LLC
Date of test: September 14, 2010
Test Team: Wes Bussman, Cliff Pugh, Garrett Spaulding
Rev 1
Scan 5 Page 1 of 1

John Zink Flue Gas Sample Collector
Results of Homogeneity Testing

CO2 Injection Location 4
Vertical multi-point scan (top to bottom)
Scan Number 6

With air flow set at 100% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Upstream air P (psig)	70
Downstream air P (psig)	60
Amb T (F)	73
Abm P (psia)	14.38

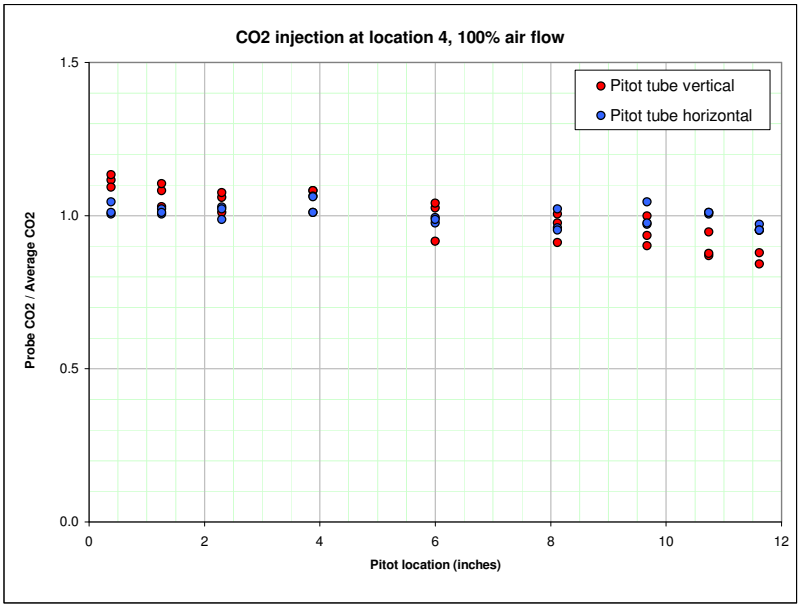
	Pitot	Run #1				Run #2				Run #3			
Data Point #	Location (inch)	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2
1	0.38	1660	670	990	1.115	1630	700	930	1.093	1660	690	970	1.134
2	1.26	1630	670	960	1.081	1610	670	940	1.104	1580	700	880	1.029
3	2.30	1610	670	940	1.059	1550	690	860	1.010	1610	690	920	1.075
4	3.88	1630	670	960	1.081	1610	690	920	1.081	1580	670	910	1.064
5 (centerline)	6.00	1610	700	910	1.025	1500	720	780	0.916	1550	660	890	1.040
6	8.12	1500	690	810	0.912	1500	670	830	0.975	1550	690	860	1.005
7	9.67	1470	670	800	0.901	1520	670	850	0.999	1470	670	800	0.935
8	10.74	1500	660	840	0.946	1410	670	740	0.869	1440	690	750	0.877
9	11.62	1470	690	780	0.879	1500	690	810	0.952	1410	690	720	0.842
			average	888				851				856	

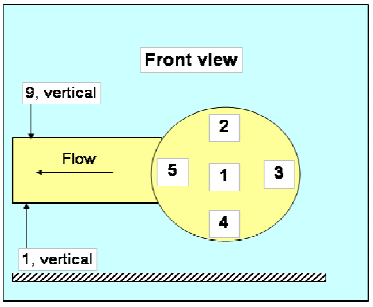
CO2 Injection Location 4
Horizontal multi-point scan (side to side)
Scan Number 6

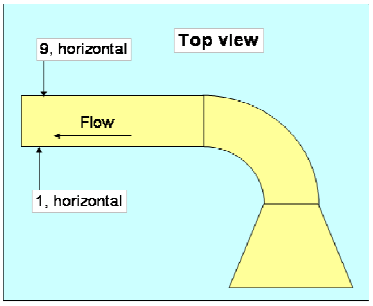
With air flow set at 100% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Upstream air P (psig)	70
Downstream air P (psig)	60
Amb T (F)	73
Abm P (psia)	14.38

	Pitot	Run #1				Run #2				Run #3			
Data Point #	Location (inch)	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2
1	0.38	1550	660	890	1.005	1550	670	880	1.010	1580	670	910	1.045
2	1.26	1580	690	890	1.005	1580	690	890	1.022	1550	670	880	1.010
3	2.30	1610	700	910	1.028	1580	690	890	1.022	1520	660	860	0.987
4	3.88	1610	670	940	1.061	1550	670	880	1.010	1550	670	880	1.010
5 (centerline)	6.00	1550	670	880	0.994	1520	670	850	0.976	1550	690	860	0.987
6	8.12	1520	670	850	0.960	1550	660	890	1.022	1500	670	830	0.953
7	9.67	1550	690	860	0.971	1520	670	850	0.976	1580	670	910	1.045
8	10.74	1580	690	890	1.005	1550	670	880	1.010	1550	670	880	1.010
9	11.62	1520	660	860	0.971	1500	670	830	0.953	1520	690	830	0.953
			average	886				871				871	







John Zink LLC
Date of test: September 14, 2010
Test Team: Wes Bussman, Cliff Pugh, Garrett Spaulding
Rev 1
Scan 6 Page 1 of 1

John Zink Flue Gas Sample Collector
Results of Homogeneity Testing

CO2 Injection Location 5
Vertical multi-point scan (top to bottom)
Scan Number 7

With air flow set at 100% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Upstream air P (psig)	70
Downstream air P (psig)	60
Amb T (F)	73
Abm P (psia)	14.38

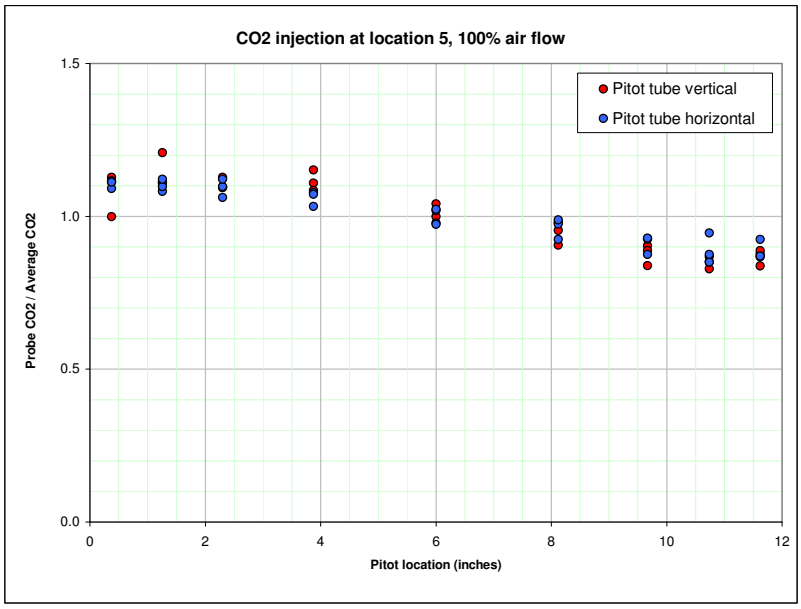
	Pitot	Run #1				Run #2				Run #3			
Data Point #	Location (inch)	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2
1	0.38	1630	580	1050	0.999	1770	600	1170	1.127	1800	610	1190	1.112
2	1.26	1830	560	1270	1.208	1750	600	1150	1.108	1800	610	1190	1.112
3	2.30	1750	600	1150	1.094	1770	600	1170	1.127	1770	600	1170	1.093
4	3.88	1770	560	1210	1.151	1750	600	1150	1.108	1800	640	1160	1.084
5 (centerline)	6.00	1660	610	1050	0.999	1690	610	1080	1.041	1750	660	1090	1.019
6	8.12	1610	580	1030	0.980	1550	610	940	0.906	1630	610	1020	0.953
7	9.67	1550	600	950	0.904	1500	630	870	0.838	1580	630	950	0.888
8	10.74	1470	600	870	0.828	1500	600	900	0.867	1520	610	910	0.850
9	11.62	1470	590	880	0.837	1520	610	910	0.877	1580	630	950	0.888
			average	1051				1038				1070	

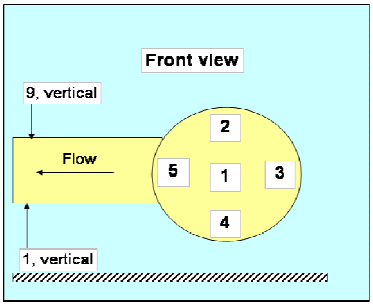
CO2 Injection Location 5
Horizontal multi-point scan (side to side)
Scan Number 7

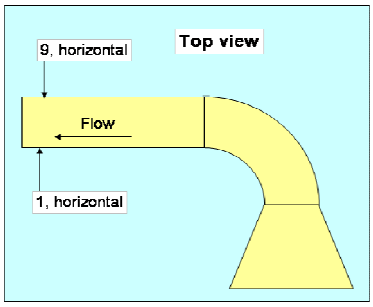
With air flow set at 100% of full eductor capacity
Full eductor capacity = 1963 ft3/min

Upstream air P (psig)	70
Downstream air P (psig)	60
Amb T (F)	73
Abm P (psia)	14.38

	Pitot	Run #1				Run #2				Run #3			
Data Point #	Location (inch)	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2	Probe CO2 (ppm)	Amb CO2 (ppm)	Probe CO2 - Amb CO2	Probe CO2 Avg CO2
1	0.38	1750	630	1120	1.091	1770	640	1130	1.116	1800	670	1130	1.111
2	1.26	1750	640	1110	1.081	1770	660	1110	1.097	1800	660	1140	1.121
3	2.30	1750	660	1090	1.062	1770	660	1110	1.097	1800	660	1140	1.121
4	3.88	1690	630	1060	1.032	1750	660	1090	1.077	1750	660	1090	1.072
5 (centerline)	6.00	1690	640	1050	1.023	1660	670	990	0.978	1660	670	990	0.974
6	8.12	1660	660	1000	0.974	1660	660	1000	0.988	1630	690	940	0.925
7	9.67	1610	660	950	0.925	1610	670	940	0.929	1580	690	890	0.875
8	10.74	1610	640	970	0.945	1550	690	860	0.850	1550	660	890	0.875
9	11.62	1550	660	890	0.867	1550	670	880	0.869	1610	670	940	0.925
			average	1027				1012				1017	







John Zink LLC
Date of test: September 14, 2010
Test Team: Wes Bussman, Cliff Pugh, Garrett Spaulding
Rev 1
Scan 7 Page 1 of 1

Correlation of Pilot Gas Flow Rate to Pilot Gas Pressure

Experimental Procedure:

1. Utilize a ½" meter run on Furnace #7 to measure flow to a pilot.
2. Utilize a calibrated pressure gauge to measure pilot gas pressure just upstream of the pilot orifice.
3. Adjust pilot gas flow to achieve approximately 15 psig on pressure gauge.
4. Print pilot gas flow report and note down pressure gauge reading.
5. Repeat procedure for all pilots to be utilized for TCEQ test.

Analysis Procedure:

1. Utilizing the John Zink Orifice program, determine the orifice coefficient for each pilot orifice.
2. Utilizing the John Zink Orifice program to determine the flow rate for each orifice at a common pressure and temperature.
3. Sum the three flow rates at common conditions for orifices associated with a flare tip.
4. Since the target pressure is above the critical pressure for natural gas, the flow rate will vary as a ratio of absolute pressure. The gas temperature will be assumed to be ambient.

Experimental Results:

Barometric Pressure during tests for pilots 1, 2, & 3 = 29.7" Hg = 14.59 psi
Barometric Pressure during tests for pilots 4, 5, & 6 = 30.13" Hg = 14.8 psi
Gas Molecular Wt = 17.1
Gas Isentropic Coefficient = 1.27

Pilot #	Gas Pressure (psig)	Gas Temp (°F)	Gas Flow (SCFH)
1	15.4	97	89.02
2	15.6	118	86.43
3	15.2	109	87.27
4	16	64	96.92
5	14.9	64	86.82
6	16.2	64	95.19

Analysis Results:

Table of Flow at Common Conditions (15.4 psig, 97°F, and 14.59 psi barometric press.)

Pilot #	Gas Flow (SCFH)
1	89.02
2	87.45
3	88.79
4	91.53
5	85.04
6	89.33

The steam assisted flare will utilize pilots 1, 2, & 3. Summation of these three pilots at common conditions yields 265.3 SCFH.

The air assisted flare will utilize pilots 4, 5, & 6. Summation of these three pilots at common conditions yields 265.9 SCFH.

The summation of flows for pilots 1, 2, & 3 and 4, 5, & 6 are very close. The average of the two values will be used for correlation of flow, 265.6 SCFH

Algorithm to be utilized for flare pilot flow:
Pilot_Gas_Pressure (psia) = Barometric pressure + PIT-3317
557°R = 97°F + 460°R
29.99 psia = 15.4 psig + 14.59 psi

$$\frac{Pilot\_Gas\_\mathrm{Pr}essure(psia)}{29.99\,psia} x265.6SCFHx\frac{557°R}{460°R + ambient\_temp°F} = Pilot\_Gas\_Flow(SCFH)$$

Convert the SCFH (60° STD Temperature) to lb/hr:

$$\frac{Pilot\_Gas\_Flow(SCFH)}{379.5(SCF/Mole)} x17.01(Lbs/Mole) = Pilot\_Gas\_Flow(Lbs/Hr)$$

Correlation of Center Steam Flow Rate to Center Steam Pressure

Experimental Procedure:

1. Shut off all upper steam globe valves.
2. Adjust center steam globe valves so a flow less that 300 lbs/hr is flowing to the flare.
3. Once flow has stabilized, note down the center steam flow and pressure.
4. Incrementing the flow upward, note down flows and pressures for multiple points till flow reaches approximately 1000 lbs/hr.

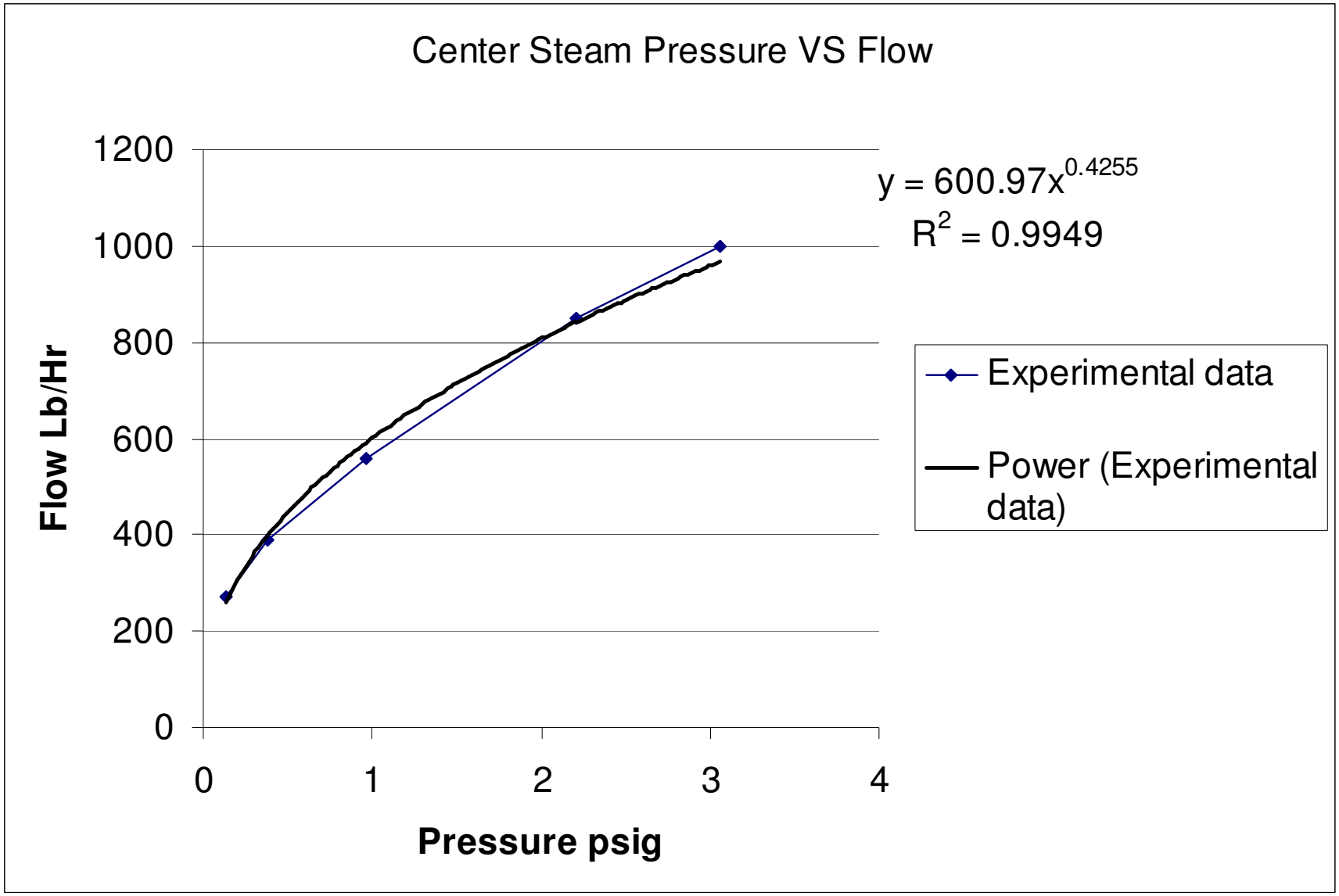
Analysis Procedure:
Utilize Excel's curve fit capability and determine a formula that provides a good fit with the experimental data.

Experimental Results:

Center Steam Pressure (psig)	Center Steam Flow (lbs/hr)
0.14	270
0.38	388
0.96	560
2.21	850
3.06	1000

Page 2 shows the plotted data along with the curve fit. The equation utilized to calculate center steam flow based on center steam pressure is:

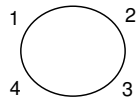
$$\boxed{Center\_Steam\_Flow(lb/hr) = 600.97x(Center\_Steam\_\mathrm{Pr}ess(psig))^{0.4255}}$$


Center Steam Pressure VS Flow
1200
1000
800
600
400
200
0
Flow Lb/Hr
0
1
2
3
4
Pressure psig
y = 600.97x^0.4255
R^2 = 0.9949
Experimental data
Power (Experimental data)

AIR ASSISTED FLARE AIR FLOW PITOT TRAVERSE TESTS

BLOWER AT 25% ROTATION DATA

Port location looking from blower to flare stack.



Port #1		Measure Point	Location from wall (in)	Traverse 1 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)	X-axis for ports 1 & 2
Air Temperature (°F)	76.3	1	1 3/16	0.01	6.77	0.01	6.77	0.01	6.77	1 3/16
Static Pressure ("w.c.)	0.08	2	6 15/16	0.01	6.77	0.01	6.77	0.01	6.77	6 15/16
Atmo. Pressure (psia)	14.48	3	10 15/16	0.01	6.77	0.01	6.77	0.01	6.77	10 15/16
Calculated Air Density (lb/ft3)	0.0729776	4	20 1/2	0.01	6.77	0.01	6.77	0.01	6.77	20 1/2

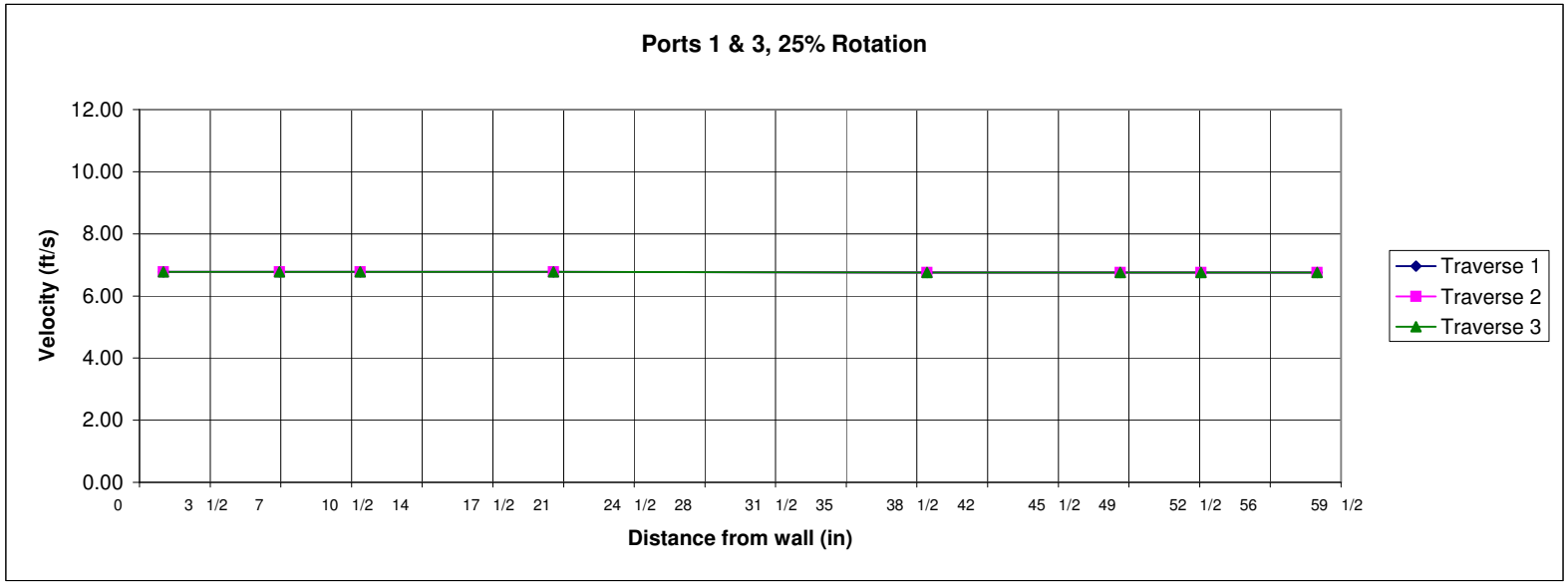
Port #3		Measure Point	Location from wall (in)	Traverse 1 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)	X-axis for ports 3 & 4
Air Temperature (°F)	72.4	4	20 1/2	0.01	6.76	0.01	6.76	0.01	6.76	39
Static Pressure ("w.c.)	0.08	3	10 15/16	0.01	6.76	0.01	6.76	0.01	6.76	48 9/16
Atmo. Pressure (psia)	14.45	2	6 15/16	0.01	6.76	0.01	6.76	0.01	6.76	52 9/16
Calculated Air Density (lb/ft3)	0.0733599	1	1 3/16	0.01	6.76	0.01	6.76	0.01	6.76	58 5/16

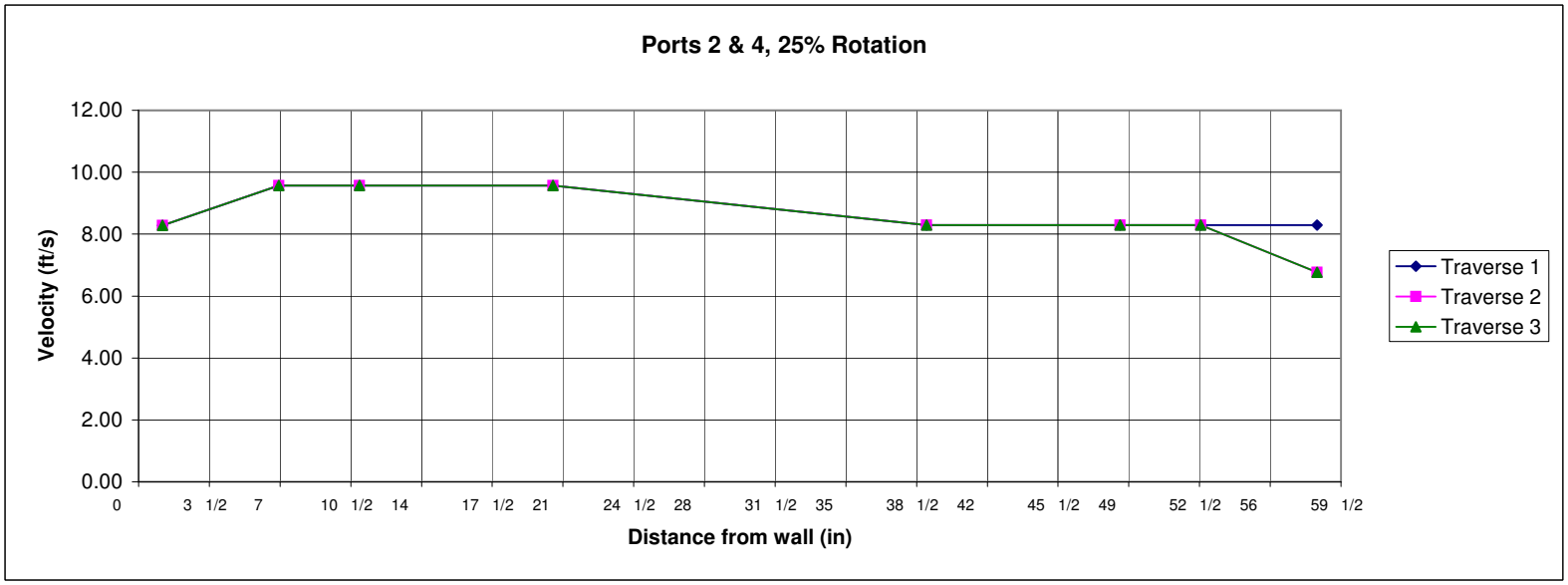
Port #2		Measure Point	Location from wall (in)	Traverse 1 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)
Air Temperature (°F)	75	1	1 3/16	0.015	8.28	0.015	8.28	0.015	8.28
Static Pressure ("w.c.)	0.08	2	6 15/16	0.02	9.57	0.02	9.57	0.02	9.57
Atmo. Pressure (psia)	14.48	3	10 15/16	0.02	9.57	0.02	9.57	0.02	9.57
Calculated Air Density (lb/ft3)	0.0731549	4	20 1/2	0.02	9.57	0.02	9.57	0.02	9.57

Port #4	4	Measure Point	Location from wall (in)	Traverse 1 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)
Air Temperature (°F)	75.7	4	20 1/2	0.015	8.29	0.015	8.29	0.015	8.29
Static Pressure ("w.c.)	0.08	3	10 15/16	0.015	8.29	0.015	8.29	0.015	8.29
Atmo. Pressure (psia)	14.48	2	6 15/16	0.015	8.29	0.015	8.29	0.015	8.29
Calculated Air Density (lb/ft3)	0.0730593	1	1 3/16	0.015	8.29	0.01	6.77	0.01	6.77

Average Vel (ft/s)	7.70
Calculated Flow (ft3/s)	148.7298

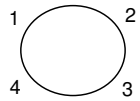
John Zink Company, LLC
Date of Test: 24 Sept. 2010
Test Team: Zach Kodesh, Richard Lawhead
Rev. 0


Ports 1 & 3, 25% Rotation
Velocity (ft/s)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
3 1/2
7
10 1/2
14
17 1/2
21
24 1/2
28
31 1/2
35
38 1/2
42
45 1/2
49
52 1/2
56
59 1/2
Distance from wall (in)
Traverse 1
Traverse 2
Traverse 3


Ports 2 & 4, 25% Rotation
Velocity (ft/s)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
3 1/2
7
10 1/2
14
17 1/2
21
24 1/2
28
31 1/2
35
38 1/2
42
45 1/2
49
52 1/2
56
59 1/2
Distance from wall (in)
Traverse 1
Traverse 2
Traverse 3

BLOWER AT 50% ROTATION DATA

Port location looking from blower to flare stack.



Port #1	
Air Temperature (°F)	76.5
Static Pressure ("w.c.)	0.35
Atmo. Pressure (psia)	14.48
Calculated Air Density (lb/ft3)	0.0729995

Measure Point	Location from wall (in)	Traverse 1 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)
1	1 3/16	0.04	13.54	0.04	13.54	0.04	13.54
2	6 15/16	0.05	15.14	0.045	14.36	0.045	14.36
3	10 15/16	0.05	15.14	0.05	15.14	0.05	15.14
4	20 1/2	0.045	14.36	0.045	14.36	0.045	14.36

X-axis for ports 1 & 2
1 3/16
6 15/16
10 15/16
20 1/2

Port #3	
Air Temperature (°F)	72.4
Static Pressure ("w.c.)	0.34
Atmo. Pressure (psia)	14.45
Calculated Air Density (lb/ft3)	0.0734076

Measure Point	Location from wall (in)	Traverse 1 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)
4	20 1/2	0.055	15.84	0.055	15.84	0.055	15.84
3	10 15/16	0.055	15.84	0.055	15.84	0.055	15.84
2	6 15/16	0.05	15.10	0.055	15.84	0.055	15.84
1	1 3/16	0.045	14.32	0.045	14.32	0.045	14.32

X-axis for ports 3 & 4
39
48 9/16
52 9/16
58 5/16

Port #2	
Air Temperature (°F)	75
Static Pressure ("w.c.)	0.35
Atmo. Pressure (psia)	14.48
Calculated Air Density (lb/ft3)	0.0732042

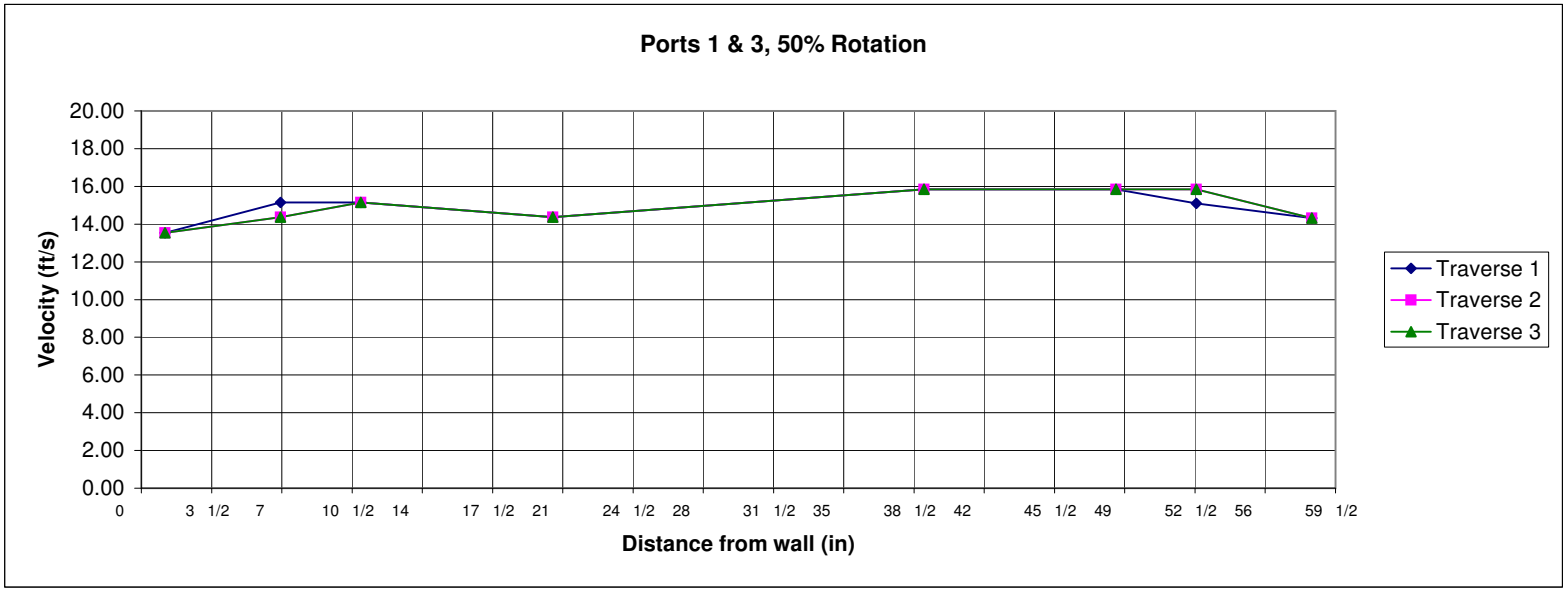
Measure Point	Location from wall (in)	Traverse 1 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)
1	1 3/16	0.05	15.12	0.05	15.12	0.05	15.12
2	6 15/16	0.065	17.24	0.055	15.86	0.06	16.56
3	10 15/16	0.065	17.24	0.06	16.56	0.065	17.24
4	20 1/2	0.065	17.24	0.055	15.86	0.06	16.56

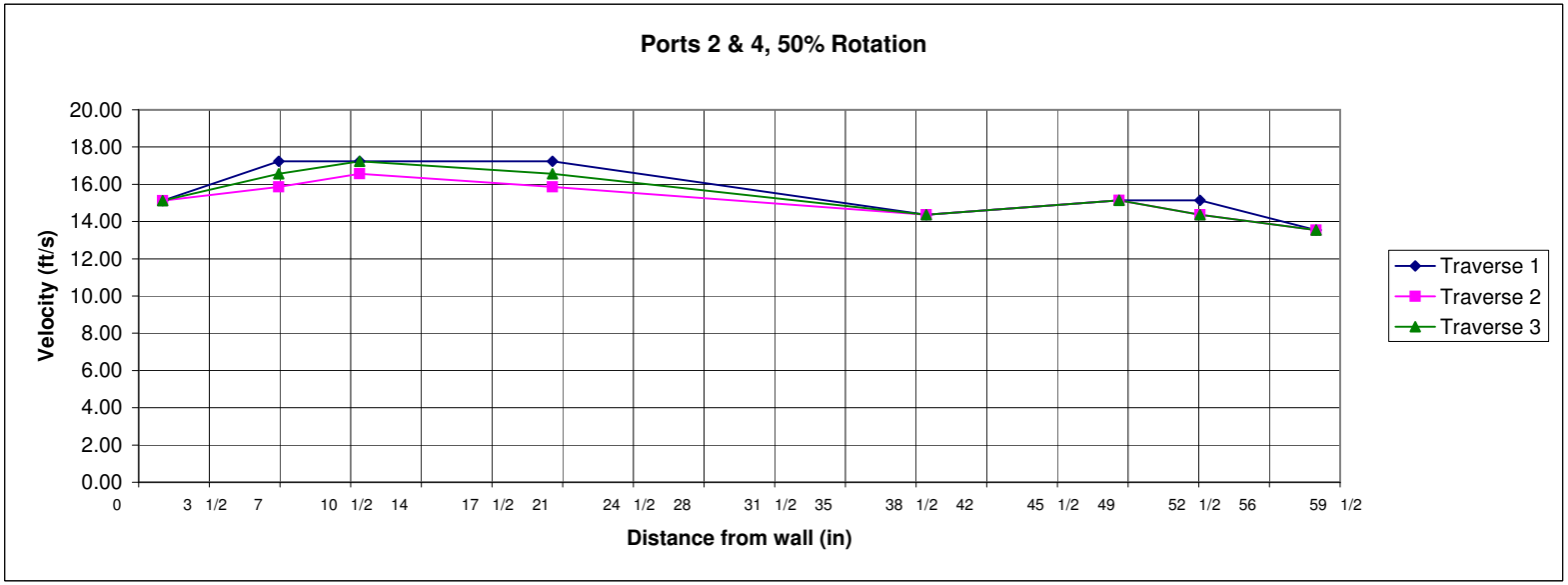
Port #4	
Air Temperature (°F)	76.5
Static Pressure ("w.c.)	0.35
Atmo. Pressure (psia)	14.48
Calculated Air Density (lb/ft3)	0.0729995

Measure Point	Location from wall (in)	Traverse 1 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)
4	20 1/2	0.045	14.36	0.045	14.36	0.045	14.36
3	10 15/16	0.05	15.14	0.05	15.14	0.05	15.14
2	6 15/16	0.05	15.14	0.045	14.36	0.045	14.36
1	1 3/16	0.04	13.54	0.04	13.54	0.04	13.54

Average Vel (ft/s)	15.14
Calculated Flow (ft3/s)	292.2693

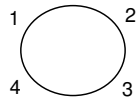
John Zink Company, LLC
Date of Test: 24 Sept. 2010
Test Team: Zach Kodesh, Richard Lawhead
Rev. 0


Ports 1 & 3, 50% Rotation
Velocity (ft/s)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
3 1/2
7
10 1/2
14
17 1/2
21
24 1/2
28
31 1/2
35
38 1/2
42
45 1/2
49
52 1/2
56
59 1/2
Distance from wall (in)
Traverse 1
Traverse 2
Traverse 3


Ports 2 & 4, 50% Rotation
Velocity (ft/s)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
3 1/2
7
10 1/2
14
17 1/2
21
24 1/2
28
31 1/2
35
38 1/2
42
45 1/2
49
52 1/2
56
59 1/2
Distance from wall (in)
Traverse 1
Traverse 2
Traverse 3

BLOWER AT 75% ROTATION DATA

Port location looking from blower to flare stack.



Port #1	
Air Temperature (°F)	77.1
Static Pressure ("w.c.)	0.8
Atmo. Pressure (psia)	14.48
Calculated Air Density (lb/ft3)	0.0729998

Measure Point	Location from wall (in)	Traverse 1 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)
1	1 3/16	0.085	19.74	0.08	19.15	0.08	19.15
2	6 15/16	0.1	21.41	0.1	21.41	0.105	21.94
3	10 15/16	0.11	22.46	0.11	22.46	0.11	22.46
4	20 1/2	0.1	21.41	0.095	20.87	0.095	20.87

X-axis for ports 1 & 2
1 3/16
6 15/16
10 15/16
20 1/2

Port #3	
Air Temperature (°F)	72.4
Static Pressure ("w.c.)	0.83
Atmo. Pressure (psia)	14.45
Calculated Air Density (lb/ft3)	0.0734974

Measure Point	Location from wall (in)	Traverse 1 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)
4	20 1/2	0.115	22.89	0.11	22.38	0.11	22.38
3	10 15/16	0.115	22.89	0.115	22.89	0.12	23.38
2	6 15/16	0.115	22.89	0.115	22.89	0.115	22.89
1	1 3/16	0.1	21.34	0.1	21.34	0.095	20.80

X-axis for ports 3 & 4
39
48 9/16
52 9/16
58 5/16

Port #2	
Air Temperature (°F)	74.7
Static Pressure ("w.c.)	0.84
Atmo. Pressure (psia)	14.48
Calculated Air Density (lb/ft3)	0.0733347

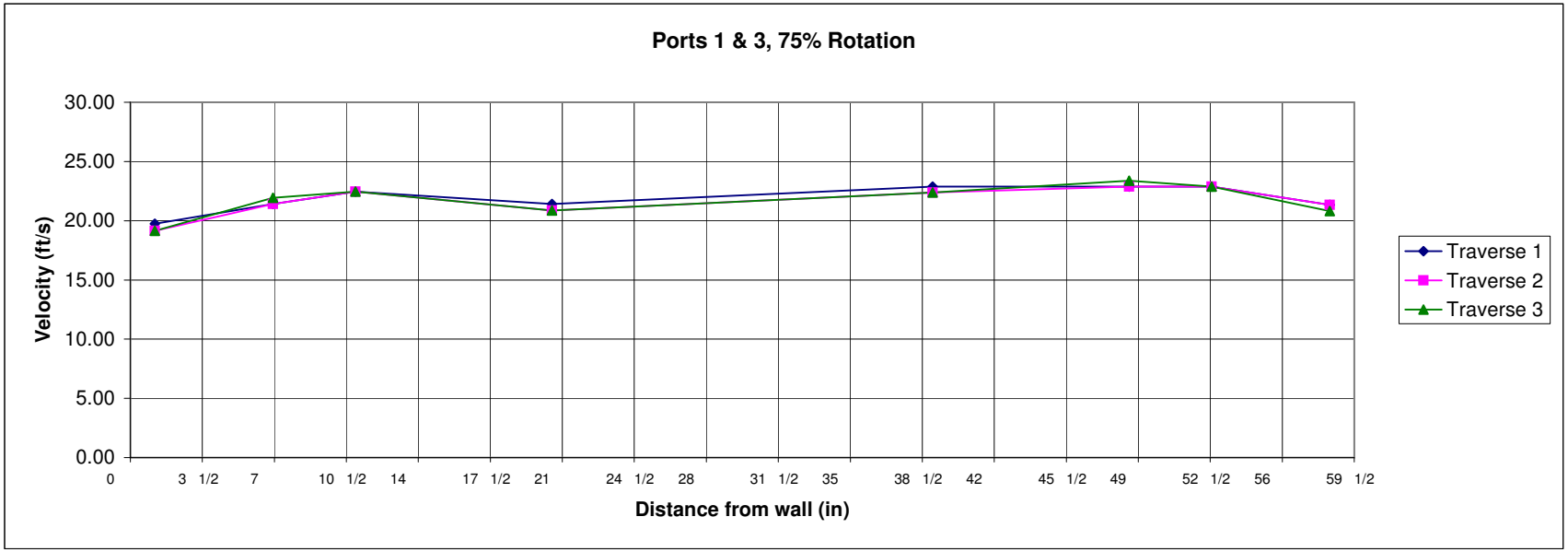
Measure Point	Location from wall (in)	Traverse 1 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)
1	1 3/16	0.105	21.89	0.1	21.36	0.105	21.89
2	6 15/16	0.12	23.40	0.13	24.36	0.13	24.36
3	10 15/16	0.13	24.36	0.135	24.82	0.14	25.28
4	20 1/2	0.125	23.89	0.125	23.89	0.13	24.36

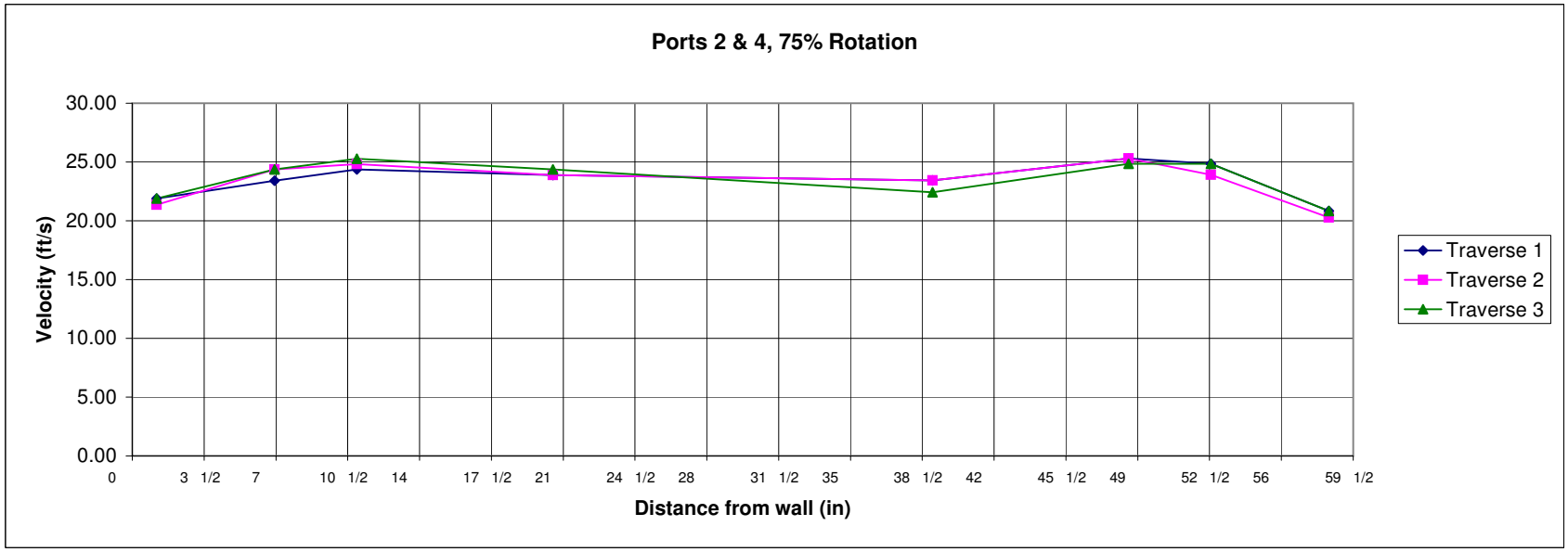
Port #4	
Air Temperature (°F)	75.7
Static Pressure ("w.c.)	0.835
Atmo. Pressure (psia)	14.48
Calculated Air Density (lb/ft3)	0.0731969

Measure Point	Location from wall (in)	Traverse 1 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)
4	20 1/2	0.12	23.43	0.12	23.43	0.11	22.43
3	10 15/16	0.14	25.30	0.14	25.30	0.135	24.85
2	6 15/16	0.135	24.85	0.125	23.91	0.135	24.85
1	1 3/16	0.095	20.84	0.09	20.29	0.095	20.84

Average Vel (ft/s)	22.63
Calculated Flow (ft3/s)	437.0604

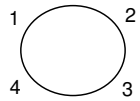
John Zink Company, LLC
Date of Test: 24 Sept. 2010
Test Team: Zach Kodesh, Richard Lawhead
Rev. 0


Ports 1 & 3, 75% Rotation
Velocity (ft/s)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
3 1/2
7
10 1/2
14
17 1/2
21
24 1/2
28
31 1/2
35
38 1/2
42
45 1/2
49
52 1/2
56
59 1/2
Distance from wall (in)
Traverse 1
Traverse 2
Traverse 3


Ports 2 & 4, 75% Rotation
Velocity (ft/s)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
3 1/2
7
10 1/2
14
17 1/2
21
24 1/2
28
31 1/2
35
38 1/2
42
45 1/2
49
52 1/2
56
59 1/2
Distance from wall (in)
Traverse 1
Traverse 2
Traverse 3

BLOWER AT 100% ROTATION DATA

Port location looking from blower to flare stack.



Port #1		Measure Point	Location from wall (in)	Traverse 1 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)	X-axis for ports 1 & 2
Air Temperature (°F)	77.2	1	1 3/16	0.16	27.07	0.145	25.77	0.15	26.21	1 3/16
Static Pressure ("w.c.)	1.5	2	6 15/16	0.19	29.49	0.18	28.71	0.185	29.10	6 15/16
Atmo. Pressure (psia)	14.48	3	10 15/16	0.205	30.64	0.195	29.88	0.19	29.49	10 15/16
Calculated Air Density (lb/ft3)	0.0731134	4	20 1/2	0.19	29.49	0.19	29.49	0.18	28.71	20 1/2

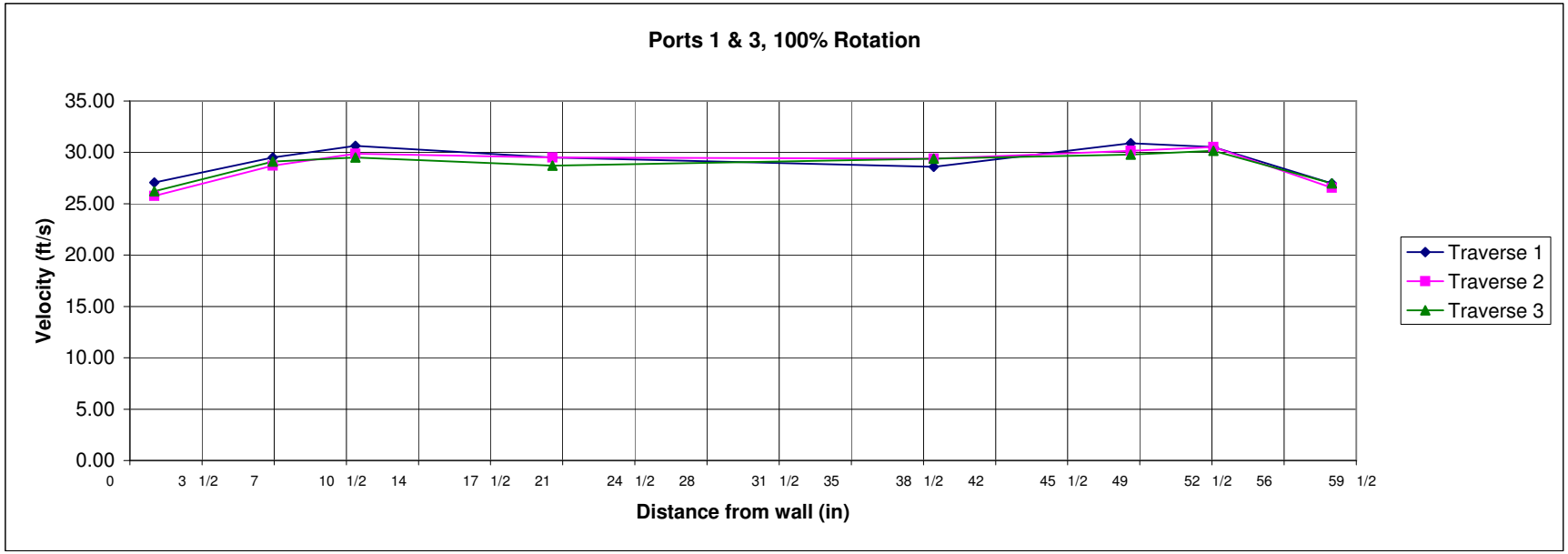
Port #3		Measure Point	Location from wall (in)	Traverse 1 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)	X-axis for ports 3 & 4
Air Temperature (°F)	72.4	4	20 1/2	0.18	28.61	0.19	29.39	0.19	29.39	39
Static Pressure ("w.c.)	1.5	3	10 15/16	0.21	30.90	0.2	30.16	0.195	29.78	48 9/16
Atmo. Pressure (psia)	14.45	2	6 15/16	0.205	30.53	0.205	30.53	0.2	30.16	52 9/16
Calculated Air Density (lb/ft3)	0.0736203	1	1 3/16	0.16	26.97	0.155	26.55	0.16	26.97	58 5/16

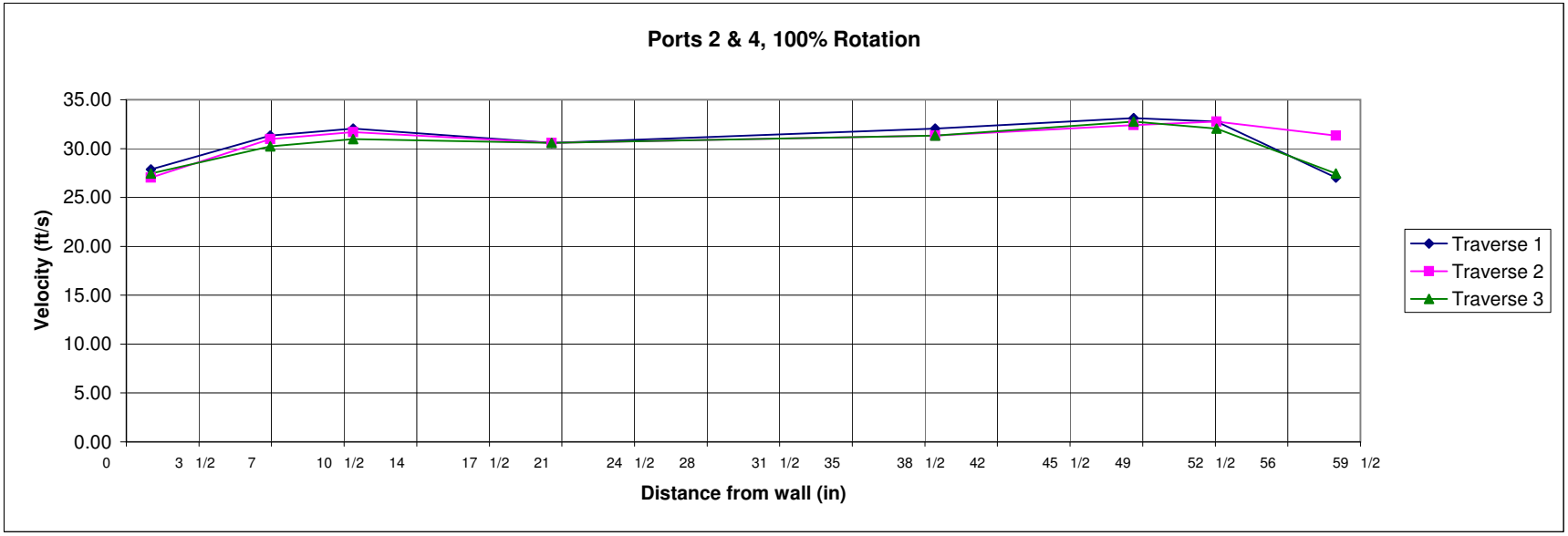
Port #2		Measure Point	Location from wall (in)	Traverse 1 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)
Air Temperature (°F)	75.6	1	1 3/16	0.17	27.86	0.16	27.03	0.165	27.44
Static Pressure ("w.c.)	1.5	2	6 15/16	0.215	31.33	0.21	30.96	0.2	30.22
Atmo. Pressure (psia)	14.48	3	10 15/16	0.225	32.05	0.22	31.69	0.21	30.96
Calculated Air Density (lb/ft3)	0.0733318	4	20 1/2	0.205	30.59	0.205	30.59	0.205	30.59

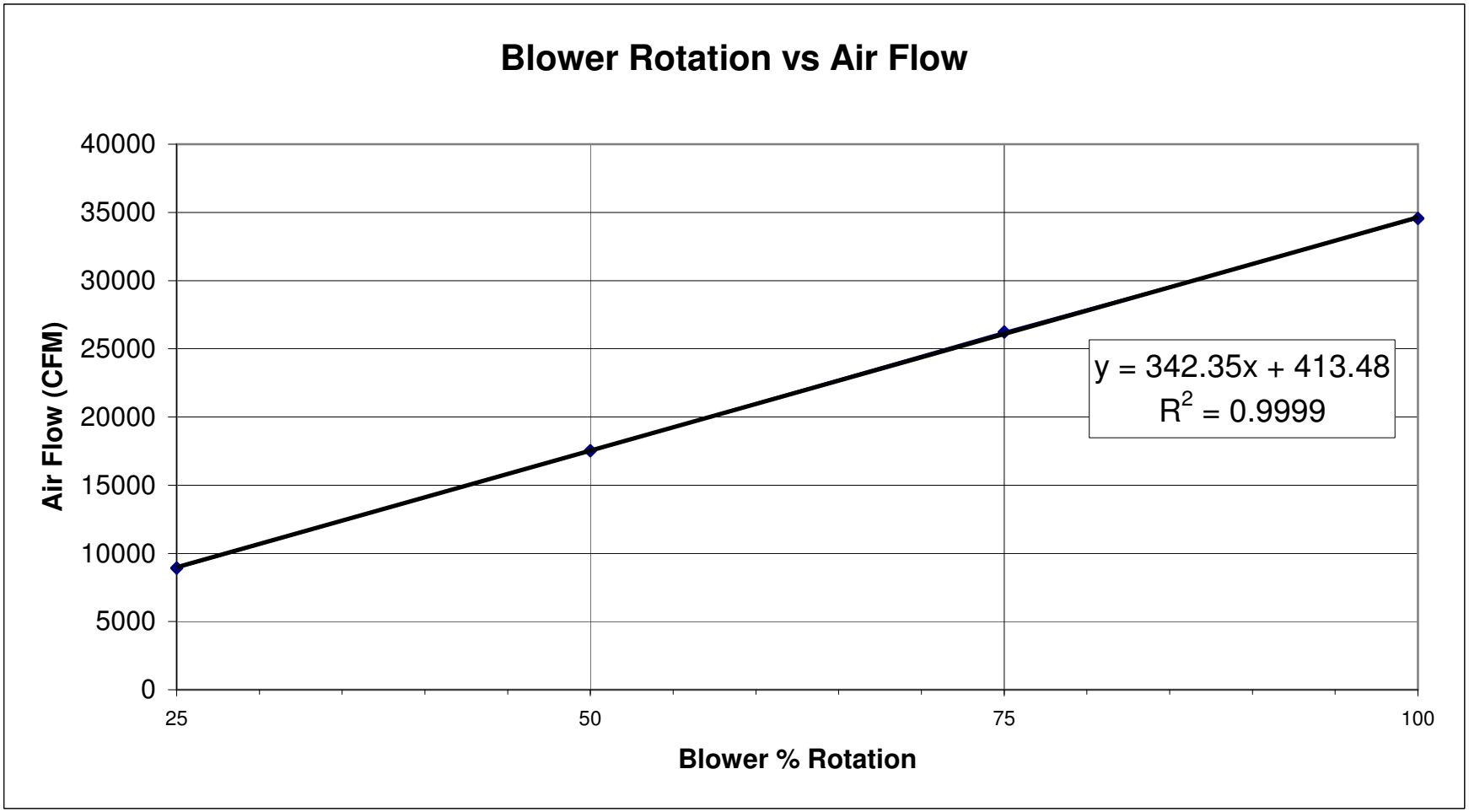
Port #4		Measure Point	Location from wall (in)	Traverse 1 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)	Traverse 2 Vel. Presure (" w.c.)	Velocity (ft/sec)
Air Temperature (°F)	76	4	20 1/2	0.225	32.06	0.215	31.34	0.215	31.34
Static Pressure ("w.c.)	1.5	3	10 15/16	0.24	33.11	0.23	32.41	0.235	32.76
Atmo. Pressure (psia)	14.48	2	6 15/16	0.235	32.76	0.235	32.76	0.225	32.06
Calculated Air Density (lb/ft3)	0.0732771	1	1 3/16	0.16	27.04	0.215	31.34	0.165	27.45

Average Vel (ft/s)	29.83
Calculated Flow (ft3/s)	575.9462

John Zink Company, LLC
Date of Test: 24 Sept. 2010
Test Team: Zach Kodesh, Richard Lawhead
Rev. 0


Ports 1 & 3, 100% Rotation
Velocity (ft/s)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
3 1/2
7
10 1/2
14
17 1/2
21
24 1/2
28
31 1/2
35
38 1/2
42
45 1/2
49
52 1/2
56
59 1/2
Distance from wall (in)
Traverse 1
Traverse 2
Traverse 3


Ports 2 & 4, 100% Rotation
Velocity (ft/s)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
3 1/2
7
10 1/2
14
17 1/2
21
24 1/2
28
31 1/2
35
38 1/2
42
45 1/2
49
52 1/2
56
59 1/2
Distance from wall (in)
Traverse 1
Traverse 2
Traverse 3


Blower Rotation vs Air Flow
Air Flow (CFM)
40000
35000
30000
25000
20000
15000
10000
5000
0
25
50
75
100
Blower % Rotation
y = 342.35x + 413.48
R2 = 0.9999

QUALITY CONTROL DOCUMENTS

PIPING PRESSURIZATION RECORD

Fuel Piping Pressurization Log

	Date	9/7/2010	9/8/2010	9/~~10~~09/2010	9/13/2010	9/13/2010	9/14/2010	9/14/2010	9/15/2010	9/15/2010	9/16/2010	9/16/2010
	Time	4:21 PM	9:58 AM	4:00 PM	5:00 PM	5:50 PM			1:45	5:30 PM	7:15 AM	5:46 PM
1	ZTOF Pressure Gauge (psig)	5	4.7	5.5	5.0	5.4			7.9	5.8	5.4	5
2	TNG Pressure Gauge (psig)		10							11	10.5	10.5
3	Propylene Pressure Gauge (psig)	5	5	5.5	5.5	6.0			8.5	6	6	5
4	Nitrogen Pressure Gauge (psig)									15	25	

	Date	9/17/2010	9/17/2010	9/20/2010	9/20/2010	9/21/2010	9/21/2010	9/22/2010	9/22/2010	9/23/2010	9/23/2010	9/24/2010
	Time	7:30 AM	5:45 PM	7:15 AM	6:40	6:30 AM	6:15 PM	7:15 AM	5:55 PM	6:35 AM	5:10 PM	
1	ZTOF Pressure Gauge (psig)	4.7	5	4.7	5	5	6	6	5.5	5	5	
2	TNG Pressure Gauge (psig)	10.5	7	7.5	8½	8	6	10	6.5	6.5	11	
3	Propylene Pressure Gauge (psig)	5	5	5.0	56	NA	10	6	5.0	5.0	6	
4	Nitrogen Pressure Gauge (psig)		53.5	41.5	54.5	56.5	10	6	38	38	26	

	Date	9/24/2010	9/27/2010	9/27/2010	9/28/2010	9/28/2010	9/29/2010	9/29/2010	9/30/2010	9/30/2010	10/1/2010	10/1/2010
	Time		7:15 AM	5:30 PM	6:41 AM	5:00 PM	6:25 AM					
1	ZTOF Pressure Gauge (psig)		4	4.9	4.5	6	5					
2	TNG Pressure Gauge (psig)		9	9	6.25	9	8					
3	Propylene Pressure Gauge (psig)		5	5	4.5	6	6					
4	Nitrogen Pressure Gauge (psig)		5	48	5.75	52	52+					

CALIBRATION EQUIPMENT CALIBRATIONS

Davis Calibration

Certificate of Calibration

4245942

Instrument Identification

Company ID: JOHZIN
JOHN ZINK-3

PO Number:

11920 E. APACHE
ATTN:CHRISTINA KING
TULSA, OK 74116

Instrument ID: **RD-A44476**
Manufacturer: FLUKE
Description: DRY WELL CALIBRATOR

Model Number: 9102S
Serial Number: A44476

Certificate Information

Reason For Service: CALIBRATION
Type of Cal: NORMAL
As Found Condition: IN TOLERANCE
As Left Condition: LEFT AS FOUND
Procedure: 33K5-4-579-1 DRY BLOCK

Remarks:

Technician: DAN CIARLO
Cal Date 18Jun2010
Cal Due Date: 30Jun2011
Interval: 12 MONTHS
Temperature: 22.0 C
Humidity: 47.0 %

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 [K=2, approx. 95% Confidence Level] was maintained unless otherwise stated.

Davis Calibration Laboratory is certified to ISO 9001:2008 by Eagle Registrations (certificate # 3046). Lab Operations meet the requirements of ANSI/NCSL Z540-1-1994 (R2002), ISO 10012:2003, 10CFR50 AppxB, and 10CFR21.

ISO/IEC 17025-2005 accredited calibrations are per ACLASS certificate # AC-1105 within the scope for which the lab is accredited.
When uncertainty measurement calculations have been calculated per customer request, reported condition statements do not take into account uncertainty of measurement.
All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.
This certificate shall not be reproduced except in full, without written consent of Davis Calibration Laboratory.

Approved By: DAN CIARLO
Service Representative

Calibration Standards

NIST Traceable#	Inst. ID#	Description	Model	Cal Date	Date Due
3378911	08-0139	PLATINUM RESISTANCE PROBE	5626-15-S	15Jul2009	15Jul2010
3950891	08-9993	DIGITAL MULTIMETER	3458A	05Mar2010	05Mar2011

Davis Calibration

Certificate of Calibration

4254674

Instrument Identification

Company ID: JOHZIN
JOHN ZINK-3

PO Number:

11920 E. APACHE
ATTN:CHRISTINA KING
TULSA, OK 74116

Instrument ID: **RD-0911251**
Manufacturer: WIKA
Description: DIGITAL PNEUMATIC CALIBRATOR

Model Number: 65-2000
Serial Number: 0911251

Pressure Accuracy: ± 0.02 % of Reading ± 3 Digits
Electrical Accuracy: ± 0.04 % of Full Scale ± 2 Digits

Certificate Information

Reason For Service: CALIBRATION
Type of Cal: NORMAL
As Found Condition: IN TOLERANCE
As Left Condition: LEFT AS FOUND
Procedure: 33K6-4-314-1 DIGITAL PRESSURE GAGES

Remarks:

Technician: DAN CIARLO
Cal Date 23Jun2010
Cal Due Date: 30Jun2011
Interval: 12 MONTHS
Temperature: 22.0 C
Humidity: 48.0 %

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 [K=2, approx. 95% Confidence Level] was maintained unless otherwise stated.

Davis Calibration Laboratory is certified to ISO 9001:2008 by Eagle Registrations (certificate # 3046). Lab Operations meet the requirements of ANSI/NCSL Z540-1-1994 (R2002), ISO 10012:2003, 10CFR50 AppxB, and 10CFR21.

ISO/IEC 17025-2005 accredited calibrations are per ACLASS certificate # AC-1105 within the scope for which the lab is accredited.
When uncertainty measurement calculations have been calculated per customer request, reported condition statements do not take into account uncertainty of measurement.
All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.
This certificate shall not be reproduced except in full, without written consent of Davis Calibration Laboratory.

Approved By: KELLY GAMBLE
Service Representative

Calibration Standards

NIST Traceable#	Inst. ID#	Description	Model	Cal Date	Date Due
3922794	08-1030	DIGITAL PRESSURE INDICATOR	PPC2+ D-A0500/G	18Feb2010	18Feb2011
4190381	08-8995	CALIBRATOR	5520A W/SC1100	18May2010	18May2011

TRANSMITTER CALIBRATIONS, TRANSMITTER SPAN LOGS, TRANSMITTER CONFIGURATION RECORDS

FT-2102

Assist Air Flow

TRANSMITTER SPAN LOG

DATE	UNITS	4mA	20mA	Name of Person Who Made the Change
5/25/10	SCFM	0	20,000	Factory

FCI FLUID COMPONENTS INTL
A limited liability company
1755 La Costa Meadows Drive, San Marcos, California 92078
(760) 744-6950 (800) 854-1993 FAX: (760) 736-6250
www.fluidcomponents.com

ST98 Series Delta 'R Version 2.32 EPROM

C#:	C050159	Serial:	326695	Dec-Box	Equip.	Cal. Due
Cust.:	JOHN ZINK CO	Date:	May 25, 2010	(Act):	EL-515	01-20-2011
Tag:	FT-2102	TagR1:		(Ref):	EL-318	11-02-2010
TagL2:		TagR2:		DVM:	EL-302	09-04-2010
TagL3:		TagR3:		250 Ω:	EL-533	01-06-2011

Nominal Sensor Resistance:	1000 Ω
Indicated Temperature at Nominal Resistance:	28.8 °F

Test Tech.:	224

Notes: ST98, calibration group 1.

Delta 'R (ohms)	VDC Across 250 ohms	mA Output	Unit A/D	Indicated Display
179.47	1.000	4.00	3371	0.000 SCFM
178.47	1.176	4.70	3352	879.7 SCFM
167.57	1.251	5.00	3148	1249 SCFM
148.83	1.499	6.00	2798	2498 SCFM
128.07	1.997	7.99	2410	4989 SCFM
107.46	2.997	11.99	2025	9995 SCFM
94.77	3.994	15.98	1788	14990 SCFM
86.32	4.992	19.97	1630	19960 SCFM

EPROM Information

Version
2.32

Date
4/4/06

CheckSum
4AE3

ST98 Parameters: Mode "D"

Version:	2.32	C4:	-856.223	KFactor:	1.0000
Scale:	1.199797	C5:	13.51101	Zero:	0.000000
Serial #	326695	Balance:	146	Sensor:	3
Customer #	C050159	Outz:	6620	Tslp:	0.2282
Curve fit:	2	Outf:	32936.0	Refr:	2264.06
BrkPt:	1972	Heater_i:	195	Caltmp:	74.24
Poly Seg. 1		Factor:	1158.553	Toff:	-442.41
C1:	520.8069	Eu:	67 (C)	Tcslp:	0.000137
C2:	-69.86597	Tot:	0	Tcslp0:	0.000000
C3:	385.8669	Tottemp:	0	Tcslp2:	0.000000
C4:	-981.5447	Totflow:	214660.359	Maxflow:	20.71200
C5:	9.426826	Rollover:	: 1e6	Minflow:	0.750900
Poly Seg. 2		Roll cnt:	0	Density:	0.074915
C1:	180.7862	Outmode:	0	Line size0:	59.500000
C2:	-25.33013	A/D Max:	3334	Line size1:	0.0000000
C3:	206.8663	A/D Min:	1462	F.S.:	20000.00

TEMPERATURE ELEMENT VERIFICATION RECORD

INSTRUMENT TAG: TE - 2102 Assist Air Temp

DATE: _____

PROCEDURE

1. If element is connected to a transmitter, calibrate the transmitter first.
2. Insert element into test device, set test device to target temperature, allow temperature of test device to stabilize.
3. Note down the test device temperature in the appropriate column.
4. Note down the data acquisition value in the appropriate column.
5. If data acquisition value is outside the range of the acceptance criteria, replace the element.

Target Temp. °F	Calibration Instrument Reading °F	Data Acquisition Value °F	Acceptance Criteria (mA)
~~150~~	235	236	+/- 5°F
150 ~~100~~	150	151	+/- 5°F
32	32	34	+/- 5°F

Element passed: X Element. replaced: _____

Verification Performed by: Charles Crowns

Date next verification is to be performed: _____

TEMPERATURE ELEMENT VERIFICATION RECORD

INSTRUMENT TAG: TE-2103 Sample Temp At Sample port

DATE: 9-10-2010

PROCEDURE

1. If element is connected to a transmitter, calibrate the transmitter first.
2. Insert element into test device, set test device to target temperature, allow temperature of test device to stabilize.
3. Note down the test device temperature in the appropriate column.
4. Note down the data acquisition value in the appropriate column.
5. If data acquisition value is outside the range of the acceptance criteria, replace the element.

Target Temp. °F	Calibration Instrument Reading °F	Data Acquisition Value °F	Acceptance Criteria (mA)
~~150~~	220.0	221.0	+/- 5°F
~~100~~	150.0	148.0	+/- 5°F
32	32.0	32.0	+/- 5°F

Element passed: X Element. replaced: _____

Verification Performed by: Marvin Thomas

Date next verification is to be performed: _____

TEMPERATURE ELEMENT VERIFICATION RECORD

INSTRUMENT TAG: TE-2104 Sample Device Inlet Temp

DATE: 9-10-2010

PROCEDURE

1. If element is connected to a transmitter, calibrate the transmitter first.
2. Insert element into test device, set test device to target temperature, allow temperature of test device to stabilize.
3. Note down the test device temperature in the appropriate column.
4. Note down the data acquisition value in the appropriate column.
5. If data acquisition value is outside the range of the acceptance criteria, replace the element.

Target Temp. °F	Calibration Instrument Reading °F	Data Acquisition Value °F	Acceptance Criteria (mA)
~~150~~	220.0	219.0	+/- 5°F
~~100~~	150.0	149.0	+/- 5°F
32	31.9	30.0	+/- 5°F

Element passed: X Element. replaced: _____

Verification Performed by: MARVIN THOMAS

Date next verification is to be performed: _____

TEMPERATURE ELEMENT VERIFICATION RECORD

INSTRUMENT TAG: TE-2105 SAMPLE DEVICE INLET TEMP

DATE: 9-10-2010

PROCEDURE

1. If element is connected to a transmitter, calibrate the transmitter first.
2. Insert element into test device, set test device to target temperature, allow temperature of test device to stabilize.
3. Note down the test device temperature in the appropriate column.
4. Note down the data acquisition value in the appropriate column.
5. If data acquisition value is outside the range of the acceptance criteria, replace the element.

Target Temp. °F	Calibration Instrument Reading °F	Data Acquisition Value °F	Acceptance Criteria (mA)
~~150~~	220.0	219.0	+/- 5°F
~~100~~	150.0	145.0	+/- 5°F
32	32.0	29.0	+/- 5°F

Element passed: X

Element. replaced: _____

Verification Performed by: MARVIN THOMAS

Date next verification is to be performed: _____

TEMPERATURE ELEMENT VERIFICATION RECORD

INSTRUMENT TAG: TE - 2106 SAMPLE DEVICE INLET TEMP

DATE: 9-14-2010

PROCEDURE

1. If element is connected to a transmitter, calibrate the transmitter first.
2. Insert element into test device, set test device to target temperature, allow temperature of test device to stabilize.
3. Note down the test device temperature in the appropriate column.
4. Note down the data acquisition value in the appropriate column.
5. If data acquisition value is outside the range of the acceptance criteria, replace the element.

Target Temp. °F	Calibration Instrument Reading °F	Data Acquisition Value °F	Acceptance Criteria (mA)
~~150~~	220.0	222.0	+/- 5°F
100	150.0	152.0	+/- 5°F
32	32.0	34.0	+/- 5°F

Element passed: X Element. replaced: _____

Verification Performed by: Charles Crown

Date next verification is to be performed: _____

Sample Collector Pitot Velocity Pressure

FIT-2107

TRANSMITTER SPAN LOG

DATE	UNITS	4mA	20mA	Name of Person Who Made the Change
9/9/10	"WC.	0	1	Charlie Crown Initial Setup

TRANSMITTER CALIBRATION RECORD

INSTRUMENT TAG: FIT-2107

DATE: 9-9-10

PROCEDURE

1. Before performing any calibration, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.
2. If any value deviates from the expected value by more than 0.5% of span, perform calibration of the transmitter.
3. If calibration is performed, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.

% of Span	Process Value	As Found			Acceptance Criteria (mA)	After Calibration		
	Units: IN/H2O	Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value		Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value
0	0	N/A	4	0.000	4 (3.9 to 4.1)			
25	.25		8	0.250	8 (7.9 to 8.1)			
50	.5		12	0.500	12 (11.9 to 12.1)			
75	.75		16	0.750	16 (15.9 to 16.1)			
100	1.0		20	1.000	20 (19.9 to 20.1)			

Trans. passed without cal: X Trans. passed with cal.: _____ Trans. replaced: _____

Calibration Performed by: Charlie Crown

Date next calibration is to be performed: _____

FIT-2107

Davis Calibration

Certificate of Calibration

4458010

Instrument Identification

Company ID: JOHZIN
JOHN ZINK-3

PO Number: 5076109

11920 E. APACHE
TULSA, OK 74116

Instrument ID: **0467750**
Manufacturer: ROSEMOUNT
Description: PRESSURE TRANSMITTER

Model Number: 3051
Serial Number: 0467750

Accuracy: ± 1% F.S.

Certificate Information

Reason For Service: CALIBRATION
Type of Cal: NORMAL
As Found Condition: IN TOLERANCE
As Left Condition: LEFT AS FOUND
Procedure: NA17-20MP-209 PRESSURE TRANSMITTER

Remarks:

Technician: DALLAS KENDRICK
Cal Date 09Sep2010
Cal Due Date: 30Sep2011
Interval: 12 MONTHS
Temperature: 21.0 C
Humidity: 49.0 %

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 [K=2, approx. 95% Confidence Level] was maintained unless otherwise stated.

Davis Calibration Laboratory is certified to ISO 9001:2008 by Eagle Registrations (certificate # 3046). Lab Operations meet the requirements of ANSI/NCSL Z540-1-1994 (R2002), ISO 10012:2003, 10CFR50 AppxB, and 10CFR21.

ISO/IEC 17025-2005 accredited calibrations are per ACLASS certificate # AC-1105 within the scope for which the lab is accredited.
When uncertainty measurement calculations have been calculated per customer request, reported condition statements do not take into account uncertainty of measurement.
All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.

This certificate shall not be reproduced except in full, without written consent of Davis Calibration Laboratory.

Approved By: DALLAS KENDRICK
Service Representative

Calibration Standards

NIST Traceable#	Inst. ID#	Description	Model	Cal Date	Date Due
4274949	08-0078	PRESSURE MODULE	700P01	30Jun2010	30Jun2011
3734712	08-0241	MULTIFUNCTION PROCESS CALIBRATOR	725	10Dec2009	10Dec2010

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Sample Collector Pitot Static Pressure

PIT-2108

TRANSMITTER SPAN LOG

DATE	UNITS	4mA	20mA	Name of Person Who Made the Change
9/9/10	"W.C.	-2	0	Charlie Crown Initial Setup

TRANSMITTER CALIBRATION RECORD

INSTRUMENT TAG: PIT-2108

DATE: 9-9-10

PROCEDURE

1. Before performing any calibration, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.
2. If any value deviates from the expected value by more than 0.5% of span, perform calibration of the transmitter.
3. If calibration is performed, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.

% of Span	Process Value	As Found			Acceptance Criteria (mA)	After Calibration		
	Units: IN/H2O	Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value		Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value
0	-2.0	N/A	4	-2.0	4 (3.9 to 4.1)			
25	-1.5		8	-1.5	8 (7.9 to 8.1)			
50	-1.0		12	-0.999	12 (11.9 to 12.1)			
75	-0.5		16	-0.499	16 (15.9 to 16.1)			
100	0.0		20	0.000	20 (19.9 to 20.1)			

Trans. passed without cal: _____ Trans. passed with cal.: _____ Trans. replaced: _____

Calibration Performed by: Charles Crown

Date next calibration is to be performed: _____

PIT-2108

Davis Calibration

Certificate of Calibration

4458030

Instrument Identification

Company ID: JOHZIN
JOHN ZINK-3

PO Number: 5075922

11920 E. APACHE
TULSA, OK 74116

Instrument ID: **0467659**
Manufacturer: ROSEMOUNT
Description: PRESSURE TRANSMITTER
Accuracy: ± 1% F.S.

Model Number: 3051
Serial Number: 0467659

Certificate Information

Reason For Service: CALIBRATION
Type of Cal: NORMAL
As Found Condition: IN TOLERANCE
As Left Condition: LEFT AS FOUND
Procedure: NA17-20MP-209 PRESSURE TRANSMITTER

Remarks:

Technician: DALLAS KENDRICK
Cal Date 09Sep2010
Cal Due Date: 30Sep2011
Interval: 12 MONTHS
Temperature: 21.0 C
Humidity: 49.0 %

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 [K=2, approx. 95% Confidence Level] was maintained unless otherwise stated.

Davis Calibration Laboratory is certified to ISO 9001:2008 by Eagle Registrations (certificate # 3046). Lab Operations meet the requirements of ANSI/NCSL Z540-1-1994 (R2002), ISO 10012:2003, 10CFR50 AppxB, and 10CFR21.

ISO/IEC 17025-2005 accredited calibrations are per ACLASS certificate # AC-1105 within the scope for which the lab is accredited.
When uncertainty measurement calculations have been calculated per customer request, reported condition statements do not take into account uncertainty of measurement.
All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.
This certificate shall not be reproduced except in full, without written consent of Davis Calibration Laboratory.

Approved By: DALLAS KENDRICK
Service Representative

Calibration Standards

NIST Traceable#	Inst. ID#	Description	Model	Cal Date	Date Due
4274949	08-0078	PRESSURE MODULE	700P01	30Jun2010	30Jun2011
3734712	08-0241	MULTIFUNCTION PROCESS CALIBRATOR	725	10Dec2009	10Dec2010

TNG Flow

FIT-3301

TRANSMITTER SPAN LOG

DATE	UNITS	4mA	20mA	Name of Person Who Made the Change
9-9-2010	lb/hr	0	20	Charlie Crown
9-15-2010	lb/hr	0	100	Charles Crown
9-23-10	"	"	20	" "
9-28-10	lb/hr	0	100	" "

TRANSMITTER CALIBRATION RECORD

INSTRUMENT TAG: PIT-3301 dP TNG DP

DATE: 8-26-10

PROCEDURE

1. Before performing any calibration, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.
2. If any value deviates from the expected value by more than 0.5% of span, perform calibration of the transmitter.
3. If calibration is performed, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.

% of Span 0-250 ± 1.25	Process Value	As Found			Acceptance Criteria (mA)	After Calibration		
	Units: IN. H_2O	Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value		Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value
0	0	0.11	N/A	N/A	4 (3.9 to 4.1)			
25	62.5	62.58			8 (7.9 to 8.1)			
50	125	125.27			12 (11.9 to 12.1)			
75	187.5	187.74			16 (15.9 to 16.1)			
100	250	250.19			20 (19.9 to 20.1)			

Trans. passed without cal: X Trans. passed with cal.: _____ Trans. replaced: _____

Calibration Performed by: Charles Crowe

Date next calibration is to be performed: _____

TRANSMITTER CALIBRATION RECORD

INSTRUMENT TAG: FIT - 3301 AP TNG Abs Pressure

DATE: 8-26-10

PROCEDURE

1. Before performing any calibration, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.
2. If any value deviates from the expected value by more than 0.5% of span, perform calibration of the transmitter.
3. If calibration is performed, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.

% of Span 0-80 ±.4	Process Value	As Found			Acceptance Criteria (mA)	After Calibration		
	Units: PSIA	Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value		Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value
0	14.45	14.47	N/A	N/A	4 (3.9 to 4.1)			
25	34.45	34.20			8 (7.9 to 8.1)			
50	54.45	54.23			12 (11.9 to 12.1)			
75	74.45	74.20			16 (15.9 to 16.1)			
100	94.45	94.18			20 (19.9 to 20.1)			

Trans. passed without cal: X Trans. passed with cal.: _____ Trans. replaced: _____

Calibration Performed by: Charles Crown

Date next calibration is to be performed: _____

TEMPERATURE ELEMENT VERIFICATION RECORD

INSTRUMENT TAG: FIT-3301 RTD TNG Temp.

DATE: 8-26-10

PROCEDURE

1. If element is connected to a transmitter, calibrate the transmitter first.
2. Insert element into test device, set test device to target temperature, allow temperature of test device to stabilize.
3. Note down the test device temperature in the appropriate column.
4. Note down the data acquisition value in the appropriate column.
5. If data acquisition value is outside the range of the acceptance criteria, replace the element.

Target Temp. °F	Calibration Instrument Reading °F	Data Acquisition Value °F	Acceptance Criteria (mA)
150	148.36	N/A	+/- 5°F
100	99.48		+/- 5°F
32	33.55		+/- 5°F

Element passed: X Element. replaced: _____

Verification Performed by: Charles Crown

Date next verification is to be performed: _____

TRANSMITTER CALIBRATION RECORD

INSTRUMENT TAG: FIT-3301 Flow TNG Flow

DATE: 8-26-10

PROCEDURE

1. Before performing any calibration, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.
2. If any value deviates from the expected value by more than 0.5% of span, perform calibration of the transmitter.
3. If calibration is performed, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.

% of Span	Process Value	As Found			Acceptance Criteria (mA)	After Calibration		
	Units: mA	Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value		Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value
0	4	N/A	3.99	0.0	4 (3.9 to 4.1)			
25	8		7.99	5.0	8 (7.9 to 8.1)			
50	12		11.99	10.0	12 (11.9 to 12.1)			
75	16		15.99	15.0	16 (15.9 to 16.1)			
100	20		19.99	20.0	20 (19.9 to 20.1)			

Trans. passed without cal: X Trans. passed with cal.: _____ Trans. replaced: _____

Calibration Performed by: Charles Crown

Date next calibration is to be performed: _____

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

General Information

Tag:	FIT-3301
Descriptor:	

Transmitter

Manufacturer:	Rosemount			
Pressure Transmitter Type:	3095MV			
DP Sensor Range:	-250	to	250	inH2O
SP Sensor Range:	0.500	to	800	psi(gauge)
PT Sensor Range:	-299	to	1510	degF

Body

Process Flange Type:	Coplanar
Drain/Vent:	Hast-C
Process Flange:	316 SST
Wetted O-ring:	PTFE

Element

Isolating Diaphram:	316 SST
Fill Fluid:	Silicone oil

Output

4-20 mA range(Analog):	0	to	100	lb/h
PV:	Flow Rate		in	lb/h
SV:	Differential Pressure		in	inH2O
TV:	Process Temperature		in	degF
4V:	Gauge Pressure		in	psi

RTD

RTD Mode:	Normal
Set Temperature:	0 degC

Flow Configuration

Fluid designation category:	Natural Gas
Fluid/Type method:	Detail Characterization Method
Fluid name:	natural gas
Category:	Orifice Plate
Primary Element:	1195 Mass ProPlate
DP Flow Low Cut-Off:	0.0200 inH20-68 degF

Primary Element Size

Min Diameter:	0.2600 inches at 68 °F
Material:	316 Stainless Steel
Meter tube Diameter:	0.6640 inches at 68 °F
Material:	316 Stainless Steel

Operating Conditions

Pressure range:	20.0000	to	50.0000	psia
Temperature range:	50.0000	to	90.0000	°F

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

Standard Conditions

Pressure:	14.6960	psia
Temperature:	60.0000	°F
Atmospheric Pressure:	14.3300	psia

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

General Information

Tag:	FIT-3301
Descriptor:	

Transmitter

Manufacturer:	Rosemount			
Pressure Transmitter Type:	3095MV			
DP Sensor Range:	-250	to	250	inH2O
SP Sensor Range:	0.500	to	800	psi(gauge)
PT Sensor Range:	-299	to	1510	degF

Body

Process Flange Type:	Coplanar
Drain/Vent:	Hast-C
Process Flange:	316 SST
Wetted O-ring:	PTFE

Element

Isolating Diaphram:	316 SST
Fill Fluid:	Silicone oil

Output

4-20 mA range(Analog):	0	to	20	lb/h
PV:	Flow Rate		in	lb/h
SV:	Differential Pressure		in	inH2O
TV:	Process Temperature		in	degF
4V:	Gauge Pressure		in	psi

RTD

RTD Mode:	Normal
Set Temperature:	0 degC

Flow Configuration

Fluid designation category:	Natural Gas
Fluid/Type method:	Detail Characterization Method
Fluid name:	natural gas
Category:	Orifice Plate
Primary Element:	1195 Mass ProPlate
DP Flow Low Cut-Off:	0.0200 inH20-68 degF

Primary Element Size

Min Diameter:	0.1090 inches at 68 °F
Material:	316 Stainless Steel
Meter tube Diameter:	0.6640 inches at 68 °F
Material:	316 Stainless Steel

Operating Conditions

Pressure range:	20.0000	to	50.0000	psia
Temperature range:	50.0000	to	90.0000	°F

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

Standard Conditions

Pressure:	14.6960	psia
Temperature:	60.0000	°F
Atmospheric Pressure:	14.3300	psia

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

General Information

Tag:	FIT-3301
Descriptor:	

Transmitter

Manufacturer:	Rosemount			
Pressure Transmitter Type:	3095MV			
DP Sensor Range:	-250	to	250	inH2O
SP Sensor Range:	0.500	to	800	psi(gauge)
PT Sensor Range:	-299	to	1510	degF

Body

Process Flange Type:	Coplanar
Drain/Vent:	Hast-C
Process Flange:	316 SST
Wetted O-ring:	PTFE

Element

Isolating Diaphram:	316 SST
Fill Fluid:	Silicone oil

Output

4-20 mA range(Analog):	0	to	100	lb/h
PV:	Flow Rate		in	lb/h
SV:	Differential Pressure		in	inH2O
TV:	Process Temperature		in	degF
4V:	Gauge Pressure		in	psi

RTD

RTD Mode:	Normal
Set Temperature:	0 degC

Flow Configuration

Fluid designation category:	Natural Gas
Fluid/Type method:	Detail Characterization Method
Fluid name:	natural gas
Category:	Orifice Plate
Primary Element:	1195 Mass ProPlate
DP Flow Low Cut-Off:	0.0200 inH20-68 degF

Primary Element Size

Min Diameter:	0.2600 inches at 68 °F
Material:	316 Stainless Steel
Meter tube Diameter:	0.6640 inches at 68 °F
Material:	316 Stainless Steel

Operating Conditions

Pressure range:	20.0000	to	50.0000	psia
Temperature range:	50.0000	to	90.0000	°F

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

Standard Conditions

Pressure:	14.6960	psia
Temperature:	60.0000	°F
Atmospheric Pressure:	14.3300	psia

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

General Information

Tag:	FIT-3301
Descriptor:	

Transmitter

Manufacturer:	Rosemount			
Pressure Transmitter Type:	3095MV			
DP Sensor Range:	-250	to	250	inH2O
SP Sensor Range:	0.500	to	800	psi(gauge)
PT Sensor Range:	-299	to	1510	degF

Body

Process Flange Type:	Coplanar
Drain/Vent:	Hast-C
Process Flange:	316 SST
Wetted O-ring:	PTFE

Element

Isolating Diaphram:	316 SST
Fill Fluid:	Silicone oil

Output

4-20 mA range(Analog):	0	to	20	lb/h
PV:	Flow Rate		in	lb/h
SV:	Differential Pressure		in	inH2O
TV:	Process Temperature		in	degF
4V:	Gauge Pressure		in	psi

RTD

RTD Mode:	Normal
Set Temperature:	0 degC

Flow Configuration

Fluid designation category:	Natural Gas
Fluid/Type method:	Detail Characterization Method
Fluid name:	natural gas
Category:	Orifice Plate
Primary Element:	1195 Mass ProPlate
DP Flow Low Cut-Off:	0.0200 inH20-68 degF

Primary Element Size

Min Diameter:	0.1090 inches at 68 °F
Material:	316 Stainless Steel
Meter tube Diameter:	0.6640 inches at 68 °F
Material:	316 Stainless Steel

Operating Conditions

Pressure range:	20.0000	to	50.0000	psia
Temperature range:	50.0000	to	90.0000	°F

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

Standard Conditions

Pressure:	14.6960	psia
Temperature:	60.0000	°F
Atmospheric Pressure:	14.3300	psia

FIT-3306 Nitrogen Flow

TRANSMITTER SPAN LOG

DATE	UNITS	4mA	20mA	Name of Person Who Made the Change
9-10-10	lb/hr	0	2500	Charles Crown
9-23-10	"	"	500	" "
9-28-10	lb/hr	0	2500	" "
10-1-10 10:32 AM	lb/hr	0	600 Propane	" "
10-1-10 12:38 PM	lb/hr	0	6000 Propane	" "
10-1-10 2:26 PM	lb/hr	0	6000 TNG	" "

TRANSMITTER CALIBRATION RECORD

INSTRUMENT TAG: FIT - 3306 V-magnen dP

DATE: 9-10-2010

PROCEDURE

1. Before performing any calibration, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.
2. If any value deviates from the expected value by more than 0.5% of span, perform calibration of the transmitter.
3. If calibration is performed, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.

% of Span ± 1.25	Process Value	As Found			Acceptance Criteria (mA)	After Calibration		
	Units: IN/H2O	Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value		Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value
0	0	.17	N/A	N/A	4 (3.9 to 4.1)			
25	62.5	62.90			8 (7.9 to 8.1)			
50	125	125.48			12 (11.9 to 12.1)			
75	187.5	187.95			16 (15.9 to 16.1)			
100	250	250.22			20 (19.9 to 20.1)			

Trans. passed without cal: X Trans. passed with cal.: _____ Trans. replaced: _____

Calibration Performed by: Charles Crown

Date next calibration is to be performed: _____

TRANSMITTER CALIBRATION RECORD

INSTRUMENT TAG: FIT - 3306 Nitrogen GAUGE PRESSURE

DATE: 9-10-2010

PROCEDURE

1. Before performing any calibration, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.
2. If any value deviates from the expected value by more than 0.5% of span, perform calibration of the transmitter.
3. If calibration is performed, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.

% of Span ±.4	Process Value	As Found			Acceptance Criteria (mA)	After Calibration		
	Units: PSIG	Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value		Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value
0	0	-0.05	N/A	N/A	4 (3.9 to 4.1)	0.06		
25	20	19.65			8 (7.9 to 8.1)	19.74		
50	40	39.58			12 (11.9 to 12.1)	39.82		
75	60	59.64			16 (15.9 to 16.1)	59.92		
100	80	79.57			20 (19.9 to 20.1)	79.99		

Trans. passed without cal: _____ Trans. passed with cal.: X Trans. replaced: _____

Calibration Performed by: Charles Crown

Date next calibration is to be performed: _____

TEMPERATURE ELEMENT VERIFICATION RECORD

INSTRUMENT TAG: TE - 3306 Nitrogen

DATE: 9-10-2010

PROCEDURE

1. If element is connected to a transmitter, calibrate the transmitter first.
2. Insert element into test device, set test device to target temperature, allow temperature of test device to stabilize.
3. Note down the test device temperature in the appropriate column.
4. Note down the data acquisition value in the appropriate column.
5. If data acquisition value is outside the range of the acceptance criteria, replace the element.

Target Temp. °F	Calibration Instrument Reading °F	Data Acquisition Value °F	Acceptance Criteria (mA)
~~150~~	220.0	219.56	+/- 5°F
~~100~~	150.0	149.54	+/- 5°F
32	32.0	31.5	+/- 5°F

Element passed: X Element. replaced: _____

Verification Performed by: Charles Crown

Date next verification is to be performed: _____

TRANSMITTER CALIBRATION RECORD

INSTRUMENT TAG: FIT-3306 Nitrogen Flow

DATE: 9-10-2010

PROCEDURE

1. Before performing any calibration, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.
2. If any value deviates from the expected value by more than 0.5% of span, perform calibration of the transmitter.
3. If calibration is performed, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.

% of Span	Process Value	As Found			Acceptance Criteria (mA)	After Calibration		
	Units: mA	Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value		Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value
0	4	NA	4	0.0	4 (3.9 to 4.1)			
25	8		8	625.0	8 (7.9 to 8.1)			
50	12		12	1250.4	12 (11.9 to 12.1)			
75	16		16	1875.7	16 (15.9 to 16.1)			
100	20		20	2500.0	20 (19.9 to 20.1)			

Trans. passed without cal: X Trans. passed with cal.: _____ Trans. replaced: _____

Calibration Performed by: Charles Crown

Date next calibration is to be performed: _____

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

General Information

Tag:	FIT-3306
Descriptor:	

Transmitter

Manufacturer:	Rosemount			
Pressure Transmitter Type:	3095MV			
DP Sensor Range:	-250	to	250	inH2O
SP Sensor Range:	0.500	to	800	psi(gauge)
PT Sensor Range:	-299	to	1510	degF

Body

Process Flange Type:	Spcl
Drain/Vent:	None
Process Flange:	Spcl
Wetted O-ring:	PTFE

Element

Isolating Diaphram:	316 SST
Fill Fluid:	Silicone oil

Output

4-20 mA range(Analog):	0	to	6000	lb/h
PV:	Flow Rate		in	lb/h
SV:	Differential Pressure		in	inH2O
TV:	Gauge Pressure		in	psi
4V:	Process Temperature		in	degF

RTD

RTD Mode:	Normal
Set Temperature:	68 degF

Flow Configuration

Fluid designation category:	Natural Gas
Fluid/Type method:	Detail Characterization Method
Fluid name:	natural gas
Category:	Orifice Plate
Primary Element:	Flange Taps, ASME
DP Flow Low Cut-Off:	0.5000 inH20-68 degF

Primary Element Size

Min Diameter:	2.6000 inches at 68 °F
Material:	316 Stainless Steel
Meter tube Diameter:	4.0000 inches at 68 °F
Material:	Carbon Steel

Operating Conditions

Pressure range:	20.0000	to	60.0000	psig
Temperature range:	50.0000	to	100.0000	°F

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

Standard Conditions

Pressure:	14.7300	psia
Temperature:	60.0000	°F
Atmospheric Pressure:	14.6960	psia

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

General Information

Tag:	FIT-3306
Descriptor:	

Transmitter

Manufacturer:	Rosemount			
Pressure Transmitter Type:	3095MV			
DP Sensor Range:	-250	to	250	inH2O
SP Sensor Range:	0.500	to	800	psi(gauge)
PT Sensor Range:	-299	to	1510	degF

Body

Process Flange Type:	Spcl
Drain/Vent:	None
Process Flange:	Spcl
Wetted O-ring:	PTFE

Element

Isolating Diaphram:	316 SST
Fill Fluid:	Silicone oil

Output

4-20 mA range(Analog):	0	to	6000	lb/h
PV:	Flow Rate		in	lb/h
SV:	Differential Pressure		in	inH2O
TV:	Gauge Pressure		in	psi
4V:	Process Temperature		in	degF

RTD

RTD Mode:	Normal
Set Temperature:	68 degF

Flow Configuration

Fluid designation category:	Database:Gas
Fluid/Type method:	propane
Fluid name:	propane
Category:	Orifice Plate
Primary Element:	Flange Taps, ASME
DP Flow Low Cut-Off:	0.5000 inH20-68 degF

Primary Element Size

Min Diameter:	2.6000 inches at 68 °F
Material:	316 Stainless Steel
Meter tube Diameter:	4.0000 inches at 68 °F
Material:	Carbon Steel

Operating Conditions

Pressure range:	25.0000	to	60.0000	psig
Temperature range:	50.0000	to	100.0000	°F

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

Standard Conditions

Pressure:	14.6960	psia
Temperature:	60.0000	°F
Atmospheric Pressure:	14.2800	psia

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

General Information

Tag:	FIT-3306
Descriptor:	

Transmitter

Manufacturer:	Rosemount			
Pressure Transmitter Type:	3095MV			
DP Sensor Range:	-250	to	250	inH2O
SP Sensor Range:	0.500	to	800	psi(gauge)
PT Sensor Range:	-299	to	1510	degF

Body

Process Flange Type:	Spcl
Drain/Vent:	None
Process Flange:	Spcl
Wetted O-ring:	PTFE

Element

Isolating Diaphram:	316 SST
Fill Fluid:	Silicone oil

Output

4-20 mA range(Analog):	0	to	600	lb/h
PV:	Flow Rate		in	lb/h
SV:	Differential Pressure		in	inH2O
TV:	Gauge Pressure		in	psi
4V:	Process Temperature		in	degF

RTD

RTD Mode:	Normal
Set Temperature:	68 degF

Flow Configuration

Fluid designation category:	Database:Gas
Fluid/Type method:	propane
Fluid name:	propane
Category:	Orifice Plate
Primary Element:	Flange Taps, ASME
DP Flow Low Cut-Off:	0.5000 inH20-68 degF

Primary Element Size

Min Diameter:	0.5000 inches at 68 °F
Material:	316 Stainless Steel
Meter tube Diameter:	4.0000 inches at 68 °F
Material:	Carbon Steel

Operating Conditions

Pressure range:	25.0000	to	60.0000	psig
Temperature range:	50.0000	to	100.0000	°F

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

Standard Conditions

Pressure:	14.6960	psia
Temperature:	60.0000	°F
Atmospheric Pressure:	14.2800	psia

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

General Information

Tag:	FIT-3306
Descriptor:	

Transmitter

Manufacturer:	Rosemount			
Pressure Transmitter Type:	3095MV			
DP Sensor Range:	-250	to	250	inH2O
SP Sensor Range:	0.500	to	800	psi(gauge)
PT Sensor Range:	-299	to	1510	degF

Body

Process Flange Type:	Spcl
Drain/Vent:	None
Process Flange:	Spcl
Wetted O-ring:	PTFE

Element

Isolating Diaphram:	316 SST
Fill Fluid:	Silicone oil

Output

4-20 mA range(Analog):	0	to	2500	lb/h
PV:	Flow Rate		in	lb/h
SV:	Differential Pressure		in	inH2O
TV:	Gauge Pressure		in	psi
4V:	Process Temperature		in	degF

RTD

RTD Mode:	Normal
Set Temperature:	68 degF

Flow Configuration

Fluid designation category:	Database:Gas
Fluid/Type method:	nitrogen
Fluid name:	nitrogen
Category:	Orifice Plate
Primary Element:	Flange Taps, ASME
DP Flow Low Cut-Off:	0.5000 inH20-68 degF

Primary Element Size

Min Diameter:	1.1870 inches at 68 °F
Material:	316 Stainless Steel
Meter tube Diameter:	4.0000 inches at 68 °F
Material:	Carbon Steel

Operating Conditions

Pressure range:	25.0000	to	60.0000	psig
Temperature range:	50.0000	to	100.0000	°F

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

Standard Conditions

Pressure:	14.6960	psia
Temperature:	60.0000	°F
Atmospheric Pressure:	14.2800	psia

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

General Information

Tag:	FIT-3306
Descriptor:	

Transmitter

Manufacturer:	Rosemount			
Pressure Transmitter Type:	3095MV			
DP Sensor Range:	-250	to	250	inH2O
SP Sensor Range:	0.500	to	800	psi(gauge)
PT Sensor Range:	-299	to	1510	degF

Body

Process Flange Type:	Spcl
Drain/Vent:	None
Process Flange:	Spcl
Wetted O-ring:	PTFE

Element

Isolating Diaphram:	316 SST
Fill Fluid:	Silicone oil

Output

4-20 mA range(Analog):	0	to	500	lb/h
PV:	Flow Rate		in	lb/h
SV:	Differential Pressure		in	inH2O
TV:	Gauge Pressure		in	psi
4V:	Process Temperature		in	degF

RTD

RTD Mode:	Normal
Set Temperature:	68 degF

Flow Configuration

Fluid designation category:	Database:Gas
Fluid/Type method:	nitrogen
Fluid name:	nitrogen
Category:	Orifice Plate
Primary Element:	Flange Taps, ASME
DP Flow Low Cut-Off:	0.5000 inH20-68 degF

Primary Element Size

Min Diameter:	0.5000 inches at 68 °F
Material:	316 Stainless Steel
Meter tube Diameter:	4.0000 inches at 68 °F
Material:	Carbon Steel

Operating Conditions

Pressure range:	25.0000	to	60.0000	psig
Temperature range:	50.0000	to	100.0000	°F

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

Standard Conditions

Pressure:	14.6960	psia
Temperature:	60.0000	°F
Atmospheric Pressure:	14.2800	psia

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

General Information

Tag:	FIT-3306
Descriptor:	

Transmitter

Manufacturer:	Rosemount			
Pressure Transmitter Type:	3095MV			
DP Sensor Range:	-250	to	250	inH2O
SP Sensor Range:	0.500	to	800	psi(gauge)
PT Sensor Range:	-299	to	1510	degF

Body

Process Flange Type:	Spcl
Drain/Vent:	None
Process Flange:	Spcl
Wetted O-ring:	PTFE

Element

Isolating Diaphram:	316 SST
Fill Fluid:	Silicone oil

Output

4-20 mA range(Analog):	0	to	2500	lb/h
PV:	Flow Rate		in	lb/h
SV:	Differential Pressure		in	inH2O
TV:	Gauge Pressure		in	psi
4V:	Process Temperature		in	degF

RTD

RTD Mode:	Normal
Set Temperature:	68 degF

Flow Configuration

Fluid designation category:	Database:Gas
Fluid/Type method:	nitrogen
Fluid name:	nitrogen
Category:	Orifice Plate
Primary Element:	Flange Taps, ASME
DP Flow Low Cut-Off:	0.5000 inH20-68 degF

Primary Element Size

Min Diameter:	1.1870 inches at 68 °F
Material:	316 Stainless Steel
Meter tube Diameter:	4.0000 inches at 68 °F
Material:	Carbon Steel

Operating Conditions

Pressure range:	25.0000	to	60.0000	psig
Temperature range:	50.0000	to	100.0000	°F

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

Standard Conditions

Pressure:	14.6960	psia
Temperature:	60.0000	°F
Atmospheric Pressure:	14.2800	psia

FIT-3312 Propene Flow

TRANSMITTER SPAN LOG

DATE	UNITS	4mA	20mA	Name of Person Who Made the Change
9-9-2010	lb/hr	0	3000	Charles Crowan
9-23-2010	lb/hr	0	600	" "
9-27-10 4:19AM	lb/hr	0	600 Propane	" "
9-27-10 3:58PM	lb/hr	0	600 Propylene	" "
9-28-10	lb/hr	0	3000	" "
9-29-10	lb/hr	0	3000 Propane	
9-30-10	lb/hr	0	3000	" "

TRANSMITTER CALIBRATION RECORD

INSTRUMENT TAG: FIT-3312 dP Propene DP

DATE: 8-25-10

PROCEDURE

1. Before performing any calibration, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.
2. If any value deviates from the expected value by more than 0.5% of span, perform calibration of the transmitter.
3. If calibration is performed, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.

% of Span	Process Value	As Found			Acceptance Criteria (mA)	After Calibration		
	Units: in H2O	Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value		Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value
0	0	0.03	N/A	N/A	4 (3.9 to 4.1)			
25	62.5	62.43			8 (7.9 to 8.1)			
50	125	125.14			12 (11.9 to 12.1)			
75	187.5	187.65			16 (15.9 to 16.1)			
100	250	250.36			20 (19.9 to 20.1)			

Trans. passed without cal: X Trans. passed with cal.: _____ Trans. replaced: _____

Calibration Performed by: Charles Crown

Date next calibration is to be performed: _____

± 1.25

TRANSMITTER CALIBRATION RECORD

INSTRUMENT TAG: FIT 3312 AP Propane Abs. Press.

DATE: 8-25-10

PROCEDURE ATMOSPHERIC PRESSURE @ 14.47

1. Before performing any calibration, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.
2. If any value deviates from the expected value by more than 0.5% of span, perform calibration of the transmitter.
3. If calibration is performed, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.

% of Span	Process Value	As Found			Acceptance Criteria (mA)	After Calibration		
	Units: PSIA	Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value		Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value
0	14.47	14.44	N/A	N/A	4 (3.9 to 4.1)	14.44	N/A	N/A
25	34.47	34.41			8 (7.9 to 8.1)	34.28		
50	54.47	54.65			12 (11.9 to 12.1)	54.35		
75	74.47	74.93			16 (15.9 to 16.1)	74.44		
100	94.47	95.18			20 (19.9 to 20.1)	94.54		

Trans. passed without cal: _____ Trans. passed with cal.: X Trans. replaced: _____

Calibration Performed by: Charles Crown

Date next calibration is to be performed: _____

± .47

TEMPERATURE ELEMENT VERIFICATION RECORD

INSTRUMENT TAG: FIT-3312 RTD Propene Temp

DATE: 8-25-10

PROCEDURE

1. If element is connected to a transmitter, calibrate the transmitter first.
2. Insert element into test device, set test device to target temperature, allow temperature of test device to stabilize.
3. Note down the test device temperature in the appropriate column.
4. Note down the data acquisition value in the appropriate column.
5. If data acquisition value is outside the range of the acceptance criteria, replace the element.

Target Temp. °F	Calibration Instrument Reading °F	Data Acquisition Value °F	Acceptance Criteria (mA)
150	148.64	N/A	+/- 5°F
100	98.75		+/- 5°F
32	30.97		+/- 5°F

Element passed: X Element. replaced: _____

Verification Performed by: CHARLES CROWN

Date next verification is to be performed: _____

TRANSMITTER CALIBRATION RECORD

INSTRUMENT TAG: FIT-3312 Flow Propene Flow

DATE: 8-25-10

PROCEDURE

1. Before performing any calibration, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.
2. If any value deviates from the expected value by more than 0.5% of span, perform calibration of the transmitter.
3. If calibration is performed, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.

% of Span	Process Value	As Found			Acceptance Criteria (mA)	After Calibration		
	Units: Lb/h	Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value		Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value
0	0	0	4.0	0	4 (3.9 to 4.1)			
25	750.6	750.6	8.0	750.2	8 (7.9 to 8.1)			
50	1499.9	1499.9	12.0	1500.3	12 (11.9 to 12.1)			
75	2250.0	2250.0	16.0	2250.7	16 (15.9 to 16.1)			
100	3000.0	3000.0	20.0	3000.0	20 (19.9 to 20.1)			

Trans. passed without cal: X Trans. passed with cal.: _____ Trans. replaced: _____

Calibration Performed by: Charles Crown

Date next calibration is to be performed: _____

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

General Information

Tag:	FT-3312
Descriptor:	

Transmitter

Manufacturer:	Rosemount			
Pressure Transmitter Type:	3095MV			
DP Sensor Range:	-250	to	250	inH2O
SP Sensor Range:	0.500	to	800	psi(absolute)
PT Sensor Range:	-299	to	1510	degF

Body

Process Flange Type:	Coplanar
Drain/Vent:	316 SST
Process Flange:	316 SST
Wetted O-ring:	PTFE

Element

Isolating Diaphram:	316 SST
Fill Fluid:	Silicone oil

Output

4-20 mA range(Analog):	0	to	3000	lb/h
PV:	Flow Rate		in	lb/h
SV:	Differential Pressure		in	inH2O
TV:	Absolute Pressure		in	psi
4V:	Process Temperature		in	degF

RTD

RTD Mode:	Normal
Set Temperature:	68 degF

Flow Configuration

Fluid designation category:	Database:Gas
Fluid/Type method:	propylene
Fluid name:	propylene
Category:	Orifice Plate
Primary Element:	Flange Taps, ASME
DP Flow Low Cut-Off:	0.5000 inH20-68 degF

Primary Element Size

Min Diameter:	1.2500 inches at 68 °F
Material:	316 Stainless Steel
Meter tube Diameter:	3.0000 inches at 68 °F
Material:	Carbon Steel

Operating Conditions

Pressure range:	30.0000	to	80.0000	psig
Temperature range:	60.0000	to	150.0000	°F

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

Standard Conditions

Pressure:	14.6960	psia
Temperature:	60.0000	°F
Atmospheric Pressure:	14.3000	psia

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

General Information

Tag:	FT-3312
Descriptor:	

Transmitter

Manufacturer:	Rosemount			
Pressure Transmitter Type:	3095MV			
DP Sensor Range:	-250	to	250	inH2O
SP Sensor Range:	0.500	to	800	psi(absolute)
PT Sensor Range:	-299	to	1510	degF

Body

Process Flange Type:	Coplanar
Drain/Vent:	316 SST
Process Flange:	316 SST
Wetted O-ring:	PTFE

Element

Isolating Diaphram:	316 SST
Fill Fluid:	Silicone oil

Output

4-20 mA range(Analog):	0	to	3000	lb/h
PV:	Flow Rate		in	lb/h
SV:	Differential Pressure		in	inH2O
TV:	Absolute Pressure		in	psi
4V:	Process Temperature		in	degF

RTD

RTD Mode:	Normal
Set Temperature:	68 degF

Flow Configuration

Fluid designation category:	Database:Gas
Fluid/Type method:	propane
Fluid name:	propane
Category:	Orifice Plate
Primary Element:	Flange Taps, ASME
DP Flow Low Cut-Off:	0.5000 inH20-68 degF

Primary Element Size

Min Diameter:	1.2500 inches at 68 °F
Material:	316 Stainless Steel
Meter tube Diameter:	3.0000 inches at 68 °F
Material:	Carbon Steel

Operating Conditions

Pressure range:	30.0000	to	80.0000	psig
Temperature range:	60.0000	to	150.0000	°F

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

Standard Conditions

Pressure:	14.6960	psia
Temperature:	60.0000	°F
Atmospheric Pressure:	14.3000	psia

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

General Information

Tag:	FT-3312
Descriptor:	

Transmitter

Manufacturer:	Rosemount			
Pressure Transmitter Type:	3095MV			
DP Sensor Range:	-250	to	250	inH2O
SP Sensor Range:	0.500	to	800	psi(absolute)
PT Sensor Range:	-299	to	1510	degF

Body

Process Flange Type:	Coplanar
Drain/Vent:	316 SST
Process Flange:	316 SST
Wetted O-ring:	PTFE

Element

Isolating Diaphram:	316 SST
Fill Fluid:	Silicone oil

Output

4-20 mA range(Analog):	0	to	3000	lb/h
PV:	Flow Rate		in	lb/h
SV:	Differential Pressure		in	inH2O
TV:	Absolute Pressure		in	psi
4V:	Process Temperature		in	degF

RTD

RTD Mode:	Normal
Set Temperature:	68 degF

Flow Configuration

Fluid designation category:	Database:Gas
Fluid/Type method:	propylene
Fluid name:	propylene
Category:	Orifice Plate
Primary Element:	Flange Taps, ASME
DP Flow Low Cut-Off:	0.5000 inH20-68 degF

Primary Element Size

Min Diameter:	1.2500 inches at 68 °F
Material:	316 Stainless Steel
Meter tube Diameter:	3.0000 inches at 68 °F
Material:	Carbon Steel

Operating Conditions

Pressure range:	30.0000	to	80.0000	psig
Temperature range:	60.0000	to	150.0000	°F

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

Standard Conditions

Pressure:	14.6960	psia
Temperature:	60.0000	°F
Atmospheric Pressure:	14.3000	psia

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

General Information

Tag:	FT-3312
Descriptor:	

Transmitter

Manufacturer:	Rosemount			
Pressure Transmitter Type:	3095MV			
DP Sensor Range:	-250	to	250	inH2O
SP Sensor Range:	0.500	to	800	psi(absolute)
PT Sensor Range:	-299	to	1510	degF

Body

Process Flange Type:	Coplanar
Drain/Vent:	316 SST
Process Flange:	316 SST
Wetted O-ring:	PTFE

Element

Isolating Diaphram:	316 SST
Fill Fluid:	Silicone oil

Output

4-20 mA range(Analog):	0	to	600	lb/h
PV:	Flow Rate		in	lb/h
SV:	Differential Pressure		in	inH2O
TV:	Absolute Pressure		in	psi
4V:	Process Temperature		in	degF

RTD

RTD Mode:	Normal
Set Temperature:	68 degF

Flow Configuration

Fluid designation category:	Database:Gas
Fluid/Type method:	propylene
Fluid name:	propylene
Category:	Orifice Plate
Primary Element:	Flange Taps, ASME
DP Flow Low Cut-Off:	0.5000 inH20-68 degF

Primary Element Size

Min Diameter:	0.5000 inches at 68 °F
Material:	316 Stainless Steel
Meter tube Diameter:	3.0000 inches at 68 °F
Material:	Carbon Steel

Operating Conditions

Pressure range:	30.0000	to	80.0000	psig
Temperature range:	60.0000	to	150.0000	°F

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

Standard Conditions

Pressure:	14.6960	psia
Temperature:	60.0000	°F
Atmospheric Pressure:	14.3000	psia

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

General Information

Tag:	FT-3312
Descriptor:	

Transmitter

Manufacturer:	Rosemount			
Pressure Transmitter Type:	3095MV			
DP Sensor Range:	-250	to	250	inH2O
SP Sensor Range:	0.500	to	800	psi(absolute)
PT Sensor Range:	-299	to	1510	degF

Body

Process Flange Type:	Coplanar
Drain/Vent:	316 SST
Process Flange:	316 SST
Wetted O-ring:	PTFE

Element

Isolating Diaphram:	316 SST
Fill Fluid:	Silicone oil

Output

4-20 mA range(Analog):	0	to	600	lb/h
PV:	Flow Rate		in	lb/h
SV:	Differential Pressure		in	inH2O
TV:	Absolute Pressure		in	psi
4V:	Process Temperature		in	degF

RTD

RTD Mode:	Normal
Set Temperature:	68 degF

Flow Configuration

Fluid designation category:	Database:Gas
Fluid/Type method:	propane
Fluid name:	propane
Category:	Orifice Plate
Primary Element:	Flange Taps, ASME
DP Flow Low Cut-Off:	0.5000 inH20-68 degF

Primary Element Size

Min Diameter:	0.5000 inches at 68 °F
Material:	316 Stainless Steel
Meter tube Diameter:	3.0000 inches at 68 °F
Material:	Carbon Steel

Operating Conditions

Pressure range:	30.0000	to	80.0000	psig
Temperature range:	60.0000	to	150.0000	°F

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

Standard Conditions

Pressure:	14.6960	psia
Temperature:	60.0000	°F
Atmospheric Pressure:	14.3000	psia

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

General Information

Tag:	FT-3312
Descriptor:	

Transmitter

Manufacturer:	Rosemount			
Pressure Transmitter Type:	3095MV			
DP Sensor Range:	-250	to	250	inH2O
SP Sensor Range:	0.500	to	800	psi(absolute)
PT Sensor Range:	-299	to	1510	degF

Body

Process Flange Type:	Coplanar
Drain/Vent:	316 SST
Process Flange:	316 SST
Wetted O-ring:	PTFE

Element

Isolating Diaphram:	316 SST
Fill Fluid:	Silicone oil

Output

4-20 mA range(Analog):	0	to	600	lb/h
PV:	Flow Rate		in	lb/h
SV:	Differential Pressure		in	inH2O
TV:	Absolute Pressure		in	psi
4V:	Process Temperature		in	degF

RTD

RTD Mode:	Normal
Set Temperature:	68 degF

Flow Configuration

Fluid designation category:	Database:Gas
Fluid/Type method:	propylene
Fluid name:	propylene
Category:	Orifice Plate
Primary Element:	Flange Taps, ASME
DP Flow Low Cut-Off:	0.5000 inH20-68 degF

Primary Element Size

Min Diameter:	0.5000 inches at 68 °F
Material:	316 Stainless Steel
Meter tube Diameter:	3.0000 inches at 68 °F
Material:	Carbon Steel

Operating Conditions

Pressure range:	30.0000	to	80.0000	psig
Temperature range:	60.0000	to	150.0000	°F

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

Standard Conditions

Pressure:	14.6960	psia
Temperature:	60.0000	°F
Atmospheric Pressure:	14.3000	psia

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

General Information

Tag:	FT-3312
Descriptor:	

Transmitter

Manufacturer:	Rosemount			
Pressure Transmitter Type:	3095MV			
DP Sensor Range:	-250	to	250	inH2O
SP Sensor Range:	0.500	to	800	psi(absolute)
PT Sensor Range:	-299	to	1510	degF

Body

Process Flange Type:	Coplanar
Drain/Vent:	316 SST
Process Flange:	316 SST
Wetted O-ring:	PTFE

Element

Isolating Diaphram:	316 SST
Fill Fluid:	Silicone oil

Output

4-20 mA range(Analog):	0	to	3000	lb/h
PV:	Flow Rate		in	lb/h
SV:	Differential Pressure		in	inH2O
TV:	Absolute Pressure		in	psi
4V:	Process Temperature		in	degF

RTD

RTD Mode:	Normal
Set Temperature:	68 degF

Flow Configuration

Fluid designation category:	Database:Gas
Fluid/Type method:	propylene
Fluid name:	propylene
Category:	Orifice Plate
Primary Element:	Flange Taps, ASME
DP Flow Low Cut-Off:	0.5000 inH20-68 degF

Primary Element Size

Min Diameter:	1.2500 inches at 68 °F
Material:	316 Stainless Steel
Meter tube Diameter:	3.0000 inches at 68 °F
Material:	Carbon Steel

Operating Conditions

Pressure range:	30.0000	to	80.0000	psig ← Adjusted pressure range
Temperature range:	60.0000	to	150.0000	°F

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

Standard Conditions

Pressure:	14.6960	psia
Temperature:	60.0000	°F
Atmospheric Pressure:	14.3000	psia

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

General Information

Tag:	FT-3312
Descriptor:	

Transmitter

Manufacturer:	Rosemount			
Pressure Transmitter Type:	3095MV			
DP Sensor Range:	-250	to	250	inH2O
SP Sensor Range:	0.500	to	800	psi(absolute)
PT Sensor Range:	-299	to	1510	degF

Body

Process Flange Type:	Coplanar
Drain/Vent:	316 SST
Process Flange:	316 SST
Wetted O-ring:	PTFE

Element

Isolating Diaphram:	316 SST
Fill Fluid:	Silicone oil

Output

4-20 mA range(Analog):	0	to	3000	lb/h
PV:	Flow Rate		in	lb/h
SV:	Differential Pressure		in	inH2O
TV:	Absolute Pressure		in	psi
4V:	Process Temperature		in	degF

RTD

RTD Mode:	Normal
Set Temperature:	68 degF

Flow Configuration

Fluid designation category:	Database:Gas
Fluid/Type method:	propylene
Fluid name:	propylene
Category:	Orifice Plate
Primary Element:	Flange Taps, ASME
DP Flow Low Cut-Off:	0.5000 inH20-68 degF

Primary Element Size

Min Diameter:	1.2500 inches at 68 °F
Material:	316 Stainless Steel
Meter tube Diameter:	3.0000 inches at 68 °F
Material:	Carbon Steel

Operating Conditions

Pressure range:	20.0000	to	50.0000	psig
Temperature range:	60.0000	to	150.0000	°F

Transmitter Report

Rosemount 3095MV

Client:	**Project:**
Unit:	**Location:**

Standard Conditions

Pressure:	14.6960	psia
Temperature:	60.0000	°F
Atmospheric Pressure:	14.3000	psia

TEMPERATURE ELEMENT VERIFICATION RECORD

INSTRUMENT TAG: TE-3315 Mixed Fuel Temp.

DATE: 9-1-10

PROCEDURE

1. If element is connected to a transmitter, calibrate the transmitter first.
2. Insert element into test device, set test device to target temperature, allow temperature of test device to stabilize.
3. Note down the test device temperature in the appropriate column.
4. Note down the data acquisition value in the appropriate column.
5. If data acquisition value is outside the range of the acceptance criteria, replace the element.

Target Temp. °F	Calibration Instrument Reading °F	Data Acquisition Value °F	Acceptance Criteria (mA)
~~150~~	235	234	+/- 5°F
150 ~~100~~	150	149	+/- 5°F
32	32	32	+/- 5°F

Element passed: X Element. replaced: _____

Verification Performed by: Charles Crown

Date next verification is to be performed: _____

PIT-3317 Pilot Gas Pressure

TRANSMITTER SPAN LOG

DATE	UNITS	4mA	20mA	Name of Person Who Made the Change
1 Sept 10	psig	0	30	Charlie Crown, Initial Set-up

TRANSMITTER CALIBRATION RECORD

INSTRUMENT TAG: PIT-3317 Pilot Gas Pressure

DATE: 9-1-10

PROCEDURE

1. Before performing any calibration, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.
2. If any value deviates from the expected value by more than 0.5% of span, perform calibration of the transmitter.
3. If calibration is performed, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.

% of Span ± 0.15	Process Value	As Found			Acceptance Criteria (mA)	After Calibration		
	Units: PSI	Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value		Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value
0	0	-0.08	3.95	0.0	4 (3.9 to 4.1)			
25	7.5	7.42	7.96	7.4	8 (7.9 to 8.1)			
50	15	14.93	11.97	14.9	12 (11.9 to 12.1)			
75	22.5	22.43	15.97	22.4	16 (15.9 to 16.1)			
100	30	29.95	19.97	29.9	20 (19.9 to 20.1)			

Trans. passed without cal: X Trans. passed with cal.: _____ Trans. replaced: _____

Calibration Performed by: Charles Croson

Date next calibration is to be performed: _____

FT-5103 Steam Flow

TRANSMITTER SPAN LOG

DATE	UNITS	4mA	20mA	Name of Person Who Made the Change
Sept 1, 10	lb/hr	0	20,000	Z. Kalak Initial setup

←2
501010077327 FLOW CELL S/N 3703
GS868 S/N 1316

PROGRAM PARAMETERS of Work
Model GS868 Ver GS3M
With 8K FIFO and 1269 receiver board.
At 08:52:25 AM on 28 JUL 10

ACTIVE PARAMETERS:

Site status	Burst
Skan/measure mode	Skan/Meas

SYSTEM PARAMETERS:

no label	
No message	
System Units	English
Pressure Units	PSI gauge
Atmospheric Press.	14.70 PSI absolute
Totalizer Option	Automatic
Equation	Standard Equation
Volumetric Units	Standard cubic ft
Volumetric Time	/sec
VOL Decimal Digits	0
Totalizer Units	Actual cubic ft
TOT Decimal Digits	0
Mass Flow Units	Pounds
Mass Flow Time	/sec
MDOT Decimal Digits	0
Mass Units	Pounds
Mass Decimal Digits	0

PIPE PARAMETERS:

Transducer number	91
Wedge frequency	100k
Wedge Tw	78.990 usec
Pipe OD	6.626 inches
Pipe Wall	0.433 inches
Path Length	7.51 inches
Axial Dimension L	5.31 inches
Fluid Type	Other
Fluid Soundspeed	1128.0 Ft/s
Reynolds correction	On
Kinematic Viscosity	26.10 E-6 ft^2/s
Calibration Factor	1.000

I/O PARAMETERS

Zero Cutoff	0.020 Ft/s
Assumed saturated	No
Temperature Input	Fixed
Fixed Temperature	250.000 deg F
Base Temp	60.000 deg F
Pressure Input	Fixed
Fixed Pressure	6.30 PSIg
Base Pressure	14.70 PSI absolute
Low Pressure Switch	No

Quality Input	Fixed
Fixed Quality	1.000

I/O PARAMETERS:

ERROR

Error Handling	Hold last value

MAIN BOARD OUTPUTS

Slot 0 Output A	Off
Slot 0 Output B	Off

OPTION CARDS

Slot 1 Output A	Off
Slot 1 Output B	Off
Slot 1 Output C	Off
Slot 1 Output D	Off
Slot 2 Input A	Off
Slot 2 Input B	Off

SETUP PARAMETERS:

SIGNAL

Signal Low Limit	20.0
Corr. Peak Limit	100
Soundspeed +-Limit	20 percent
Velocity Low Limit	-75.000 Ft/s
Velocity HighLimit	75.000 Ft/s
Acceleration Limit	15.000 Ft/s
Amp Discrim Low	14
Amp Discrim High	34
Delta T Offset	0.00 usec
Skan T Offset	50.742 usec
% Peak (Skan)	50 percent
Xmit Sample Size	8
M>S Switch	50.000 usec
# of Shifts	3
A Divisor	2.500
# Transmit Pulses	4
T Window (cycles)	0
R Window (cycles)	10

AVERAGE

Response Time	30 readings
Static Density?	No
Multi K Fact?	No

COMMUNICATION PARAMETERS:

```
 Baud Rate            9600
 UART bits            8 data, no parity
 Network ID            1
 MODBUS Card not installed

SECURITY
 Security mode        UNlocked

♀
```

LOG TITLE: ID 1 GS3M Model GS868 Ver GS3M Channel
START: 28 JUL 10 08:43:18
END: 28 JUL 10 08:45:38
INTERVAL: 5 seconds

PRINTOUT OF SELECTED LOG CHANNELS

DATE MM-DD-YY	TIME HH:MM:SS	ID#1 CH1 VEL Ft/s	ID#1 CH1 SS up	ID#1 CH1 SS do	ID#1 CH1 SNDSP Ft/s	ID#1 CH1 DELTA usec
07-28-10	08:43:20	0.00	67.5	67.5	1126.831	0.001
07-28-10	08:43:26	0.00	67.5	67.5	1126.793	-0.008
07-28-10	08:43:32	0.00	67.5	67.5	1126.793	-0.008
07-28-10	08:43:38	0.00	67.5	67.5	1126.815	0.005
07-28-10	08:43:44	0.00	67.5	67.5	1126.791	0.002
07-28-10	08:43:50	0.00	67.5	67.5	1126.808	0.023
07-28-10	08:43:56	0.00	67.5	67.5	1126.801	-0.008
07-28-10	08:44:02	0.00	67.5	67.5	1126.808	0.023
07-28-10	08:44:08	0.00	67.5	67.5	1126.816	0.006
07-28-10	08:44:14	0.00	67.5	67.5	1126.817	0.015
07-28-10	08:44:20	0.00	67.5	67.5	1126.804	0.027
07-28-10	08:44:26	0.00	67.5	67.5	1126.816	0.006
07-28-10	08:44:32	0.00	67.5	67.5	1126.821	0.011
07-28-10	08:44:38	0.00	67.5	67.5	1126.802	-0.007
07-28-10	08:44:44	0.00	67.5	67.5	1126.803	-0.008
07-28-10	08:44:50	0.00	67.5	67.5	1126.793	-0.008
07-28-10	08:44:56	0.00	67.5	67.5	1126.794	0.013
07-28-10	08:45:02	0.00	67.5	67.5	1126.821	0.011
07-28-10	08:45:08	0.00	67.5	67.5	1126.821	0.011
07-28-10	08:45:14	0.00	67.5	67.5	1126.821	0.011
07-28-10	08:45:20	0.00	67.5	67.5	1126.796	-0.011
07-28-10	08:45:26	0.00	67.5	67.5	1126.821	0.011
07-28-10	08:45:32	0.00	67.5	67.5	1126.808	0.023
07-28-10	08:45:38	0.00	67.5	67.5	1126.802	-0.007

♀

PIT-5103

Steam Pressure into FIT-5103

TRANSMITTER SPAN LOG

DATE	UNITS	4mA	20mA	Name of Person Who Made the Change
Sept 1, 10	PSig	0	300	Charlie Crown, Initial setup

TRANSMITTER CALIBRATION RECORD

INSTRUMENT TAG: FIT - 5103 (PIT-5103 into FIT-5103) Steam Flow

DATE: 9-1-10

PROCEDURE

1. Before performing any calibration, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.
2. If any value deviates from the expected value by more than 0.5% of span, perform calibration of the transmitter.
3. If calibration is performed, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.

% of Span ± 1.5	Process Value	As Found			Acceptance Criteria (mA)	After Calibration		
	Units: PSI	Process Value from Transmitter Display	Analog ~~Output~~ INPUT (mA)	Data Acquisition Process Value		Process Value from Transmitter Display	Analog ~~Output~~ INPUT (mA)	Data Acquisition Process Value
0	0		4	.08	4 (3.9 to 4.1)		4	0.00
25	75		8	75.57	8 (7.9 to 8.1)		8	75.00
50	150		12	151.09	12 (11.9 to 12.1)		12	150.01
75	225		16	226.61	16 (15.9 to 16.1)		16	225.00
100	300		20	300.00	20 (19.9 to 20.1)		20	300.00

Trans. passed without cal: _____ Trans. passed with cal.: X Trans. replaced: _____

Calibration Performed by: Charles Crown

Date next calibration is to be performed: _____

TT-5103

Steam Flow

TRANSMITTER SPAN LOG

DATE	UNITS	4mA	20mA	Name of Person Who Made the Change
Sept 1, 10	°F	0	500	Charlie Crown, Initial Set-up

TRANSMITTER CALIBRATION RECORD

INSTRUMENT TAG: TT-5103 Steam Flow

DATE: 9-1-10

PROCEDURE

1. Before performing any calibration, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.
2. If any value deviates from the expected value by more than 0.5% of span, perform calibration of the transmitter.
3. If calibration is performed, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.

% of Span	Process Value	As Found			Acceptance Criteria (mA)	After Calibration		
	Units: °F	Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value		Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value
0	0	-.14	3.99	0.27	4 (3.9 to 4.1)			
25	125	124.92	7.99	126.28	8 (7.9 to 8.1)			
50	250	~~2~~49.82	~~249.82~~ 11.99	252.22	12 (11.9 to 12.1)			
75	375	374.83	15.99	378.16	16 (15.9 to 16.1)			
100	500	499.90	19.99	500.00	20 (19.9 to 20.1)			

Trans. passed without cal: X Trans. passed with cal.: _____ Trans. replaced: _____

Calibration Performed by: Charles Crown

Date next calibration is to be performed: _____

TEMPERATURE ELEMENT VERIFICATION RECORD

INSTRUMENT TAG: TE -5103 Steam Flow

DATE: 9-1-10

PROCEDURE

1. If element is connected to a transmitter, calibrate the transmitter first.
2. Insert element into test device, set test device to target temperature, allow temperature of test device to stabilize.
3. Note down the test device temperature in the appropriate column.
4. Note down the data acquisition value in the appropriate column.
5. If data acquisition value is outside the range of the acceptance criteria, replace the element.

Target Temp. °F	Calibration Instrument Reading °F	Data Acquisition Value °F	Acceptance Criteria (mA)
240.3 ~~150~~	240.27		+/- 5°F
150 ~~100~~	149.33		+/- 5°F
32	32.89		+/- 5°F

Element passed: X

Element. replaced: _____

Verification Performed by: Charles Crown

Date next verification is to be performed: _____

PIT-5104 Center Steam Pressure

TRANSMITTER SPAN LOG

DATE	UNITS	4mA	20mA	Name of Person Who Made the Change
1 Sept 10	psig	0	10	Charlie Crown, Initial Setup
30 Sept 10	psig	0	200	" " , changed for hybrid test.

TRANSMITTER CALIBRATION RECORD

INSTRUMENT TAG: PIT - 5104 Center Steam Pressure

DATE: 9-1-10

PROCEDURE

1. Before performing any calibration, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.
2. If any value deviates from the expected value by more than 0.5% of span, perform calibration of the transmitter.
3. If calibration is performed, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.

% of Span ± .05	Process Value	As Found			Acceptance Criteria (mA)	After Calibration		
	Units: PSI	Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value		Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value
0	-0.03	0	3.95	0.0	4 (3.9 to 4.1)			
25	2.5	2.48	7.97	2.5	8 (7.9 to 8.1)			
50	5	4.99	11.99	5.0	12 (11.9 to 12.1)			
75	7.5	7.4	15.98	7.5	16 (15.9 to 16.1)			
100	10	9.98	19.97	10.0	20 (19.9 to 20.1)			

Trans. passed without cal: X Trans. passed with cal.: _____ Trans. replaced: _____

Calibration Performed by: Charles Crown

Date next calibration is to be performed: _____

TEMPERATURE ELEMENT VERIFICATION RECORD

INSTRUMENT TAG: TE-5105 (2") Center Steam Temp

DATE: 9-1-10

PROCEDURE

1. If element is connected to a transmitter, calibrate the transmitter first.
2. Insert element into test device, set test device to target temperature, allow temperature of test device to stabilize.
3. Note down the test device temperature in the appropriate column.
4. Note down the data acquisition value in the appropriate column.
5. If data acquisition value is outside the range of the acceptance criteria, replace the element.

Target Temp. °F	Calibration Instrument Reading °F	Data Acquisition Value °F	Acceptance Criteria (mA)
150	232.3	229.0	+/- 5°F
150 ~~100~~	150.0	147.0	+/- 5°F
32	32.0	31.0	+/- 5°F

Element passed: X Element. replaced: _____

Verification Performed by: Charles Crown

Date next verification is to be performed: _____

Upper Steam Press.

PIT-5106

TRANSMITTER SPAN LOG

DATE	UNITS	4mA	20mA	Name of Person Who Made the Change
Sept 1, 10	psig	0	50	Charlie Crown, Initial Setup

TRANSMITTER CALIBRATION RECORD

INSTRUMENT TAG: PIT-5106

DATE: 9-1-10

PROCEDURE

1. Before performing any calibration, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.
2. If any value deviates from the expected value by more than 0.5% of span, perform calibration of the transmitter.
3. If calibration is performed, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.

% of Span ±.25	Process Value	As Found			Acceptance Criteria (mA)	After Calibration		
	Units: PSI	Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value		Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value
0	0	-.04	3.99	0.0	4 (3.9 to 4.1)			
25	12.5	12.46	7.99	12.4	8 (7.9 to 8.1)			
50	25	24.96	11.99	24.9	12 (11.9 to 12.1)			
75	37.5	36.98	15.83	36.9	16 (15.9 to 16.1)			
100	50	49.98	19.99	49.9	20 (19.9 to 20.1)			

Trans. passed without cal: X Trans. passed with cal.: _____ Trans. replaced: _____

Calibration Performed by: Charles Crown

Date next calibration is to be performed: _____

TEMPERATURE ELEMENT VERIFICATION RECORD

INSTRUMENT TAG: TE-5107 (4") Upper Steam Temp

DATE: 9-1-10

PROCEDURE

1. If element is connected to a transmitter, calibrate the transmitter first.
2. Insert element into test device, set test device to target temperature, allow temperature of test device to stabilize.
3. Note down the test device temperature in the appropriate column.
4. Note down the data acquisition value in the appropriate column.
5. If data acquisition value is outside the range of the acceptance criteria, replace the element.

Target Temp. °F	Calibration Instrument Reading °F	Data Acquisition Value °F	Acceptance Criteria (mA)
229.4 ~~150~~	229.4	229.0	+/- 5°F
150 ~~100~~	150.0	149.0	+/- 5°F
32	32.0	34.0	+/- 5°F

Element passed: X Element. replaced: _____

Verification Performed by: Charles Crown

Date next verification is to be performed: _____

TRANSMITTER CALIBRATION RECORD

INSTRUMENT TAG: FT-320 dP (CO_2 Flow Meter)

DATE: 8-26-10

PROCEDURE

1. Before performing any calibration, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.
2. If any value deviates from the expected value by more than 0.5% of span, perform calibration of the transmitter.
3. If calibration is performed, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.

% of Span	Process Value	As Found			Acceptance Criteria (mA)	After Calibration		
	Units: IN/H_2O	Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value		Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value
0	0	0.0	N/A	N/A	4 (3.9 to 4.1)			
25	207.5	207.4			8 (7.9 to 8.1)			
50	415	414.8			12 (11.9 to 12.1)			
75	622.5	621.9			16 (15.9 to 16.1)			
100	830	829.7			20 (19.9 to 20.1)			

Trans. passed without cal: X Trans. passed with cal.: _____ Trans. replaced: _____

Calibration Performed by: Charles Crown

Date next calibration is to be performed: _____

+1 4.15

TRANSMITTER CALIBRATION RECORD

INSTRUMENT TAG: FT - 320 AP (CO2 Flow Meter)

DATE: 8-26-10

PROCEDURE

1. Before performing any calibration, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.
2. If any value deviates from the expected value by more than 0.5% of span, perform calibration of the transmitter.
3. If calibration is performed, input all five test points into the transmitter and note down: process value from the transmitter display, milli-amp output values, and the value displayed in the data acquisition system in the appropriate columns.

% of Span	Process Value	As Found			Acceptance Criteria (mA)	After Calibration		
	Units: PSIA	Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value		Process Value from Transmitter Display	Analog Output (mA)	Data Acquisition Process Value
0	14.3	14.3	N/A	N/A	4 (3.9 to 4.1)			
25	34.3	34.2			8 (7.9 to 8.1)			
50	54.3	54.07			12 (11.9 to 12.1)			
75	74.3	74.0			16 (15.9 to 16.1)			
100	94.3	94.19			20 (19.9 to 20.1)			

Trans. passed without cal: X Trans. passed with cal.: _____ Trans. replaced: _____

Calibration Performed by: Charles Crown

Date next calibration is to be performed: _____

TEMPERATURE ELEMENT VERIFICATION RECORD

INSTRUMENT TAG: FT-320 RTD (CO_2 Flow Meter)

DATE: 8-26-10

PROCEDURE

1. If element is connected to a transmitter, calibrate the transmitter first.
2. Insert element into test device, set test device to target temperature, allow temperature of test device to stabilize.
3. Note down the test device temperature in the appropriate column.
4. Note down the data acquisition value in the appropriate column.
5. If data acquisition value is outside the range of the acceptance criteria, replace the element.

Target Temp. °F	Calibration Instrument Reading °F	Data Acquisition Value °F	Acceptance Criteria (mA)
150	149.2	N/A	+/- 5°F
100	99.08		+/- 5°F
32	30.7		+/- 5°F

Element passed: X Element. replaced: _____

Verification Performed by: Charles Crown

Date next verification is to be performed: _____

CALIBRATIONS FOR OTHER DEVICES

CO_2 Analyzer (Bad Readings)

FIELD ENVIRONMENTAL INSTRUMENTS, INC.
www.fieldenvironmental.com

301 Brushton Avenue
Suite A
Pittsburgh PA 15221
800-393-4009 Toll Free
(412) 436-2600 Local
(412) 436-2616 Fax

Multi-Gas Detector Calibration Certificate

Fresh Air			**Reading %**	**Acceptable Range**
Oxygen			20.9	(20.7 - 21.2)
Cal Gas	**Lot #**	**Expiration**	**Reading %**	**Acceptable Range**
LEL	10-3939	08/18/11	49	(48 - 52)
Cal Gas	**Lot #**	**Expiration**	**Reading %**	**Acceptable Range**
%Vol				(13% - 17%)
Cal Gas	**Lot #**	**Expiration**	**Reading ppm**	**Acceptable Range**
H2S				(24 - 26)
Cal Gas	**Lot #**	**Expiration**	**Reading ppm**	**Acceptable Range**
CO			50	(48 - 52)
Cal Gas	**Lot #**	**Expiration**	**Reading ppm**	**Acceptable Range**
CO2			4860	(4500 - 5500)
Cal Gas	**Lot #**	**Expiration**	**Reading ppm**	**Acceptable Range**
VOC	9-3816	05/23/11	100	(98 - 102)
			Response Factor	
			1.0	

Model	MultiRae IR		
Lamp	10.6 eV		
S/N	80000231	**Pump Flow**	**Acceptable Range**
Barcode	U231X	226	(130 - 250)
Order #	151804		

Calibrated By: Gene Donofrio

Date of Calibration: 08/24/10

All calibrations performed by FEI conform to manufacturer's specifications. Please report any issues within 24 hours of receiving equipment.

All calibration gas used is traceable to NIST. Additional documentation is available upon request.

JOHN ZINK COMPANY

CO_2 Analyzer (Sample Collector Measurements)

FIELD ENVIRONMENTAL INSTRUMENTS, INC.
www.fieldenvironmental.com

301 Brushton Avenue
Suite A
Pittsburgh PA 15221
800-393-4009 Toll Free
(412) 436-2600 Local
(412) 436-2616 Fax

Multi-Gas Detector Calibration Certificate

Fresh Air			**Reading %**	**Acceptable Range**
Oxygen			20.9	(20.7 - 21.2)
Cal Gas	**Lot #**	**Expiration**	**Reading %**	**Acceptable Range**
LEL	10-3939	08/18/11	49	(48 - 52)
Cal Gas	**Lot #**	**Expiration**	**Reading %**	**Acceptable Range**
%Vol				(13% - 17%)
Cal Gas	**Lot #**	**Expiration**	**Reading ppm**	**Acceptable Range**
H2S				(24 - 26)
Cal Gas	**Lot #**	**Expiration**	**Reading ppm**	**Acceptable Range**
CO			51	(48 - 52)
Cal Gas	**Lot #**	**Expiration**	**Reading ppm**	**Acceptable Range**
CO2			5000	(4500 - 5500)
Cal Gas	**Lot #**	**Expiration**	**Reading ppm**	**Acceptable Range**
VOC	10-4034	01/22/12	100	(98 - 102)
			Response Factor	
Model	MultiRae IR			
Lamp	10.6 eV			
S/N	80001196		**Pump Flow**	**Acceptable Range**
Barcode	U49191X		230	(130 - 250)
Order #	151804			

Calibrated By: John Shandrick

Date of Calibration: 09/02/10

All calibrations performed by FEI conform to manufacturer's specifications. Please report any issues within 24 hours of receiving equipment.

All calibration gas used is traceable to NIST. Additional documentation is available upon request.

JOHN ZINK COMPANY

CO2 Analyzer (Ambient measurements)

FIELD ENVIRONMENTAL INSTRUMENTS, INC.
www.fieldenvironmental.com

301 Brushton Avenue
Suite A
Pittsburgh PA 15221
800-393-4009 Toll Free
(412) 436-2600 Local
(412) 436-2616 Fax

Multi-Gas Detector Calibration Certificate

Fresh Air Oxygen			Reading %	Acceptable Range
			20.9	(20.7 - 21.2)
Cal Gas LEL	Lot #	Expiration	Reading %	Acceptable Range
	10-3939	08/18/11	50	(48 - 52)
Cal Gas %Vol	Lot #	Expiration	Reading %	Acceptable Range
				(13% - 17%)
Cal Gas H2S	Lot #	Expiration	Reading ppm	Acceptable Range
				(24 - 26)
Cal Gas CO	Lot #	Expiration	Reading ppm	Acceptable Range
			49	(48 - 52)
Cal Gas CO2	Lot #	Expiration	Reading ppm	Acceptable Range
			4690	(4500 - 5500)
Cal Gas VOC	Lot #	Expiration	Reading ppm	Acceptable Range
	10-3972	10/27/11	100	(98 - 102)
			Response Factor	
			1.0	

Model	MultiRae IR
Lamp	10.6 eV
S/N	080-901296
Barcode	U59152X
Order #	152502

Pump Flow	Acceptable Range
180	(130 - 250)

Calibrated By: Dan Williams

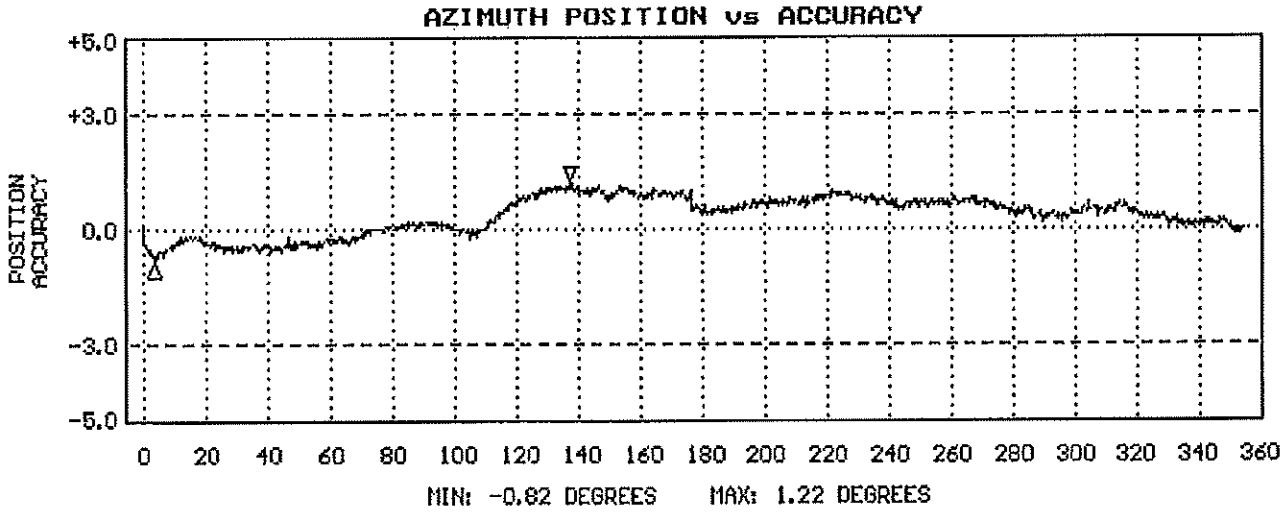
Date of Calibration: 09/01/10

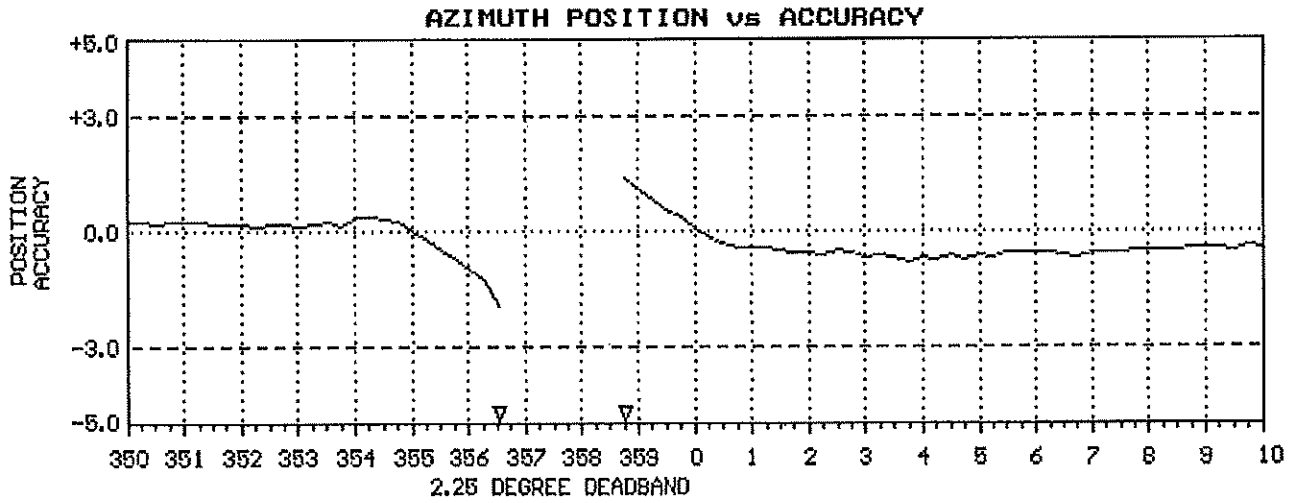
All calibrations performed by FEI conform to manufacturer's specifications. Please report any issues within 24 hours of receiving equipment.
All calibration gas used is traceable to NIST. Additional documentation is available upon request.

R. M. YOUNG COMPANY WIND SENSOR CALIBRATION CERTIFICATE

SENSOR: 05103 WIND MONITOR
SENSOR SERIAL NUMBER: WM102958
BEARINGS: SEALED/GREASE LUBE
DATE: JUL 20 2010
WIND SPEED THRESHOLD TEST: PASS
LOW WIND SPEED AMPLITUDE/FREQUENCY TEST: PASS
HIGH WIND SPEED AMPLITUDE/FREQUENCY TEST: PASS
VANE TORQUE TEST: PASS
SPECIAL NOTES:
SPECIAL NOTES:

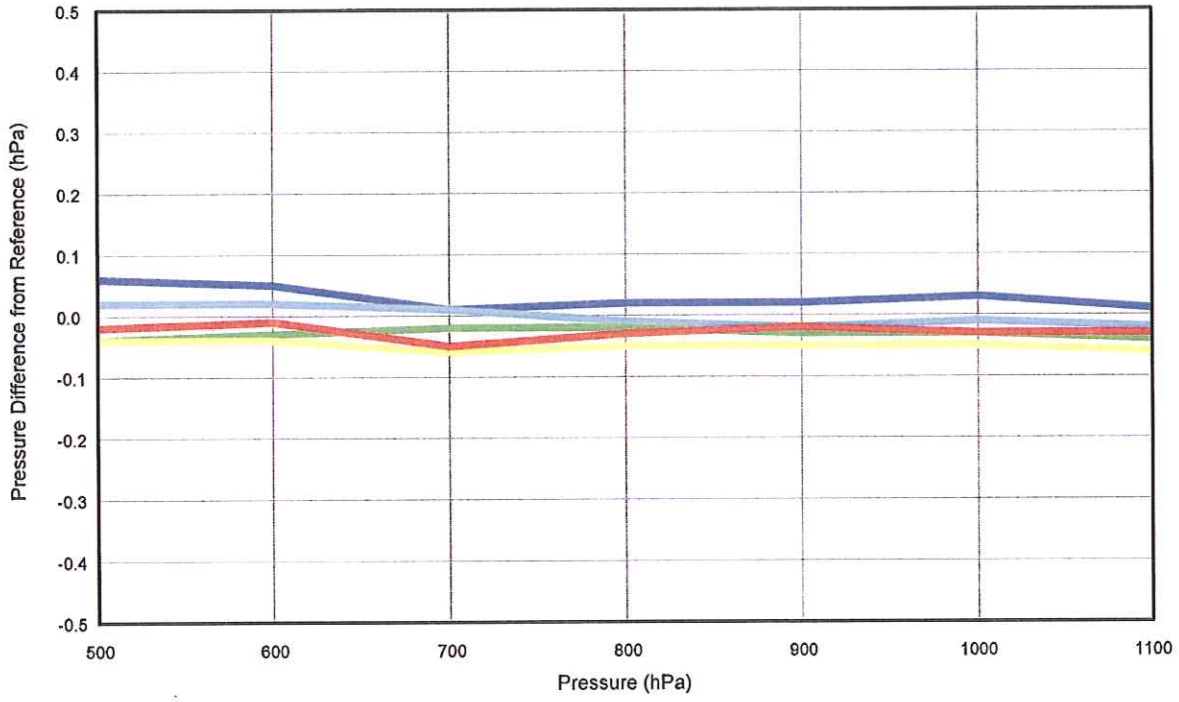
INSP





NOTE: Azimuth Position vs Accuracy graphs are accurate to within 0.5 degrees. The accuracy shown in the potentiometer deadband region between 355 and 0 degrees is the result of no resistance change while position changes. The gap represents the actual deadband (open circuit).

R. M. Young Company
Barometric Pressure Sensor Calibration Record
Serial Number: BPA2067
Calibration Date: August 02, 2010



LEGEND:
-40°C
-25°C
-0°C
25°C
60°C

Sensor calibration checked from 500 to 1100 hPa in 100 hPa increments at 5 temperatures.
Pressure reference traceable to NIST.

Average Difference from Pressure Reference: -0.02 hPa
Standard Deviation: 0.03 hPa

61000 Baro 2010-08-02-22-50-57.cal
R. M. Young Company, 2801 Aero Park Drive, Traverse City, MI 49686 USA
CR61200

VALIDATION OF ORIFICE DIMENSIONS

Performed by Zach Kodesh

Method: For orifices larger than 1”, a digital caliper is utilized. For orifices smaller than 1”, plug gauges were utilized.

Orifice Tag	Marked Size	Measured Size	Date
FE-3301	0.260”	0.260”	9/3/2010
FE-3301	0.109	0.109	9/9/2010
FE-3306	1.187”	1.187”	9/3/2010
FE-3306	0.500”	0.500”	9/3/2010
FE-3312	1.250”	1.250”	9/3/2010
FE-3312	0.500”	0.500”	9/3/2010

GAS ANALYSIS RECORDS

PROPYLENE ANALYSIS

PROPYLENE,

WESTERN
INTERNATIONAL GAS & CYLINDERS, INC.

P.O. Box 668
Bellville, Texas 77418
979-413-2323
800-847-5664

WESTERN INTERNATIONAL GAS
PO BOX 668
BELLVILLE TX 77418
1 800 847 5664
SALE # 857 DATE 09/20/10 11:35:16
COUNT: START 0.0 END 5000.2
NET DELIVERY 5000.2 GALLONS
PROPYLENE LPG 1
VOLUME CORRECTED TO 60.0°F

John Zink Co
11920 E. Apache St.
Tulsa, OK 74116

SENT TO ACCT.
9-20-10

ENTERED
9-20-10

"WARNING: Flammable Gas. The installation, modification, or repair of an LPG system by a person who is not licensed or registered to install, modify, or repair an LPG system may cause injury, harm, or loss. Contact a person licensed or registered to install, modify, or repair an LPG system. A person licensed to install or repair an LPG system may not be liable for damages caused by the modification of an LPG system by an unlicensed person except as otherwise provided by applicable law."

Flammable Gas UN 1077

Driver Signature	☐ Check if tank not full	53995
Payment Received $_____ ☐ Cash ☐ Check	Customer Signature X	

Sample Date 8/26/2010 **Truck/Trailer No.:** 39 1603

Property	Result	Specification
Methane, PPM Wgt.	BDL	Note (1)
Ethane, PPM Wgt.	6	Note (1)
Ethylene, PPM Wgt.	BDL	100 max.
Propane, Wgt. %	0.37	0.5 max.
Propylene, Wgt. %	99.63	99.5 min.
Total Saturated C4's, PPM Mole	BDL	Note (1)
Propadiene, PPM Wgt.	BDL	5 max.
Methyl Acetylene, PPM Wgt.	BDL	7 max.
Acetylene, PPM Wgt.	BDL	3 max.
Total Butadienes, PPM Wgt.	BDL	10 max.
Total Butenes, PPM Wgt.	BDL	100 max.
1-Butyne, PPM Wgt.	BDL	7 max.
2-Butyne, PPM Wgt.	BDL	7 max.
Cyclopropane, PPM Wgt.	BDL	1 max.
3-Methyl 1-Butene, PPM Wgt.	BDL	1 max.
Total > C5, PPM Wgt.	BDL	20 max.
Carbon Monoxide, PPM Wgt.	BDL	0.033 max.
Carbon Dioxide, PPM Wgt.	0.22	2 max.
Carbonyl Sulfide, PPM Wgt.	BDL	0.043 max.
Hydrogen Sulfide, PPM Wgt.	BDL	1 max.
Total Sulfur, PPM Wgt.	BDL	1 max.
Arsine, PPM Wgt.	BDL	0.056 max.
Phosphine, PPM Wgt.	BDL	0.1 max.
Methanol, PPM Wgt.	BDL	4 max.
2-Propanol, PPM Wgt.	BDL	7 max.
Water, PPM Wgt.	0.1	2 max.
Hydrogen, PPM Wgt.	BDL	1 max.
Oxygen, PPM Wgt.*	BDL	2 max.
Nitrogen, PPM Wgt.	BDL	Note (1)
Ammonia, PPM Wgt.	BDL	0.2 max.

SAS

REF ID# CM10586 by/for Larry P. Stoltz

SOURCE Tank 5 Laboratory Supervisor

Note (1) Total Non-Propane Inerts = 1000 Wt. ppm max

revised 7/14/98

PROPYLENE "B"

MOISTURE .29

Client:	Louis Dreyfus Olefins, LLC	Requested by:	
Sample:	Propylene	Date/Time:	9/14/2010 14:06
Lab. No.:	Geismar	P. O. No.	
Operator:	Timothy P. Beary	Data File:	C:\HPCHEM\3\DATA\SIG14022.D
Sample Info.:	Sample Log Number:GE100914002		

??

Peak Name	Mol%	Wt%
Methane	0.0000	0.0000
Ethane	0.0002	0.0001
Propane	0.1090	0.1142
Isobutane	0.0000	0.0000
n-Butane	0.0000	0.0000
Isopentane	0.0000	0.0000
n-Pentane	0.0000	0.0000
Neopentane	0.0000	0.0000
Ethylene	0.0000	0.0000
Propylene	99.8908	99.8856
1-Butene	0.0000	0.0000
c-2-Butene	0.0000	0.0000
t-2-Butene	0.0000	0.0000
Isobutene	0.0000	0.0000
1,3-Butadiene	0.00000	0.00000
Acetylene	0.00000	0.00000
Methylacetylene	0.00000	0.00000
Propadiene	0.00000	0.00000
Carbon monoxide	0.00000	0.00000
Carbon dioxide	0.00001	0.00001
	100.0000	100.0000

SPGliq	0.5226
RVP	232.7491

227.2 psia Published

LDH Energy Olefins, LLC
Sulfur Analysis
9/14/2010 2:08:11 PM
C:\HPCHEM\4\METHODS\C3-SULF.M
C:\HPCHEM\4\DATA\SIG17553.D
Sample Log Number:GE100914002 ->

#	Compound Name	wt ppm	Area	Meas. R
1	hydrogen sulfide	0.0000	0.000	0.000
2	carbonyl sulfide	0.0000	0.000	0.000
3	methyl mercaptan	0.0000	0.000	0.000
4	ethyl mercaptan	0.0000	0.000	0.000
5	diMethyl sulfide	0.0000	0.000	0.000
6	ethylmethylsulfide	0.0000	0.000	0.000
7	thiophene	0.0000	0.000	0.000
8	diEthyl sulfide	0.0000	0.000	0.000
9	nbutyl mercaptan	0.0000	0.000	0.000
10	Dimethyldisulfide	0.0000	0.000	0.000
11	2-methyl-1-butanethiol	0.0000	0.000	0.000
12	3-methyl-1-butanethiol	0.0000	0.000	0.000
13	1-pentanethiol	0.0000	0.000	0.000
14	ditertbutylsulfide	0.0000	0.000	0.000
15	Diethyldisulfide	0.0000	0.000	0.000
16	disecbutylsulfide	0.0000	0.000	0.000
17	diisobutylsulfide	0.0000	0.000	0.000
18	dinbutylsulfide	0.0000	0.000	0.000
19	DiPropyldisulfide	0.0000	0.000	0.000
20	Dibutyldisulfide	0.0000	0.000	0.000
----Total known sulfur cmpds----------		0.0000		

==========

Total Known Sulfur: 0.000

Total Sulfur: 0.000

==========

Timothy P. Beary

LDH Energy Olefins, LLC
Trace Oxygenates Analysis
9/14/2010 2:42:26 PM
C:\HPCHEM\4\METHODS\TRA-OXY.M
C:\HPCHEM\4\DATA\SIG17554.D
Sample Log Number:GE100914002 ->

#	Compound Name	wt ppm	Area	Meas. R
1	DME	0.000	0.000	0.000
2	ETBE	0.000	0.000	0.000
3	MTBE	0.000	0.000	0.000
4	2-methoxy-2-methylbutane	0.000	0.000	0.000
5	Methanol	0.000	0.000	0.000
6	Acetone	0.000	0.000	0.000
7	Ethanol	0.000	0.000	0.000
8	propanol/iso-prop	0.000	0.000	0.000
9	tert-Butanol	0.000	0.000	0.000
10	Butanol	0.000	0.000	0.000

Quantitation Report (QT Reviewed)

Data File : C:\MSDCHEM\1\DATA\2010\20100914\PROPY1.D Vial: 1
Acq On : 9-14-2010 02:55:52 PM Operator: RG
Sample : PROPYLENE B Inst : Instrumen
Misc : GE100914002 Multiplr: 1.00
Sample Amount: 0.00

IntFile : AUTOINT1.E
Quant Time: Sep 14 14:58:23 2010 Quant Results File: PROPYHON.RES

Quant Method : C:\MSDCHEM\1\METHODS\PROPYHON.M (Chemstation Integrator)
Title : GL550E
Last Update : Wed Aug 04 09:18:20 2010
Response via : Initial Calibration
DataAcq Meth : PROPYHON.M

Volume Inj. :
Signal Phase :
Signal Info :

	Compound	R.T.	Response	Conc Units
Target Compounds				
1)	hydrogen	0.55	887876	0.009 ppm w
2)	oxygen	0.67	13040653	0.795 ppm w
3)	nitrogen	0.76	34267284	1.240 ppm w

(f)=RT Delta > 1/2 Window (m)=manual int.
PROPY1.D PROPYHON.M Tue Sep 14 14:58:59 2010

LDH Energy Olefins, LLC
Geismar site
Propylene
9/14/2010 2:06:46 PM
C:\HPCHEM\3\METHODS\PROPLIQ.M
C:\HPCHEM\3\DATA\SIG14022.D
Sample Log Number:GE100914002 ->

#	Compound Name	Amount (mol%)	Area	Meas. R
1	Carbon monoxide	0.00000	0.000	0.000
2	Carbon dioxide	0.00001	0.505	2.533
3	Methane	0.00000	0.000	0.000
4	Ethane	0.00019	1.385	3.834
5	Ethylene	0.00000	0.000	0.000
6	Propane	0.10900	1.308e3	4.630
7	Propylene	0.00000	1.262e6	5.135
8	Acetylene	0.00000	0.000	0.000
9	Isobutane	0.00000	0.000	0.000
10	Propadiene	0.00000	0.000	0.000
11	n-Butane	0.00000	0.000	0.000
12	t-2-Butene	0.00000	0.000	0.000
13	1-Butene	0.00000	0.000	0.000
14	Isobutene	0.00000	0.000	0.000
15	c-2-Butene	0.00000	0.000	0.000
16	Isopentane	0.00000	0.000	0.000
17	Methylacetylene	0.00000	0.000	0.000
18	n-Pentane	0.00000	0.000	0.000
19	1,3-Butadiene	0.00000	0.000	0.000
		0.10920		

PROPYLENE,

WESTERN
INTERNATIONAL GAS & CYLINDERS, INC.

P.O. Box 668
Bellville, Texas 77418
979-413-2100

ENTERED
9-24-10

SENT TO ACCT.
9-24-10

Gallons del 20548

8,960 lbs.

John Zink Co.
11920 E. 11th St.
Tulsa, OK. 74116

Flammable Gas UN 1077

Driver Signature	☐ Check if tank not full	52495
Payment Received $_____ ☐ Cash ☐ Check	Customer Signature X	

ATTN.
STEPHANIE
SOUTHERLAND

Certificate of Analysis
for
Polymer Grade Propylene

Sample Date 9/22/2010 **Truck/Trailer No.:** 60 – 602

Property	Result	Specification
Methane, PPM Wgt.	BDL	Note (1)
Ethane, PPM Wgt.	4	Note (1)
Ethylene, PPM Wgt.	BDL	100 max.
Propane, Wgt. %	0.41	0.5 max.
Propylene, Wgt. %	99.58	99.5 min.
Total Saturated C4's, PPM Mole	BDL	Note (1)
Propadiene, PPM Wgt.	BDL	5 max.
Methyl Acetylene, PPM Wgt.	BDL	7 max.
Acetylene, PPM Wgt.	BDL	3 max.
Total Butadienes, PPM Wgt.	BDL	10 max.
Total Butenes, PPM Wgt.	BDL	100 max.
1-Butyne, PPM Wgt.	BDL	7 max.
2-Butyne, PPM Wgt.	BDL	7 max.
Cyclopropane, PPM Wgt.	BDL	1 max.
3-Methyl 1-Butene, PPM Wgt.	BDL	1 max.
Total > C5, PPM Wgt.	4.1	20 max.
Carbon Monoxide, PPM Wgt.	BDL	0.033 max.
Carbon Dioxide, PPM Wgt.	0.03	2 max.
Carbonyl Sulfide, PPM Wgt.	BDL	0.043 max.
Hydrogen Sulfide, PPM Wgt.	BDL	1 max.
Total Sulfur, PPM Wgt.	BDL	1 max.
Arsine, PPM Wgt.	BDL	0.056 max.
Phosphine, PPM Wgt.	BDL	0.1 max.
Methanol, PPM Wgt.	BDL	4 max.
2-Propanol, PPM Wgt.	BDL	7 max.
Water, PPM Wgt.	BDL	2 max.
Hydrogen, PPM Wgt.	BDL	1 max.
Oxygen, PPM Wgt.*	BDL	2 max.
Nitrogen, PPM Wgt.	BDL	Note (1)
Ammonia, PPM Wgt.	BDL	0.2 max.

REF ID# CM23778
SOURCE Tank 5

by/for EGH
Larry P. Stoltz
Laboratory Supervisor

Note (1) Total Non-Propane Inerts = 1000 Wt. ppm max

revised 7/14/98

NITROGEN ANALYSIS

Airgas

Airgas-Mid South, Inc.
31 N. Peoria
Tulsa, OK 74110
918-834-7331
FAX: 834-8724

CERTIFICATE OF CONFORMANCE

Date : September 2, ~~2009~~ 2010

Supplier Name : Airgas Mid South
Address: 31 N. Peoria
Tulsa, OK 74120

Lot Number:
Product: Industrial Nitrogen, Grade L

Dear Sir,
This is to certify that all Industrial Nitrogen, Grade L, supplied by Airgas Mid-South meets or exceeds the following commodity specifications: Trailer number I-29 delivered on 9-2-2010

Product Specification

Oxygen	< 10 PPM
Purity	> 99.998%
Dew Point	-90°F
Water	< 4PPM

Greg R. Fairclough
Approval Signature

0wAirgas-Mid South NI TT FLARE JOB 17029294297
31 N PEORIA
TULSA OK 74101-1152 DSQ42
[918] 585-2611
379577-00

JOHN ZINK JOHN ZINK CO 08/31/10

11920 E APACHE 001 OF 001
TULSA OK 74116 21-Sep-10 09:24AM CRT:TNA4165

CHRG-DP 106 197 2 0 X OUR TRUCK TH13 08/31/10 106 JAS

4w QTY SHIP	UNIT	HM	---------DESCRIPTION--------- & HAZARD CLASS	ID NUMBER	LINE NO	------ITEM------ NUMBER	LOC	QTY ORDER	--CYLINDERS-- SHIP	RETN	VOL/ WT	UNIT AMOUNT	EXTENDED AMOUNT
1	HH	X	UN1066 NITROGEN, COMPRESSED 2.2 (NITROGEN TUBE TRAILER (HH UOM))		2	NI TT	FR3	1			100		

Cust Item # : 1144716

<<<<<<<<Estimated delivery:09/01>>>>>>>>
DELV NI TT I29 TO CUST FOR FLARE JOB PER REQT OF LAFATE ROBERTS

RENTAL PO # FROM 9/1/09 TO 9/30/10 IS 5054473 PART# 1258580
ALL SIGNED PINK COPIES OF TICKETS MUST BE
GIVEN TO CAROL IN FRONT OFFICE OF R&D.

Customer phone number: 918-234-1967
EMERGENCY CONTACT 1-866-734-3438

379577-00

0w
JOHN ZINK

11920 E APACHE
TULSA OK 74116

NI TT FLARE JOB DSQ42 00 0

379577-00 08/31/10 OUR TRUCK -NONE-

Airgas MID SOUTH

Nitrogen Trailer Fill Record

Start Date: 8-27-10 Finish Date: 8-27-10

Water Volume: 278.8 Trailer Number: I-29

Starting Pressure/Temperature: 900 psi 65° Pumper: PW

Ending Pressure/Temperature: 3000 90° Pumper: PW

Total Volume of Nitrogen Pumped: 34,472

Notes On Trailer or System:

DELIVERY ORDER

Airgas

For location nearest you visit www.airgas.com

DELOF-001 (Rev. 10/07)

	FILLED	REVIEWED	STAGING AREA	TOTAL PKGS	TOTAL CYLINDERS SHP.	REF.	FREIGHT CHARGES	SHIPPED: DELIVERED VIA ON _____, BL # _____			
								PCS	ZONE	GR WEIGHT	DECL VALUE $
ITEM COUNT											
BY											

SOLD BY:
Airgas Mid South
31 N PEORIA
TULSA OK 74101-1152
(918) 585-2611

SHIP TO:
JOHN ZINK
11920 E APACHE
TULSA OK 74116

P/O NO: RI TT FLARE JOB

REL NO:

SOLD TO:
JOHN ZINK CO

INTERNAL USE ONLY: 1693236627/5

CUST. NO: 05042

ORDER NO: 379577-00

ORD DATE: 08/31/10

PAGE NO: 001 OF 001

31-Aug-10 05:06PM CRT:TNA5365

TRAN TYPE	SLSM	BRCH	TERR	UPS	PPD	COLL	SHIP VIA	ROUTING	SCHEDULED SHIP DATE	REGION	ENTERED BY
CHRG	105	197		2	N	X	OUR TRUCK	THL3	08/31/10	106	JAS

QTY SHIP	UNIT OF MEASURE	DESCRIPTION & HAZARD CLASS	LO NUMBER	LINE NO	ITEM NUMBER	LOC	QTY ORDER	CYLINDERS SHP	REF	UNIT PRICE	UNIT MEASURE	EXTENDED AMOUNT
1	UNIT	X UN1066 NITROGEN, COMPRESSED 2.2 (NITROGEN IN TRAILER (ON HOH))	2	10	11	FR3	1			100		

Flare Pad

Cost Ctr $: 114716

<<<<<<<Estimated delivery:09/01>>>>>>>
ORD# 2 11 (2) TO COST FOR FLARE JOB PER REQ OF LARAD ROBERTS

RENTAL PO $ FROM 9/1/09 TO 9/30/10 IS 5054473 PRICE 1235.80
ALL SIGNED PINK COPIES OF TICKETS MUST BE
GIVEN TO CAROL IN FRONT OFFICE OF RSO.

Customer phone number: 918-734 1967
EMERGENCY CONTACT 1-866-734-3438

2.28 WC 278.3
3000 PSI x 244

SENT TO ACCT.
9-2-10

ENTERED
9-2-10

SHIPPED BY:

UPS SHIPPER NO.

PKG ID# 379577 00

THIS AGREEMENT SUBJECT TO AIRGAS' STANDARD TERMS AND CONDITIONS. SEE REVERSE SIDE FOR IMPORTANT SAFETY INFORMATION.

PLACARDS OFFERED
ACCEPT REJECT
CUSTOMER MUST INITIAL CHOICE

ACCEPTED FOR THE ABOVE CUSTOMER X _____
NAME PLEASE PRINT _____

SHIP TO:
JOHN ZINK
11920 E APACHE
TULSA OK 74116

PO.	CUST.	UPS
RI TT FLARE JOB	05042	00 0

ORDER	DATE	SHIP VIA
379577 00	08/31/10	OUR TRUCK -NONE-

Emergency Contact: 866-734-3438
(International - call: 1-703-527-3887)

Purchaser agrees to obtain Material Safety Data Sheets (MSDS) from one of the following sources; Point of purchase, Airgas Web site at <www.airgas.com>, or by calling the above listed emergency contact phone number and selecting option #3.

THIS IS TO CERTIFY THAT THE NAMED MATERIALS ARE PROPERLY CLASSIFIED, DESCRIBED, PACKAGED, MARKED AND LABELLED AND ARE IN PROPER CONDITION FOR TRANSPORTATION ACCORDING TO THE APPLICABLE REGULATIONS OF THE DEPARTMENT OF TRANSPORTATION

AIRGAS PERSONNEL _____ DATE _____ T.O.D. _____

JOHN ZINK COMPANY

Airgas
Merchant Gases

Certificate of Analysis

All NF Nitrogen delivered by Airgas Merchant Gases, when used in a medical application or by medical customers properly registered with the FDA, is classified as NF Nitrogen

Shipped From:
Airgas Merchant Gases
500 Industrial Park Road
Mulberry, AR 72947
Phone: 479-997-2677

Company Name: **Airgas Merchant Gases**

Product: **Nitrogen, NF**

Product Code: **104009**

Trailer No: **53395**

Load No: **2**

Tank No: **N1**

Time In: **10:28** Time Out: **10:49**

Load Date: **9/1/10**

Tare Weight: **31,760 lbs** Gross Weight: **78,840 lbs** Net Weight: **47,080 lbs**

Lot Number: **7937 N1 0244 2 53395**

Produced By: **Air Liquefaction**

Assay per NF requirements is by difference of O2 only

	Results	Units	USP / NF Specifications	AMG Specifications
Purity Pre-Fill:	**Pass**		**Pass ***	**Pass ***
Purity Post-Fill:	**99.999**	**%**	> = 99.0%	> = 99.999%
Assay, By Difference				
O2:	**0.43**	**ppm/V**	< = 1.0%	< = 5.0 ppm
O2 Tested By: Teledyne 316RA Electrochemical				
CO:	**0.20**	**ppm/V**	< = 10.0 ppm	< = 10.0 ppm
CO Tested By: Teledyne IR 7000 Non-Dispersive Infrared				
Odor:	**None**		None	None
Odor Tested By: Organoleptic				
Identity:	**Nitrogen**		Nitrogen	Nitrogen
Identity Tested By: AMG DP 4.2				

** The Pre-Fill is tested against AMG and USP / NF specifications and a Pass indicates that the results met or exceeded the applicable specifications. The results of the Pre-Fill tests are kept on file.*

HAZARDOUS MATERIAL SHIPPING INFORMATION

HM XX Nitrogen, Refrigerated Liquid (Cryogenic Liquid) 2.2 UN1977

Quantity: 47,080 Gallon 6,982 Cubic 649,826

NON-FLAMMABLE GAS
Spill, Leak, Fire, Exposure, or Accident:
Chemical Emergency: Call Chemtrec 800-424-9300

Airgas Analyst: *I declare that this analysis was completed within all AMG policy and procedures and that the product meets all AMG and USP/NF specifications.*

Signed: _____ Date / Time: 09/01/10 / 10:52

Product Release Specialist / Released By: *I declare that this certificate is accurate, complete and compliant with all applicable policies and procedures and that the product meets all AMG and USP/NF specifications.*

Signed: _____ Date / Time: 9/1/10 / 10:52

Picked Up By: *I declare that I have received the required documentation for shipment of this product and that I have the North American Emergency Response Guide or a MSDS.*

Signed: James Watson Date: 9/1/10

DP 5.4F-2
Revision: 0
Page 1 of 1
09-01-10

JOHN ZINK COMPANY

Airgas

(01) 176-TJ

AIRGAS MERCHANT GASES (479) 997-2578
500 Industrial Park Drive
Mulberry AR 72947

LIQUID SHIPPING ORDER
Delivery no: 86627982
Delivery date: 9/1/10

Sold to: ARG/TULSA E56TH ST
9741 E 56TH ST N
TULSA OKLAHOMA 74117

TRUCK # 22355

Purchase order and/or release

TRL # 53395

Customer no
000001FCWX

Lot # 7937 N10244 2 53395

Product: UN 1977, NITROGEN, REFRIGERATED LIQUID, 2.2

Tank # 50639 Lev Before 127 Lev After 220 Qty Del 2201

Meter end 2201
Meter Start Ø
Qty del 2201

TRAILER LIN TANK ON WEST SIDE -KD

204,935

~~Delivered quantity (Pounds): 14244 lbs~~ JW 9-1-10

Notes / Comments:

This is to certify that above named materials are properly classified, described, marked and labeled and are in proper condition for transportation according to applicable regulations of the Department of Transportation.
** The customer herein consents to and accepts the above products subject to **
** all conditions as set forth on reverse side hereof and the existing **
** contract between the parties. By: AIRGAS **

Quantities received as shown above:

Customer: _____ AIRGAS: _____

JOHN ZINK COMPANY

Airgas

Airgas-Mid South, Inc.
31 N. Peoria
Tulsa, OK 74110
918-834-7331
FAX: 834-8724

CERTIFICATE OF CONFORMANCE

Date : September 8, ~~2009~~ 2010

Supplier Name : Airgas Mid South
Address: 31 N. Peoria
Tulsa, OK 74120

Lot Number:
Product: Industrial Nitrogen, Grade L

Dear Sir,
This is to certify that all Industrial Nitrogen, Grade L, supplied by Airgas Mid-South meets or exceeds the following commodity specifications: Trailer number J-17 delivered on 9-8-2010

Product Specification

Oxygen	< 10 PPM
Purity	> 99.998%
Dew Point	-90°F
Water	< 4PPM

Greg R. Fairclough
Approval Signature

Airgas

Airgas Merchant Gases
1-800-242-0105

01-176 TT

CERTIFICATE OF ANALYSIS
DELIVERY TICKET

87 - 292284

SOLD BY: AMG
Mulberry Av

SHIP TO: ARG
Tulsa, OK

LOT NUMBER 7937N1 0249 19702

Customer Number	Shipping Location No.	SHIPPING DATE MO.	DAY	YR.
1FCWZ		9	6	10

PURCHASE ORDER AND/OR RELEASE NUMBER

SHIPPED VIA: ☒ AIRGAS EQUIP. ☐ OTHER ☐ CUSTOMER EQUIP.

☐ THIS BLOCK MUST BE CHECKED WHEN PRODUCTS OBTAINED AT A NON-AIRGAS PRODUCING FACILITY. (ADDRESS ON FILE)

TRIP REPORT NUMBER	VEHICLE NUMBER
28009401	22393 9702

LIQUID PRODUCTS SHIPPING ORDER

	Min purity:	Results:
☒ **UN 1977, NITROGEN, REFRIGERATED LIQUID, 2.2, GRADE NF** PRODUCED BY AIR LIQUEFACTION; ASSAY BY DIFFERENCE OF OXYGEN, ODOR TEST COMPLETED BY ORGANOLEPTIC METHOD O2 ANALYZER: MFR. Teledyne ; TYPE: Electrochemical ; MODEL: 316 RA CO ANALYZER: MFR. Teledyne ; TYPE: NDIR Infrared ; MODEL: IR7000	≤ 10 ppm ≥ 99.99% ≤ 5 ppm NONE	0.60 ppm CO 99.999 % N2 1.34 ppm O2 None ODOR
☐ UN 1977, NITROGEN, REFRIGERATED LIQUID, 2.2 PRODUCED BY AIR LIQUEFACTION	≤ 10 ppm ≤ 5 ppm NONE	____ ppm CO ____ ppm O2 ____ ODOR
☐ **UN 1073, OXYGEN, REFRIGERATED LIQUID, 2.2, (5.1) GRADE USP** PRODUCED BY AIR LIQUEFACTION; ODOR TEST COMPLETED BY ORGANOLEPTIC METHOD O2 ANALYZER: MFR. ____ ; TYPE: ____ ; MODEL: ____	≥ 99.50% NONE	____ % O2 ____ ODOR
☐ UN 1073 OXYGEN, REFRIGERATED LIQUID, 2.2, (5.1) PRODUCED BY AIR LIQUEFACTION	≥ 99.50% NONE	____ % O2 ____ ODOR
☐ UN 1951, ARGON REFRIGERATED LIQUID, 2.2 PRODUCED BY AIR LIQUEFACTION	≤ 15 ppm ≤ 10 ppm	____ ppm N2 ____ ppm O2
☐ UN 2187, CARBON DIOXIDE, REFRIGERATED, 2.2 ☐ Meets USP requirements ☐ Acceptable for food beverage, not for human drug use.		

	METER DELIVERY	CUSTOMER SCALE DELIVERY
TANK ID # 50639	METER END 1845	WEIGHT IN ____
LEVEL BEFORE 150	METER START 0	WEIGHT OUT ____
LEVEL AFTER 225 T.C.	METER QTY. DLVD. 1845	WEIGHT DLVD. ____

COMMENTS: 171788

This is to certify that the above named materials are properly classified, described, packaged marked and labeled and are in proper condition for transportation according to the applicable regulations of the Department of Transportation.

By AIRGAS MERCHANT GASES

The customer herein consents to and accepts the above products subject to all the conditions as set forth on reverse side here of and the existing conditions between the parties.

QUANTITIES RECEIVED AS SHOWN ABOVE

REVIEWER/CUSTOMER Robert Coffman DATE 9-6-10

SUPPLIER/DRIVER DATE

JOHN ZINK COMPANY

CUSTOMER COPY

Rev (9-09)

Airgas MID SOUTH

Nitrogen Trailer Fill Record

Start Date: 9-7-10 Finish Date: 9-7-10

Water Volume: 743.9 Trailer Number: J-19

Starting Pressure/Temperature: 1600psi 68° Pumper: PW

Ending Pressure/Temperature: 3000 76° Pumper: PW

Total Volume of Nitrogen Pumped: 60,963

Notes On Trailer or System:

DELIVERY ORDER

AIRGAS

For location nearest you, call www.airgas.com

FILED	REVIEWED	STAGING AREA	TOTAL PICKS	TOTAL CYLINDERS SHIP	TOTAL CYLINDERS RET	FREIGHT CHARGES	SHIPPED/DELIVERED VIA			
								POS	ZONE	GW WEIGHT	DECL VALUE $

SOLD BY:
Airgas-Mid South
31 N PEORIA
TULSA OK 74101-1152
(918) 585-2611

SHIP TO:
JOHN ZINK
11920 E APACHE
TULSA OK 74116

P/O NO: NI TT D/S KEYED
REL NO:
SEP 20 2010

SOLD TO:
JOHN ZINK CO

08-Sep-10 12:40PM CRT:TNA2128

INTERNAL USE ONLY
CUST. NO:
ORDER NO:
ORD DATE:
PAGE NO: 1 OF 1

TRANTYPE	SUBM	BRCH	TERR	UPS	PPD	COLL	SHIP VIA	ROUTING	SCHEDULED SHIP DATE	REGION	ENTERED BY
CHRG-DP	106	197		2	0	X	OUR TRUCK	TH13	09/08/10	106	BT

QTY ORDER	QTY SHIP	QTY BACK	UNIT MM	DESCRIPTION & HAZARD CLASS	ID NUMBER	LINE NO	ITEM NUMBER	LOC	QTY ORDER	QTY SHIP	BACK	VOL/UT	UNIT AMOUNT	EXTENDED AMOUNT
1			AH	X NITROGEN, COMPRESSED		2	NI TT		FRE	1		100		
				(NITROGEN TUBE TRAILER FRE CGM/)										
				CUSE Tare # : 1140 LB										
				D/S AL JUMBO TT J-17 & PICK UP A HIKI PER CUST. REQ.										
				ALL SIGNED PINK COPIES OF TICKETS MUST BE										
				user phone number: 918-294-1967										
				Drop JIT WO-143.00										136.50
				PU 532 WO-336.00										620.72
														122.27

SHIPPED BY:

UPS SHIPPER NO.

PKG ID#
00825-00

THIS AGREEMENT SUBJECT TO AIRGAS STANDARD TERMS AND CONDITIONS. SEE REVERSE SIDE FOR IMPORTANT SAFETY INFORMATION.

PLACARDS OFFERED: YES NO

ACCEPTED FOR THE ABOVE CUSTOMER X
NAME
PLEASE PRINT

CUSTOMER MUST INITIAL ABOVE

Emergency Contact: 800-734-3438
(International: call 1-703-527-3887)

Purchaser agrees to notify Airgas Safety Data Sheets (SDS) sent one of the following options. Point of purchase, Airgas Web site at www.airgas.com, or by calling the phone number on the SDS. Contact phone number and specify option #3.

THIS IS TO CERTIFY THAT THE ABOVE MATERIALS ARE PROPERLY CLASSIFIED, DESCRIBED, PACKAGED, MARKED AND LABELED, AND ARE IN PROPER CONDITION FOR TRANSPORTATION, ACCORDING TO THE APPLICABLE REGULATIONS OF THE DEPARTMENT OF TRANSPORTATION.

SHIP TO:
JOHN ZINK
11920 E APACHE
TULSA OK 74116

	CUST	UPS	
NI TT D/S	DS042	00	0

Airgas
Merchant Gases

Certificate of Analysis

All NF Nitrogen delivered by Airgas Merchant Gases, when used in a medical application or by medical customers properly registered with the FDA, is classified as NF Nitrogen

Shipped From:
Airgas Merchant Gases
500 Industrial Park Road
Mulberry, AR 72947
Phone: 479-997-2677

Company Name: **Airgas Merchant Gases**
Product: **Nitrogen, NF**

Product Code: **104009**
Trailer No: **9702**
Tank No: **N1**
Load Date: **9/6/10**

Load No: **1**
Time In: **04:45** Time Out: **5:10**

Tare Weight: **32,460** lbs Gross Weight: **78,780** lbs Net Weight: **46,320** lbs

Lot Number: **7937 N1 0249 1 9702**

Produced By: **Air Liquefaction**

Assay per NF requirements is by difference of O2 only

	Results	Units	USP / NF Specifications	AMG Specifications
Purity Pre-Fill:	**Pass**		**Pass ***	**Pass ***
Purity Post-Fill: *Assay, By Difference*	**99.999**	%	> = 99.0%	> = 99.999%
O2: *O2 Tested By: Teledyne 316RA Electrochemical*	**1.34**	ppm/V	< = 1.0%	< = 5.0 ppm
CO: *CO Tested By: Teledyne IR 7000 Non-Dispersive Infrared*	**0.60**	ppm/V	< = 10.0 ppm	< = 10.0 ppm
Odor: *Odor Tested By: Organoleptic*	**None**		None	None
Identity: *Identity Tested By: AMG DP 4.2*	**Nitrogen**		Nitrogen	Nitrogen

** The Pre-Fill is tested against AMG and USP / NF specifications and a Pass indicates that the results met or exceeded the applicable specifications. The results of the Pre-Fill tests are kept on file.*

HAZARDOUS MATERIAL SHIPPING INFORMATION

HM XX Nitrogen, Refrigerated Liquid (Cryogenic Liquid) 2.2 UN1977
Quantity: 46,320 Gallon 6,869 Cubic 839,336

NON-FLAMMABLE GAS
Spill, Leak, Fire, Exposure, or Accident:
Chemical Emergency: Call Chemtrec 800-424-9300

Airgas Analyst: *I declare that this analysis was completed within all AMG policy and procedures and that the product meets all AMG and USP/NF specifications.*

Signed: [signature] Date / Time: 09/06/10 / 05:12

Product Release Specialist / Released By: *I declare that this certificate is accurate, complete and compliant with all applicable policies and procedures and that the product meets all AMG and USP/NF specifications.*

Signed: [signature] Date / Time: 9/6/10 / 0514

Picked Up By: *I declare that I have received the required documentation for shipment of this product and that I have the North American Emergency Response Guide or a MSDS.*

Signed: Robert Coffman Date: 9-6-10 0517

DP 5.4F-2
Revision: 0
Page 1 of 1
09-01-10

Airgas

Airgas-Mid South, Inc.
31 N. Peoria
Tulsa, OK 74110
918-834-7331
FAX: 834-8724

CERTIFICATE OF CONFORMANCE

Date : September 20, ~~2009~~ 2010

Supplier Name : Airgas Mid South
Address: 31 N. Peoria
Tulsa, OK 74120

Lot Number:
Product: Industrial Nitrogen, Grade L

Dear Sir,
This is to certify that all Industrial Nitrogen, Grade L, supplied by Airgas Mid-South meets or exceeds the following commodity specifications: Trailer number 2-10-400 delivered on 9-20-2010

Product Specification

Oxygen	< 10 PPM
Purity	> 99.998%
Dew Point	-90°F
Water	< 4PPM

Greg R. Fairclough
Approval Signature

MO

0wAirgas-Mid South NI TT 17028896676
31 N PEORIA
TULSA OK 74101-1152 DSQ42
[918] 585-2611
435959-00

JOHN ZINK JOHN ZINK CO 09/20/10

11920 E APACHE 001 OF 001
TULSA OK 74116 21-Sep-10 08:54AM CRT:TNA4165

CHRG-DP 106 197 2 0 X OUR TRUCK TH13 09/20/10 106 BCT

4w QTY SHIP	UNIT HM	---------DESCRIPTION--------- & HAZARD CLASS	ID NUMBER	LINE NO	------ITEM------ NUMBER	LOC	QTY ORDER	--CYLINDERS-- SHIP	RETN	VOL/ WT	UNIT AMOUNT	EXTENDED AMOUNT
1 HH	X	UN1066 NITROGEN, COMPRESSED 2.2 (NITROGEN TUBE TRAILER (HH UOM))		2	NI TT	FR3	1			100	1.090	1.09

Cust Item # : 1144716

<<<<<<<<Estimated delivery:09/21>>>>>>>>
JUMBO NI TT D/S 2-10-400/J-17 NO H&R ON 9/20/10

RENTAL PO # FROM 9/1/09 TO 9/30/10 IS 5054473 PART# 1258580
ALL SIGNED PINK COPIES OF TICKETS MUST BE
GIVEN TO CAROL IN FRONT OFFICE OF R&D.

Subtotal	1.09
Tax:	.00
Total Sale	1.09

Customer phone number: 918-234-1967
EMERGENCY CONTACT 1-866-734-3438

435959-00

0w
JOHN ZINK

11920 E APACHE
TULSA OK 74116

NI TT DSQ42 00 0

435959-00 09/20/10 OUR TRUCK -NONE-

MO

Airgas MID SOUTH

Nitrogen Trailer Fill Record

Start Date: 9-20-10 Finish Date: 9-20-10

Water Volume: 767 Trailer Number: 210400

Starting Pressure/Temperature: 1350 @ 74° Pumper: JR.

Ending Pressure/Temperature: 2650 @ 84° Pumper: JR

Total Volume of Nitrogen Pumped: 59 449

Notes On Trailer or System:

DELIVERY ORDER

Airgas.

For location nearest you visit www.airgas.com

DSCH-001 (Rev. 10/07)

	FILLED	REVIEWED	STAGING AREA	TOTAL PKGS	TOTAL CYLINDERS SHP.	RET.	FREIGHT CHARGES	SHIPPED: DELIVERED VIA ON _____ , BL # _____			
ITEM COUNT								PCS	ZONE	GR WEIGHT	DECL VALUE $
BY											

SOLD BY:
Airgas-Mid South
31 N PEORIA
TULSA OK 74101-1152
[918] 585-2611

P/O NO: NI TT

REL NO:

INTERNAL USE ONLY: 17023037180

CUST. NO: DSQ42

ORDER NO: 435959-00

ORD DATE: 09/20/10

PAGE NO: 001 OF 001

SHIP TO:
JOHN ZINK

11920 E APACHE
TULSA OK 74116

SOLD TO:
JOHN ZINK CO

20-Sep-10 11:11AM CRT:TNA2156

RAN TYPE	SLSM	BRCH	TERR	UPS	PPD	COLL	SHIP VIA	ROUTING	SCHEDULED SHIP DATE	REGION	ENTERED BY
CHRG-DP	106	197		2	0	X	OUR TRUCK	TH13	09/20/10	106	BCT

QTY SHIP	UNIT MM	DESCRIPTION & HAZARD CLASS	TO NUMBER	LINE NO	ITEM NUMBER	LOC	QTY ORDER	CYLINDERS SHIP	RETN	VOL/ UT	UNIT AMOUNT	EXTENDED AMOUNT
1	MM X	UN1066 NITROGEN, COMPRESSED 2.2 (NITROGEN TUBE TRAILER (MM UOM))	2	NI TT		FR3	1			100		

Cust Item # : 1144716

<<<<<<<<Estimated delivery:09/21>>>>>>>>
JUMBO NI TT D/S 2-10-400/J-17 NO M&R ON 9/20/10

RENTAL PO # FROM 9/1/09 TO 9/30/10 IS 5054473 PART# 1258580
ALL SIGNED PINK COPIES OF TICKETS MUST BE
GIVEN TO CAROL IN FRONT OFFICE OF R&D.

Customer phone number: 918-234-1967
EMERGENCY CONTACT 1-866-734-3438

w/V
J-17-OUT 743.9 300080
210400 IN 767.0 2400

SENT TO ACCT.
9-20-10

ENTERED
9-20-10

SHIPPED BY:

UPS SHIPPER NO.

PKG ID# 435959-00

SHIP TO:
JOHN ZINK

11920 E APACHE
TULSA OK 74116

PO.	CUST.	UPS
NI TT	DSQ42	00 0

ORDER	DATE	SHIP VIA
435959-00	09/20/10	OUR TRUCK -NONE-

THIS AGREEMENT SUBJECT TO AIRGAS' STANDARD TERMS AND CONDITIONS. SEE REVERSE SIDE FOR IMPORTANT SAFETY INFORMATION.

PLACARDS OFFERED
ACCEPT REJECT
CUSTOMER MUST INITIAL CHOICE

ACCEPTED FOR THE ABOVE CUSTOMER X _____

NAME PLEASE PRINT Leon Longacre

Emergency Contact/ 866-734-3438
(International - call: 1-703-527-3887)

Purchaser agrees to obtain Material Safety Data Sheets (MSDS) from one of the following sources; Point of purchase, Airgas Web site at <www.airgas.com>, or by calling the above listed emergency contact phone number and selecting option #3.

THIS IS TO CERTIFY THAT THE NAMED MATERIALS ARE PROPERLY CLASSIFIED, DESCRIBED, PACKAGED, MARKED AND LABELED AND ARE IN PROPER CONDITION FOR TRANSPORTATION ACCORDING TO THE APPLICABLE REGULATIONS OF THE DEPARTMENT OF TRANSPORTATION.

AIRGAS PERSONNEL | DATE | T.O.D.

JOHN ZINK COMPANY

Certificate of Analysis

All NF Nitrogen delivered by Airgas Merchant Gases, when used in a medical application or by medical customers properly registered with the FDA, is classified as NF Nitrogen

Shipped From:
Airgas Merchant Gases
500 Industrial Park Road
Mulberry, AR 72947
Phone: 479-997-2677

Company Name: Airgas Merchant Gases

Product: Nitrogen, NF

Product Code: 104009

Trailer No: 9701

Tank No: N1

Load No: 2

Time In: 10:06 Time Out: 10:29

Load Date: 9/19/10

Tare Weight: 32,320 lbs Gross Weight: 78,780 lbs

Net Weight: 46,460 lbs

Lot Number: 7937 N1 0262 2 9701

Produced By: Air Liquefaction

Assay per NF requirements is by difference of O2 only

	Results	Units	USP / NF Specifications	AMG Specifications
Purity Pre-Fill:	Pass		Pass *	Pass *
Purity Post-Fill:	≥ 99.999	%	> = 99.0%	> = 99.999%
Assay, By Difference				
O2:	0.54	ppm/V	< = 1.0%	< = 5.0 ppm
O2 Tested By: Teledyne 316RA Electrochemical				
CO:	0.40	ppm/V	< = 10.0 ppm	< = 10.0 ppm
CO Tested By: Teledyne IR 7000 Non-Dispersive Infrared				
Odor:	None		None	None
Odor Tested By: Organoleptic				
Identity:	Nitrogen		Nitrogen	Nitrogen
Identity Tested By: AMG DP 4.2				

** The Pre-Fill is tested against AMG and USP / NF specifications and a Pass indicates that the results met or exceeded the applicable specifications. The results of the Pre-Fill tests are kept on file.*

HAZARDOUS MATERIAL SHIPPING INFORMATION

HM XX Nitrogen, Refrigerated Liquid (Cryogenic Liquid) 2.2 UN1977

Quantity: 47,780 Gallon 7,086 Cubic 659,488

NON-FLAMMABLE GAS

Spill, Leak, Fire, Exposure, or Accident:

Chemical Emergency: Call Chemtrec 800-424-9300

Airgas Analyst: *I declare that this analysis was completed within all AMG policy and procedures and that the product meets all AMG and USP/NF specifications.*

Signed: [signature] Date / Time: 9-19-10 / 1032

Product Release Specialist / Released By: *I declare that this certificate is accurate, complete and compliant with all applicable policies and procedures and that the product meets all AMG and USP/NF specifications.*

Signed: [signature] Date / Time: 9-19-10 / 10:33

Picked Up By: *I declare that I have received the required documentation for shipment of this product and that I have the North American Emergency Response Guide or a MSDS.*

Signed: Billy N. Kelly Date: 9-19-10

DP 5.4F-2
Revision: 0
Page 1 of 1
09-01-10

JOHN ZINK COMPANY

Airgas

03-176-TT

AIRGAS MERCHANT GASES
500 Industrial Park Drive
Mulberry AR 72947
Ship to: ARG/TULSA E 56TH 918 376 4559
9741 E 56TH ST N
TULSA OKLAHOMA 74117

DELIVERY TICKET
Delivery no: 86639092
Date: 9/19/10

Purchase order and/or release

Customer no	Trip number	Vehicle number	Billing unit
000001FCWX	28009564	22387P / 9701P	gl

[ ] Indicate with an "X" if product is obtained at facility other than Airgas (address on file)

Lot Number: 7937N10262 2 9701

Product: UN 1977, NITROGEN, REFRIGERATED LIQUID, 2.2 PRODUCT GRADE ON COA

LIST OF TANKS AT DISTRIBUTION POINT

Tank#	DP name	Capacity	Lev.bef	Lev.aft	Qty
50639	ARG/TULSA E 56TH ST	5700 gl	104	205	2422

Meter delivery (Gallons)
Meter end: 2422
Meter start: 0
Meter qty dlvd: 2422

Customer scale delivery (LBS)
Weight in:
Weight out:
Weight dlvd:

Notes / Comments: 225512

This is to certify that above named materials are properly classified, described, marked and labeled and are in proper condition for transportation according to applicable regulations of the Department of Transportation. The customer herein consents to and accepts the above products subject to all conditions as set forth on reverse side hereof and the existing contract between the parties.

Quantities received as shown:

Supplier/Driver Billy N. Kelly Date 9-19-10 Customer THANK YOU JOHN ZINK COMPANY Date 9-19-10

Airgas

Airgas-Mid South, Inc.
31 N. Peoria
Tulsa, OK 74110
918-834-7331
FAX: 834-8724

CERTIFICATE OF CONFORMANCE

Date : September 20, ~~2009~~ 2010

Supplier Name : Airgas Mid South
Address: 31 N. Peoria
Tulsa, OK 74120

Lot Number:
Product: Industrial Nitrogen, Grade L

Dear Sir,
This is to certify that all Industrial Nitrogen, Grade L, supplied by Airgas Mid-South meets or exceeds the following commodity specifications: Trailer number J-17 delivered on 9-20-2010

Product Specification

Oxygen	< 10 PPM
Purity	> 99.998%
Dew Point	-90°F
Water	< 4PPM

Greg R. Fairclough
Approval Signature

DELIVERY ORDER

Airgas

For location nearest you visit
www.airgas.com

DELCF-001 (Rev. 10/07)

	FILLED	REVIEWED	STAGING AREA	TOTAL PKGS	TOTAL CYLINDERS SHP.	REL.	FREIGHT CHARGES	SHIPPED: DELIVERED VIA ON _____ BL # _____			
ITEM COUNT								PCS	ZONE	GR WEIGHT	DECL VALUE $
BY											

SOLD BY:
Airgas NAT South
21 N PERSIA
TULSA OK 74103 1-52
(918) 585 2611

P/O NO: [illegible]

INTERNAL USE ONLY: [illegible]

CUST. NO: 05042

REL NO:

ORDER NO: 434411-00

SHIP TO:
JOHN ZINK
11920 E APACHE
TULSA OK 74116

SOLD TO: [illegible]

ORD DATE: 09/21/10

PAGE NO: 001 OF 001

TRAN TYPE	SLSM	BRCH	TERR	UPS	FPD	COLL	SHIP VIA	ROUTING	SCHEDULED SHIP DATE	REGION	ENTERED BY
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

ITEM	DESCRIPTION	ORDERED	SHIPPED	B.O.	UNIT PRICE	EXTENSION
[illegible]	[illegible] AUTOCLAVE, CORROSSED 22 (AUTOCLAVE HOSE TRAILER (AH HOG))	2	1	[illegible]	[illegible]	

Cost Item [illegible]

Estimated delivery 09/22
DELV AT 11 (07/AS-FOR-PLACE 308)

[illegible] PO [illegible] 9/30/10 [illegible]
ALL SIGNED PINK COPIES OF TICKETS MUST BE
GIVEN TO CREW [illegible]
Customer phone number: 918 234 1967
[illegible] 1-866-734-3438

Reg [illegible]
[illegible]
2750-70°F

SENT TO ACCT.
9-21-10

ENTERED
9-21-10

SHIPPED BY:

UPS SHIPPER NO.

PKG ID# [illegible]

SHIP TO: JOHN ZINK
11920 E APACHE
TULSA OK 74116

P.O. [illegible]	CUST. 05042	UPS [illegible]

ORDER [illegible]	DATE [illegible]	SHIP VIA [illegible]

THIS AGREEMENT SUBJECT TO AIRGAS' STANDARD TERMS AND CONDITIONS. SEE REVERSE SIDE FOR IMPORTANT SAFETY INFORMATION.

PLACARDS OFFERED
ACCEPT REJECT
CUSTOMER MUST INITIAL CHOICE

ACCEPTED FOR THE ABOVE CUSTOMER X _____
NAME PLEASE PRINT _____

Emergency Contact: 866-734-3438
(International - call: 1-703-527-3887)

Purchaser agrees to obtain Material Safety Data Sheets (MSDS) from one of the following sources; Point of purchase, Airgas Web site at <www.airgas.com>, or by calling the above listed emergency contact phone number and selecting option #3.

THIS IS TO CERTIFY THAT THE NAMED MATERIALS ARE PROPERLY CLASSIFIED, DESCRIBED, PACKAGED, MARKED AND LABELED AND ARE IN PROPER CONDITION FOR TRANSPORTATION ACCORDING TO THE APPLICABLE REGULATIONS OF THE DEPARTMENT OF TRANSPORTATION.

AIRGAS PERSONNEL | DATE | T.O.D.

JOHN ZINK COMPANY

Airgas MID SOUTH

Nitrogen Trailer Fill Record

Start Date: 9-20-10 Finish Date: 9-20-10

Water Volume: 743.9 Trailer Number: J-17

Starting Pressure/Temperature: 300 @ 84 Pumper: E.

Ending Pressure/Temperature: 2900 @ 84 Pumper: JR

Total Volume of Nitrogen Pumped: 120,907

Notes On Trailer or System:

Holly Refinery

Airgas

Airgas-Mid South, Inc.
31 N. Peoria
Tulsa, OK 74110
918-834-7331
FAX: 834-8724

CERTIFICATE OF CONFORMANCE

Date : September 20, ~~2009~~ 2010

Supplier Name : Airgas Mid South
Address: 31 N. Peoria
Tulsa, OK 74120

Lot Number:
Product: Industrial Nitrogen, Grade L

Dear Sir,
This is to certify that all Industrial Nitrogen, Grade L, supplied by Airgas Mid-South meets or exceeds the following commodity specifications: Trailer number J-22 delivered on 9-20-2010

Product Specification

Oxygen	< 10 PPM
Purity	> 99.998%
Dew Point	-90°F
Water	< 4PPM

Greg R. Fairclough
Approval Signature

0wAirgas-Mid South NI TT 17028898946
31 N PEORIA
TULSA OK 74101-1152 DSQ42
[918] 585-2611
438401-00

JOHN ZINK JOHN ZINK CO 09/20/10

11920 E APACHE 001 OF 001
TULSA OK 74116 21-Sep-10 08:55AM CRT:TNA4165

CHRG-DP 106 197 2 0 X OUR TRUCK TH13 09/20/10 106 JAS

4w QTY SHIP	UNIT HM	---------DESCRIPTION--------- & HAZARD CLASS	ID NUMBER	LINE NO	------ITEM------ NUMBER	LOC	QTY ORDER	--CYLINDERS-- SHIP	RETN	VOL/ WT	UNIT AMOUNT	EXTENDED AMOUNT
1 HH	X	UN1066 NITROGEN, COMPRESSED 2.2 (NITROGEN TUBE TRAILER (HH UOM))		2	NI TT	FR3	1			100		

Cust Item # : 1144716

<<<<<<<<Estimated delivery:09/21>>>>>>>>
TAKE TRLR # J22 TO ZINK, DELV 9/20/10 5-6PM

RENTAL PO # FROM 9/1/09 TO 9/30/10 IS 5054473 PART# 1258580
ALL SIGNED PINK COPIES OF TICKETS MUST BE
GIVEN TO CAROL IN FRONT OFFICE OF R&D.

Customer phone number: 918-234-1967
EMERGENCY CONTACT 1-866-734-3438

438401-00

0w
JOHN ZINK

11920 E APACHE
TULSA OK 74116

NI TT DSQ42 00 0

438401-00 09/20/10 OUR TRUCK -NONE-

MO

DELIVERY ORDER

Airgas.

For location nearest you visit www.airgas.com

DSLCF-001 (Rev. 10/07)

	FILLED	REVIEWED	STAGING AREA	TOTAL PKGS	TOTAL CYLINDERS SHP.	TOTAL CYLINDERS REF.	FREIGHT CHARGES	SHIPPED: DELIVERED VIA ON _____, BL # _____			
ITEM COUNT								PCS	ZONE	GR WEIGHT	DECL VALUE $
BY											

SOLD BY: AIRGAS USA LLC
TUL M, OK

P/O NO:

REL NO:

SHIP TO: JOHN ZINK
TULSA, OK.
74110

SOLD TO:

INTERNAL USE ONLY

CUST. NO: D5R-10

ORDER NO:

ORD DATE: 9-30-10

PAGE NO:

TRAN TYPE	SLSM	BRCH	TERR	UPS	PPD	COLL	SHIP VIA	ROUTING	SCHEDULED SHIP DATE	REGION	ENTERED BY

NITROGEN CONVERTER 50-M

TRL 3-22 IN
3100 # +/

TRL 3-100 OUT
3000 # +/

ENTERED
9-20-10

SENT TO ACCT.
9-20-10

SHIPPED BY:

UPS SHIPPER NO.

PKG ID#

SHIP TO:

THIS AGREEMENT SUBJECT TO AIRGAS' STANDARD TERMS AND CONDITIONS. SEE REVERSE SIDE FOR IMPORTANT SAFETY INFORMATION.

PLACARDS OFFERED
ACCEPT REJECT
CUSTOMER MUST INITIAL CHOICE

ACCEPTED FOR THE ABOVE CUSTOMER X _____

NAME PLEASE PRINT _____

Emergency Contact: 866-734-3438
(International - call: 1-703-527-3887)

Purchaser agrees to obtain Material Safety Data Sheets (MSDS) from one of the following sources; Point of purchase, Airgas Web site at <www.airgas.com>, or by calling the above listed emergency contact phone number and selecting option #3.

THIS IS TO CERTIFY THAT THE NAMED MATERIALS ARE PROPERLY CLASSIFIED, DESCRIBED, PACKAGED, MARKED AND LABELED AND ARE IN PROPER CONDITION FOR TRANSPORTATION ACCORDING TO THE APPLICABLE REGULATIONS OF THE DEPARTMENT OF TRANSPORTATION.

P.O.	CUST.	UPS

ORDER	DATE	SHIP VIA

AIRGAS PERSONNEL | DATE | T.O.D.

JOHN ZINK COMPANY

Airgas AIRGAS MERCHANT GASES
500 Industrial Park Drive
Mulberry AR 72947

01

CERTIFICATE OF ANALYSIS
DELIVERY TICKET
Delivery no: 86550002
Date: 4/27/10

Ship to: ARG/TULSA E 56TH 918.376.4559
9741 E 56TH ST N
TULSA OKLAHOMA 74117

50639

___ Indicate with an "X" if product is obtained at other than Airgas facility (address on file)

Purchase order and/or release

Customer no	Trip number	Vehicle number	Billing unit	Lot Number
000001FCWX	28007787	22384P / 53397P	gl	ZA-117-10-17N-G

Product: UN 1977, NITROGEN, REFRIGERATED LIQUID, 2.2

PRODUCED BY AIR LIQUEFACTION

REPORT OF ANALYSIS (Analyst signature on file)

Component	Op	Value	Unit	Analysis required	Result
CO	<=	10	PPM	Yes	0.0 PPM
O2	<=	5	PPM	Yes	0.45 PPM
Odor	=	0	None	Yes	None

LIST OF TANKS AT DISTRIBUTION POINT

Tank#	DP name	Capacity	Lev.bef	Lev.aft	Qty
50639	ARG/TULSA E 56TH ST	5700 gl	0	243	6000

Meter delivery (Gallons)
Meter end: 6000
Meter start: 0
Meter qty dlvd: 6000

Customer scale delivery (LBS)
Weight in:
Weight out:
Weight dlvd:

Notes / Comments: 558,660

Received 4-27-10 2:30PM

This is to certify that above named materials are properly classified, described, marked and labeled and are in proper condition for transportation according to applicable regulations of the Department of Transportation. The customer herein consents to and accepts the above products subject to all conditions as set forth on reverse side hereof and the existing contract between the parties.

Quantities received as shown:

Supplier/Driver [signature] Date 27 Apr 10 Customer Clyde Maples Date

JOHN ZINK COMPANY

Airgas

Airgas-Mid South, Inc.
31 N. Peoria
Tulsa, OK 74110
918-834-7331
FAX: 834-8724

CERTIFICATE OF CONFORMANCE

Date : September 20, ~~2009~~ 2010

Supplier Name : Airgas Mid South
Address: 31 N. Peoria
Tulsa, OK 74120

Lot Number:
Product: Industrial Nitrogen, Grade L

Dear Sir,
This is to certify that all Industrial Nitrogen, Grade L, supplied by Airgas Mid-South meets or exceeds the following commodity specifications: Trailer number T-75 delivered on 9-20-2010

Product Specification

Oxygen	< 10 PPM
Purity	> 99.998%
Dew Point	-90°F
Water	< 4PPM

Greg R. Fairclough
Approval Signature

0wAirgas-Mid South NI TT 17028897765
31 N PEORIA
TULSA OK 74101-1152 DSQ42
[918] 585-2611
437580-00

JOHN ZINK JOHN ZINK CO 09/20/10

11920 E APACHE 001 OF 001
TULSA OK 74116 21-Sep-10 08:54AM CRT:TNA4165

CHRG-DP 106 197 2 0 X OUR TRUCK TH13 09/20/10 106 JAS

4w QTY SHIP	UNIT HM	---------DESCRIPTION--------- & HAZARD CLASS	ID NUMBER	LINE NO	------ITEM------ NUMBER	LOC	QTY ORDER	--CYLINDERS-- SHIP	RETN	VOL/ WT	UNIT AMOUNT	EXTENDED AMOUNT
1 HH	X	UN1066 NITROGEN, COMPRESSED 2.2 (NITROGEN TUBE TRAILER (HH UOM))		2	NI TT	FR3	1			100		

Cust Item # : 1144716

<<<<<<<<Estimated delivery:09/21>>>>>>>>
NI TT D/S T75/I29 DELVD 9/20/10

RENTAL PO # FROM 9/1/09 TO 9/30/10 IS 5054473 PART# 1258580
ALL SIGNED PINK COPIES OF TICKETS MUST BE
GIVEN TO CAROL IN FRONT OFFICE OF R&D.

Customer phone number: 918-234-1967
EMERGENCY CONTACT 1-866-734-3438

437580-00

0w
JOHN ZINK

11920 E APACHE
TULSA OK 74116

NI TT DSQ42 00 0

437580-00 09/20/10 OUR TRUCK -NONE-

Airgas MID SOUTH

Nitrogen Trailer Fill Record

Start Date: 9-20-10 Finish Date: 9-20-10

Water Volume: 334.9 Trailer Number: T-75

Starting Pressure/Temperature: 72 @ 455psi Pumper: E.

Ending Pressure/Temperature: 2450 86 Pumper: MB

Total Volume of Nitrogen Pumped: 42,212

Notes On Trailer or System:

DELIVERY ORDER

Airgas.

For location nearest you visit www.airgas.com

DELCF-001 (Rev. 10/07)

	FILLED	REVIEWED	STAGING AREA	TOTAL PKGS	TOTAL CYLINDERS SHP	TOTAL CYLINDERS REL	FREIGHT CHARGES	SHIPPED: DELIVERED VIA ON _____, BL # _____			
ITEM COUNT								PCS	ZONE	GR WEIGHT	DECL VALUE $
BY											

SOLD BY: AIRGAS-MID SOUTH TULSA, OK

P/O NO:

REL NO:

INTERNAL USE ONLY

CUST. NO: DSQ642

ORDER NO: 9-20-10

ORD DATE:

PAGE NO:

SHIP TO: JOHN ZINK TULSA, OK R&D

SOLD TO:

RAN TYPE	SLSM	BRCH	TERR	UPS	PPD	COLL	SHIP VIA	ROUTING	SCHEDULED SHIP DATE	REGION	ENTERED BY

NITROGEN - COMPRESSED
W/V
T-75 - IN 334.9 2600@88
I 29 OUT 278.8 300@88

SENT TO ACCT.
9-20-10

ENTERED
9-20-10

SHIPPED BY:

UPS SHIPPER NO.

PKG ID#

SHIP TO:

THIS AGREEMENT SUBJECT TO AIRGAS' STANDARD TERMS AND CONDITIONS. SEE REVERSE SIDE FOR IMPORTANT SAFETY INFORMATION.

PLACARDS OFFERED
ACCEPT REJECT
CUSTOMER MUST INITIAL CHOICE

ACCEPTED FOR THE ABOVE CUSTOMER X

NAME PLEASE PRINT

Emergency Contact: 866-734-3438
(International - call: 1-703-527-3887)

Purchaser agrees to obtain Material Safety Data Sheets (MSDS) from one of the following sources; Point of purchase, Airgas Web site at <www.airgas.com>, or by calling the above listed emergency contact phone number and selecting option #3.

THIS IS TO CERTIFY THAT THE NAMED MATERIALS ARE PROPERLY CLASSIFIED, DESCRIBED, PACKAGED, MARKED AND LABELED AND ARE IN PROPER CONDITION FOR TRANSPORTATION ACCORDING TO THE APPLICABLE REGULATIONS OF THE DEPARTMENT OF TRANSPORTATION.

D.	CUST.	UPS

RDER	DATE	SHIP VIA

AIRGAS PERSONNEL | DATE | T.O.D.

JOHN ZINK COMPANY

Certificate of Analysis

All NF Nitrogen delivered by Airgas Merchant Gases, when used in a medical application or by medical customers properly registered with the FDA, is classified as NF Nitrogen

Shipped From:
Airgas Merchant Gases
500 Industrial Park Road
Mulberry, AR 72947
Phone: 479-997-2677

Company Name: Airgas Merchant Gases

Product: Nitrogen, NF

Product Code: 104009

Trailer No: 9701

Tank No: N1

Load No: 2

Time In: 10:06 Time Out: 10:29

Load Date: 9/19/10

Tare Weight: 32,320 lbs Gross Weight: 78,780 lbs Net Weight: 46,460 lbs

Lot Number: 7937 N1 0262 2 9701

Produced By: Air Liquefaction

Assay per NF requirements is by difference of O2 only

	Results	Units	USP / NF Specifications	AMG Specifications
Purity Pre-Fill:	Pass		Pass *	Pass *
Purity Post-Fill:	≥99.999	%	> = 99.0%	> = 99.999%
Assay, By Difference				
O2:	0.54	ppm/V	< = 1.0%	< = 5.0 ppm
O2 Tested By: Teledyne 316RA Electrochemical				
CO:	0.40	ppm/V	< = 10.0 ppm	< = 10.0 ppm
CO Tested By: Teledyne IR 7000 Non-Dispersive Infrared				
Odor:	None		None	None
Odor Tested By: Organoleptic				
Identity:	Nitrogen		Nitrogen	Nitrogen
Identity Tested By: AMG DP 4.2				

** The Pre-Fill is tested against AMG and USP / NF specifications and a Pass indicates that the results met or exceeded the applicable specifications. The results of the Pre-Fill tests are kept on file.*

HAZARDOUS MATERIAL SHIPPING INFORMATION

HM XX Nitrogen, Refrigerated Liquid (Cryogenic Liquid) 2.2 UN1977

Quantity: 47,780 Gallon 7,086 Cubic 659,488

NON-FLAMMABLE GAS

Spill, Leak, Fire, Exposure, or Accident:

Chemical Emergency: Call Chemtrec 800-424-9300

Airgas Analyst: *I declare that this analysis was completed within all AMG policy and procedures and that the product meets all AMG and USP/NF specifications.*

Signed: [signature] Date / Time: 9-19-10 / 1032

Product Release Specialist / Released By: *I declare that this certificate is accurate, complete and compliant with all applicable policies and procedures and that the product meets all AMG and USP/NF specifications.*

Signed: [signature] Date / Time: 9-19-10 / 10:33

Picked Up By: *I declare that I have received the required documentation for shipment of this product and that I have the North American Emergency Response Guide or a MSDS.*

Signed: Billy N. Kelly Date: 9-19-10

DP 5.4F-2
Revision: 0
Page 1 of 1
09-01-10

Airgas

03-176-TT

AIRGAS MERCHANT GASES
500 Industrial Park Drive
Mulberry AR 72947

DELIVERY TICKET
Delivery no: 86639092
Date: 9/19/10

Ship to: ARG/TULSA E 56TH 918.376.4559
9741 E 56TH ST N
TULSA OKLAHOMA 74117

Purchase order and/or release

Customer no	Trip number	Vehicle number	Billing unit
000001FCWX	28009564	22387P / 9701P	gl

[ ] Indicate with an "X" if product is obtained at facility other than Airgas (address on file)

Lot Number: 7937N1 026229701

Product: UN 1977, NITROGEN, REFRIGERATED LIQUID, 2.2 PRODUCT GRADE ON COA

LIST OF TANKS AT DISTRIBUTION POINT

Tank#	DP name	Capacity	Lev.bef	Lev.aft	Qty
50639	ARG/TULSA E 56TH ST	5700 gl	104	205	2422

Meter delivery (Gallons)
Meter end: 2422
Meter start: 0
Meter qty dlvd: 2422

Customer scale delivery (LBS)
Weight in:
Weight out:
Weight dlvd:

Notes / Comments: 225512

This is to certify that above named materials are properly classified, described, marked and labeled and are in proper condition for transportation according to applicable regulations of the Department of Transportation. The customer herein consents to and accepts the above products subject to all conditions as set forth on reverse side hereof and the existing contract between the parties.

Quantities received as shown:

Supplier/Driver Billy D. Kell Date 9-19-10 Customer THANK YOU Date 9-19-10

JOHN ZINK COMPANY

Airgas

Airgas-Mid South, Inc.
31 N. Peoria
Tulsa, OK 74110
918-834-7331
FAX: 834-8724

CERTIFICATE OF CONFORMANCE

Date : September 21, ~~2009~~ 2010

Supplier Name : Airgas Mid South
Address: 31 N. Peoria
Tulsa, OK 74120

Lot Number:
Product: Industrial Nitrogen, Grade L

Dear Sir,
This is to certify that all Industrial Nitrogen, Grade L, supplied by Airgas Mid-South meets or exceeds the following commodity specifications: Trailer number 210-400 delivered on 9-21-2010

Product Specification

Oxygen	< 10 PPM
Purity	> 99.998%
Dew Point	-90°F
Water	< 4PPM

Greg R. Fairclough
Approval Signature

DELIVERY ORDER

Airgas.

For location nearest you visit www.airgas.com

DELCK-001 (Rev. 10/07)

	FILLED	REVIEWED	STAGING AREA	TOTAL PKGS	TOTAL CYLINDERS SHP.	TOTAL CYLINDERS RET.	FREIGHT CHARGES	SHIPPED: DELIVERED VIA ON _____, BL # _____			
ITEM COUNT								PCS	ZONE	GR WEIGHT	DECL VALUE $
BY											

SOLD BY:
Airgas-Mid South
31 N PLOETA
TULSA OK 74101-1152
(918) 585 2611

SHIP TO:
JOHN ZINK
11920 E APACHE
TULSA OK 74116

P/O NO: RT START JOB

REL NO:

SOLD TO: ~~JN ZINK CO~~

21-Sep-10 03:07PM CR1:TNA

INTERNAL USE ONLY: 1/0331467A2

CUST. NO: 05042

ORDER NO: 442021-00

ORD DATE: 09/21/10

PAGE NO: 001 OF 001

TRAN TYPE	SLSM	BRCH	TERR	UPS	PPD	COLL	SHIP VIA	ROUTING	SCHEDULED SHIP DATE	REGION	ENTERED BY
CHRG							TRUCK				

QTY ORD	QTY SHP	DESCRIPTION	UNIT PRICE	EXTENSION
1	1	X GRADE NITROGEN, COMPRESSED 2.2 (NITROGEN TUBE TRAILER (DOT 3AA))	2 EA 11 FR3 1	0.00
		Cust Item # : 1144716		
		Estimated delivery:09/22 D/S NT TT 210400/ ON 9/21/10		
		RENTAL PO # 1808 9/1/08 TO 9/30/10 CS 5054473 PORTE 1258580 ALL SIGNED PINK COPIES OF TICKETS MUST BE GIVEN TO CAROL IN FRONT OFFICE @ RSO.		
		Customer phone number: 918-234-1957 EMERGENCY CONTACT 1-866-734-3438		

SENT TO ACCT.
9-21-10

ENTERED
9-21-10

Full Drop & Swap look mini
Empty
WO 318-400
WO 765.00
2650 c 90 °F
WO 318-400

SHIPPED BY:

UPS SHIPPER NO.

PKG ID# 2021-00

THIS AGREEMENT SUBJECT TO AIRGAS' STANDARD TERMS AND CONDITIONS. SEE REVERSE SIDE FOR IMPORTANT SAFETY INFORMATION.

PLACARDS OFFERED
ACCEPT REJECT
CUSTOMER MUST INITIAL CHOICE

ACCEPTED FOR THE ABOVE CUSTOMER X
NAME PLEASE PRINT

SHIP TO: JOHN ZINK
11920 E APACHE
TULSA OK 74116

Emergency Contact: 866-734-3438
(International - call: 1-703-527-3887)

Purchaser agrees to obtain Material Safety Data Sheets (MSDS) from one of the following sources; Point of purchase, Airgas Web site at <www.airgas.com>, or by calling the above listed emergency contact phone number and selecting option #3.

THIS IS TO CERTIFY THAT THE NAMED MATERIALS ARE PROPERLY CLASSIFIED, DESCRIBED, PACKAGED, MARKED AND LABELED AND ARE IN PROPER CONDITION FOR TRANSPORTATION ACCORDING TO THE APPLICABLE REGULATIONS OF THE DEPARTMENT OF TRANSPORTATION.

P.O. RT START JOB	CUST. 05042	UPS 00 0
ORDER 442021-00	DATE 9/21/10	SHIP VIA TRUCK NONE

AIRGAS PERSONNEL | DATE 9-21-10 | JOHN ZINK COMPANY | T.O.D.

Airgas MID SOUTH

Nitrogen Trailer Fill Record

Start Date: 9-21-10 Finish Date: 9-21-10

Water Volume: 767 Trailer Number: 210-400

Starting Pressure/Temperature: 300 psi 70° Pumper: PW

Ending Pressure/Temperature: 2650 90° Pumper: KD

Total Volume of Nitrogen Pumped: 112,219

Notes On Trailer or System:

Airgas

Airgas-Mid South, Inc.
31 N. Peoria
Tulsa, OK 74110
918-834-7331
FAX: 834-8724

CERTIFICATE OF CONFORMANCE

Date : September 22nd, 2010

Supplier Name : Airgas Mid South
Address: 31 N. Peoria
Tulsa, OK 74120

Lot Number:
Product: Industrial Nitrogen, Grade L

Dear Sir,
This is to certify that all Industrial Nitrogen, Grade L, supplied by Airgas Mid-South meets or exceeds the following commodity specifications: Trailer number 203 delivered on 9-23-2010

Product Specification

Oxygen	< 10 PPM
Purity	> 99.998%
Dew Point	-90°F
Water	< 4PPM

Greg R. Fairclough
Approval Signature

Airgas MID SOUTH

Nitrogen Trailer Fill Record

Start Date: 9-22-10 Finish Date: 9-22-10

Water Volume: 644.3 Trailer Number: 203

Starting Pressure/Temperature: 1300/82 Pumper: PW

Ending Pressure/Temperature: 3000/100 Pumper: KG

Total Volume of Nitrogen Pumped: 61,807

Notes On Trailer or System:

DELIVERY ORDER

Airgas

For location nearest you visit www.airgas.com

DEL-CF-001 (Rev. 10/07)

	FILLED	REVIEWED	STAGING AREA	TOTAL PKGS	TOTAL CYLINDERS SHP.	TOTAL CYLINDERS RET.	FREIGHT CHARGES	SHIPPED: DELIVERED VIA ON _____, BL # _____			
								PCS	ZONE	GR WEIGHT	DECL VALUE $
ITEM COUNT											
BY											

SOLD BY:
Airgas-Mid South
31 N PEORIA
TULSA OK 74101-3162
(918) 585-2611

P/O NO: NE TT

INTERNAL USE ONLY: 17042257400

CUST. NO: 05042

REL NO:

ORDER NO: 447443-00

SHIP TO:
JOHN ZINK

11920 E APACHE
TULSA OK 74116

SOLD TO: JOHN ZINK CO

ORD DATE: 09/23/10

PAGE NO: 001 OF 001

23-Sep-10 07:54AM CRITINA/ZZ

TRAN TYPE	SLSM	BRCH	TERR	UPS	PPD	COLL	SHIP VIA	ROUTING	SCHEDULED SHIP DATE	REGION	ENTERED BY
CHRG	105	117		2			OUR TRUCK	THL3	09/23/	0	110 JAS

QTY ORD	QTY SHP	QTY BO	DESCRIPTION	UNIT PRICE	EXTENSION
1	1	0	2.2 (NITROGEN NOS TRAILER (NH NOM))	100	

Cust Tkt # : 1144716

<<<<<<Estimated delivery:09/24>>>>>>>
DELV O/S 082037 PER REQ1

RENTAL PO # FROM 9/1/09 TO 9/30/10 IS 5094473 PART# 125 6560
ALL SIGNED PINK COPIES OF TICKETS MUST BE
GIVEN TO CARDI IN FRONT OFFICE OF R&D.

Customer phone number: 918-234-1967
EMERGENCY CONTACT 1-866-734-3438

Drop 405 WO-644.3 2800-72°

Pu 422 WO-711.1 490-26°

ENTERED 9-23-10

SENT TO ACCT. 9-23-10

SHIPPED BY:

UPS SHIPPER NO.

PKG ID# 447443-00

SHIP TO: JOHN ZINK

11920 E APACHE
TULSA OK 74116

P.O.	CUST.	UPS
NE TT	05042	00 0

ORDER	DATE	SHIP VIA
447443-00	09/23/10	OUR TRUCK NONE

THIS AGREEMENT SUBJECT TO AIRGAS' STANDARD TERMS AND CONDITIONS. SEE REVERSE SIDE FOR IMPORTANT SAFETY INFORMATION.

PLACARDS OFFERED ☐ ACCEPT ☐ REJECT
CUSTOMER MUST INITIAL CHOICE

ACCEPTED FOR THE ABOVE CUSTOMER X _____
NAME PLEASE PRINT _____

Emergency Contact: 866-734-3438
(International - call: 1-703-527-3887)

Purchaser agrees to obtain Material Safety Data Sheets (MSDS) from one of the following sources; Point of purchase, Airgas Web site at <www.airgas.com>, or by calling the above listed emergency contact phone number and selecting option #3.

THIS IS TO CERTIFY THAT THE NAMED MATERIALS ARE PROPERLY CLASSIFIED, DESCRIBED, PACKAGED, MARKED AND LABELED AND ARE IN PROPER CONDITION FOR TRANSPORTATION ACCORDING TO THE APPLICABLE REGULATIONS OF THE DEPARTMENT OF TRANSPORTATION.

AIRGAS PERSONNEL _____ DATE 9-23-10 T.O.D. _____ JOHN ZINK COMPANY

Airgas
Merchant Gases

Certificate of Analysis

All NF Nitrogen delivered by Airgas Merchant Gases, when used in a medical application or by medical customers properly registered with the FDA, is classified as NF Nitrogen

Shipped From:
Airgas Merchant Gases
500 Industrial Park Road
Mulberry, AR 72947
Phone: 479-997-2677

Company Name: **Airgas Merchant Gases**

Product: **Nitrogen**

Grade: [X] **NF - Medical**
[ ] **Non-Medical**

Product Code: **104009**

Trailer No: 53395

Load Date: 09-22-2010

Lot Number: 53395-09/22/2010-12:57

Produced By: **Air Liquefaction**

Assay per NF requirements is by difference of O2 only

	Results	Units	USP / NF Specifications	AMG Specifications
Purity Pre-Fill:	PASS		Pass *	Pass *
Purity Post-Fill:	99.999	%	>= 99.0%	>= 99.999%
Assay, By Difference				
O2:	0.24	ppm/V	<= 1.0%	<= 5.0 ppm
O2 Tested By: Delta F/FAH0100/Electrochemical *(make / model / methodology)*				
CO:	NA	ppm/V	<= 10.0 ppm	<= 10.0 ppm
CO Tested By: NA *(make / model / methodology)*				
Odor:	NONE		None	None
Odor Tested By: Organoleptic				
Identity:	NONE		Nitrogen	Nitrogen
Identity Tested By: AMG DP 4.2				

** The Pre-Fill is tested against AMG / supplier and USP / NF specifications and a Pass indicated that the results met and exceeded the applicable specifications. The results of the Pre-Fill tests are kept on file.*

Product Receipt: I declare that the product meets all AMG specifications and that all transcribed data is available on file.

Supplier Signature: William Holley

Date: 09-22-2010

DP 5.4F-8
Revision: 0
Page 1 of 1
09-01-10

Airgas

Airgas-Mid South, Inc.
31 N. Peoria
Tulsa, OK 74110
918-834-7331
FAX: 834-8724

CERTIFICATE OF CONFORMANCE

Date : September 29rd, 2010

Supplier Name : Airgas Mid South
Address: 31 N. Peoria
Tulsa, OK 74120

Lot Number:
Product: Industrial Nitrogen, Grade L

Dear Sir,
This is to certify that all Industrial Nitrogen, Grade L, supplied by Airgas Mid-South meets or exceeds the following commodity specifications: Trailer number 210-400 delivered on 9-30-2010

Product Specification

Oxygen	< 10 PPM
Purity	> 99.998%
Dew Point	-90°F
Water	< 4PPM

Greg R. Fairclough
Approval Signature

Airgas MID SOUTH

Nitrogen Trailer Fill Record

Start Date: 9-29-10 Finish Date: 9-29-10

Water Volume: 767 Trailer Number: -210-400

Starting Pressure/Temperature: 500 psi / 68° Pumper: PW

Ending Pressure/Temperature: 2600 / 80° Pumper: PW

Total Volume of Nitrogen Pumped: 101,813

Notes On Trailer or System:

Airgas

07-176TT

AIRGAS MERCHANT GASES
500 Industrial Park Drive
Mulberry AR 72947

DELIVERY TICKET
Delivery no: 86644812
Date: 9/28/10

Ship to: ARG/TULSA E 56TH 918.376.4559
9741 E 56TH ST N
TULSA OKLAHOMA 74117

Purchase order and/or release

Customer no	Trip number	Vehicle number	Billing unit
000001FCWZ	28009661	22392PSL / 9701P	gl

[ ] Indicate with an "X" if product is obtained at facility other than Airgas (address on file)

Lot Number: 7937 111 0271 2 9702

Product: UN 1977, NITROGEN, REFRIGERATED LIQUID, 2.2 PRODUCT GRADE ON COA

LIST OF TANKS AT DISTRIBUTION POINT

Tank#	DP name	Capacity	Inv.bef	Inv aft	Qty
50639	ARG/TULSA E 56TH ST	5700 gl	132	2722	2590

Meter delivery (Gallons)

Meter end: 2590
Meter start: 0
Meter qty dlvd: 2590

Customer scale delivery (LBS)

Weight in:
Weight out:
Weight dlvd.

Notes / Comments: 241155

Thanks

This is to certify that above named materials are properly classified, described, marked and labeled and are in proper condition for transportation according to applicable regulations of the Department of Transportation. The customer herein consents to and accepts the above products subject to all conditions as set forth on reverse side hereof and the existing contract between the parties.

Quantities received as shown:

Supplier/Driver [signature] Date 9/28/10 Customer _____ Date _____

Airgas
Merchant Gases

Certificate of Analysis

All NF Nitrogen delivered by Airgas Merchant Gases, when used in a medical application or by medical customers properly registered with the FDA, is classified as NF Nitrogen

Shipped From:
Airgas Merchant Gases
500 Industrial Park Road
Mulberry, AR 72947
Phone: 479-997-2677

Company Name: **Airgas Merchant Gases**

Product: **Nitrogen, NF**

Product Code: **104009**

Trailer No: **9702**

Load No: **2**

Tank No: **N1**

Time In: **08:04** Time Out: **8:23**

Load Date: **9/28/10**

Tare Weight: **39,520 lbs** Gross Weight: **78,820 lbs**

Net Weight: **39,300 lbs**

Lot Number: **7937 N1 0271 2 9702**

Produced By: **Air Liquefaction**

Assay per NF requirements is by difference of O2 only

	Results	Units	USP / NF Specifications	AMG Specifications
Purity Pre-Fill:	**Pass**		Pass *	Pass *
Purity Post-Fill:	≥ **99.999**	%	> = 99.0%	> = 99.999%
Assay, By Difference				
O2:	**1.27**	ppm/V	< = 1.0%	< = 5.0 ppm
O2 Tested By: Teledyne 316RA Electrochemical				
CO:	**0.80**	ppm/V	< = 10.0 ppm	< = 10.0 ppm
CO Tested By: Teledyne IR 7000 Non-Dispersive Infrared				
Odor:	**None**		None	None
Odor Tested By: Organoleptic				
Identity:	**Nitrogen**		Nitrogen	Nitrogen
Identity Tested By: AMG DP 4.2				

** The Pre-Fill is tested against AMG and USP / NF specifications and a Pass indicates that the results met or exceeded the applicable specifications. The results of the Pre-Fill tests are kept on file.*

HAZARDOUS MATERIAL SHIPPING INFORMATION

HM XX Nitrogen, Refrigerated Liquid (Cryogenic Liquid) 2.2 UN1977

Quantity: 47,820 Gallon 7,092 Cubic 660,040

NON-FLAMMABLE GAS
Spill, Leak, Fire, Exposure, or Accident:
Chemical Emergency: Call Chemtrec 800-424-9300

Airgas Analyst: *I declare that this analysis was completed within all AMG policy and procedures and that the product meets all AMG and USP/NF specifications.*

Signed: _____ Date / Time: 09/28/10 / 08:25

Product Release Specialist / Released By: *I declare that this certificate is accurate, complete and compliant with all applicable policies and procedures and that the product meets all AMG and USP/NF specifications.*

Signed: _____ Date / Time: 9/28/10 / 08:27

Picked Up By: *I declare that I have received the required documentation for shipment of this product and that I have the North American Emergency Response Guide or a MSDS.*

Signed: _____ Date: 9/28/10

DP 5.4F-2
Revision: 0
Page 1 of 1
09-01-10

JOHN ZINK COMPANY

TNG ANALYSIS

J-W Measurement Company

Tulsa, OK
W2.METRONGAS.COM
918-827-5770

Customer	: 035 - JOHN ZINK COMPANY LLC	**Date Sampled**	: 9/15/2010
Station ID	: 03501	**Date Analyzed**	: 9/16/2010
Cylinder ID	: 4794	**Effective Date**	: 10/01/2010
Producer	: JOHN ZINK COMPANY LLC	**Line Pressure**	:
Lease	: NAT TEST	**Cyl Pressure**	: 35.00
Area	: TULSA	**Temp**	: .0
Sampled by	: L WINN	**Cylinder Type**	
Formation	:		

COMPONENT	MOL %	GPM @ 14.696(PSIA)
Methane	93.8225	0.000
Ethane	3.5835	0.956
Propane	0.3447	0.095
Iso-Butane	0.0119	0.004
Normal-Butane	0.0365	0.011
Hexanes++	0.0056	0.002
Nitrogen	1.8457	0.000
Carbon-Dioxide	0.3497	0.000
TOTAL	**100.0000**	**1.068**

Compressibility Factor (Z) @ 14.696 PSIA @ 60 DEG. F = 0.9979

Real Gravity: 0.588 **Ideal Gravity:** 0.586

BTU @ (PSIA)	**@14.65**	**@14.696**	**@14.73**	**@15.025**
GPM	1.065	1.068	1.071	1.092
Ideal BTU Dry	1018.36	1021.56	1023.92	1044.43
Ideal BTU Sat	1000.54	1003.74	1006.10	1026.61
Real BTU Dry	1020.53	1023.74	1026.11	1046.71
Real BTU Sat	1002.95	1006.16	1008.53	1029.13

Comments:

J-W Measurement Company

Tulsa, OK
W2.METRONGAS.COM
918-827-5770

Customer	: 035 - JOHN ZINK COMPANY LLC	**Date Sampled**	: 9/17/2010
Station ID	: 03501	**Date Analyzed**	: 9/20/2010
Cylinder ID	: 4723	**Effective Date**	: 10/01/2010
Producer	: JOHN ZINK COMPANY LLC	**Line Pressure**	:
Lease	: NAT TEST	**Cyl Pressure**	: 34.00
Area	: TULSA	**Temp**	: .0
Sampled by	: L WINN	**Cylinder Type**	
Formation	:		

COMPONENT	MOL %	GPM @ 14.696(PSIA)
Methane	93.7742	0.000
Ethane	3.6694	0.979
Propane	0.3476	0.096
Iso-Butane	0.0141	0.005
Normal-Butane	0.0415	0.013
Normal-Pentane	0.0063	0.002
Hexanes++	0.0085	0.004
Nitrogen	1.8451	0.000
Carbon-Dioxide	0.2932	0.000
TOTAL	**100.0000**	**1.098**

Compressibility Factor (Z) @ 14.696 PSIA @ 60 DEG. F = 0.9979

Real Gravity: 0.588 **Ideal Gravity:** 0.587

BTU @ (PSIA)	**@14.65**	**@14.696**	**@14.73**	**@15.025**
GPM	1.095	1.098	1.100	1.123
Ideal BTU Dry	1020.10	1023.30	1025.67	1046.21
Ideal BTU Sat	1002.25	1005.45	1007.82	1028.36
Real BTU Dry	1022.28	1025.49	1027.87	1048.50
Real BTU Sat	1004.67	1007.88	1010.26	1030.90

Comments:

J-W Measurement Company

Tulsa, OK
W2.METRONGAS.COM
918-827-5770

Customer	: 035 - JOHN ZINK COMPANY LLC	**Date Sampled**	: 9/20/2010
Station ID	: 03501	**Date Analyzed**	: 9/20/2010
Cylinder ID	: 4789	**Effective Date**	: 10/01/2010
Producer	: JOHN ZINK COMPANY LLC	**Line Pressure**	:
Lease	: NAT TEST	**Cyl Pressure**	: 34.00
Area	: TULSA	**Temp**	: .0
Sampled by	: L WINN	**Cylinder Type**	
Formation	:		

COMPONENT	MOL %	GPM @ 14.696(PSIA)
Methane	93.7933	0.000
Ethane	3.5259	0.941
Propane	0.3448	0.095
Iso-Butane	0.0189	0.006
Normal-Butane	0.0488	0.015
Iso-Pentane	0.0053	0.002
Normal-Pentane	0.0068	0.002
Hexanes++	0.0103	0.004
Nitrogen	1.9345	0.000
Carbon-Dioxide	0.3114	0.000
TOTAL	**100.0000**	**1.066**

Compressibility Factor (Z) @ 14.696 PSIA @ 60 DEG. F = 0.9979

Real Gravity: 0.588 **Ideal Gravity:** 0.587

BTU @ (PSIA)	**@14.65**	**@14.696**	**@14.73**	**@15.025**
GPM	1.062	1.066	1.068	1.090
Ideal BTU Dry	1018.41	1021.61	1023.97	1044.48
Ideal BTU Sat	1000.59	1003.79	1006.15	1026.66
Real BTU Dry	1020.57	1023.78	1026.16	1046.75
Real BTU Sat	1002.99	1006.21	1008.58	1029.18

Comments:

JW MEASUREMENT
Chain of Custody Record

Work Order #

Page 1 of 1

Client Name:	JOHN ZINK COMPANY
Address 1:	11920 EAST APACHE
Address 2:	TULSA, OK 74116
Phone:	918-234-1804
Contact:	LEON LONGACRE
Email:	LEON.LONGACRE@JOHNZINK.COM
Project:	
Site Name:	
Site Location:	
Invoice To:	

REQUESTED ANALYSIS

SAMPLE ID	Cylinder#	Gas Analysis - C6 Plus	Gas Analysis - Extended	Liquid Analysis - C6 Plus	Liquid Analysis - Extended	Other	Other	Other	Other
1 03501	4794	X							
2 03501	4801	X							
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

Customer Remarks:

Laboratory Remarks:

SAMPLE COLLECTED BY: [signature] 9-21-10 11:30

WITNESSED BY: [signature] 9-21-10

J-W Measurement Company

Tulsa, OK
W2.METRONGAS.COM
918-827-5770

Customer	: 035 - JOHN ZINK COMPANY LLC	**Date Sampled**	:
Station ID	: 03501	**Date Analyzed**	: 9/21/2010
Cylinder ID	: 4801	**Effective Date**	: 00/00/0000
Producer	: JOHN ZINK COMPANY LLC	**Line Pressure**	:
Lease	: NAT TEST	**Cyl Pressure**	: 40.00
Area	: TULSA	**Temp**	: .0
Sampled by	: L WINN	**Cylinder Type**	
Formation	:		

COMPONENT	MOL %	GPM @ 14.696(PSIA)
Methane	93.8344	0.000
Ethane	3.4991	0.933
Propane	0.3541	0.097
Iso-Butane	0.0170	0.006
Normal-Butane	0.0415	0.013
Iso-Pentane	0.0070	0.003
Normal-Pentane	0.0058	0.002
Hexanes++	0.0145	0.006
Nitrogen	1.8452	0.000
Carbon-Dioxide	0.3814	0.000
TOTAL	**100.0000**	**1.060**

Compressibility Factor (Z) @ 14.696 PSIA @ 60 DEG. F = 0.9979

Real Gravity: 0.588 **Ideal Gravity:** 0.587

BTU @ (PSIA)	**@14.65**	**@14.696**	**@14.73**	**@15.025**
GPM	1.057	1.060	1.063	1.084
Ideal BTU Dry	1018.53	1021.72	1024.09	1044.60
Ideal BTU Sat	1000.70	1003.90	1006.26	1026.77
Real BTU Dry	1020.69	1023.91	1026.28	1046.88
Real BTU Sat	1003.11	1006.33	1008.70	1029.30

Comments:

JW MEASUREMENT
Chain of Custody Record

Work Order #

Page 1 of 1

Client Name:	JOHN ZINK COMPANY
Address 1:	11920 EAST APACHE
Address 2:	TULSA, OK 74116
Phone:	918-234-1804
Contact:	LEON LONGACRE
Email:	LEON.LONGACRE@JOHNZINK.COM
Project:	
Site Name:	
Site Location:	
Invoice To:	

REQUESTED ANALYSIS

SAMPLE ID	Cylinder#	Gas Analysis - C6 Plus	Gas Analysis - Extended	Liquid Analysis - C6 Plus	Liquid Analysis - Extended	Other	Other	Other	Other
1 03501	4696	X							
2 03501	4825	X							
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

Customer Remarks:

Laboratory Remarks:

SAMPLE COLLECTED BY: [illegible signature] 9-22-10 3:40

WITNESSED BY: [illegible signature] 9/22/10

J-W Measurement Company

Tulsa, OK
W2.METRONGAS.COM
918-827-5770

Customer	: 035 - JOHN ZINK COMPANY LLC	**Date Sampled**	: 9/22/2010
Station ID	: 03501	**Date Analyzed**	: 9/23/2010
Cylinder ID	: 4825	**Effective Date**	: 10/01/2010
Producer	: JOHN ZINK COMPANY LLC	**Line Pressure**	:
Lease	: NAT TEST	**Cyl Pressure**	: 40.00
Area	: TULSA	**Temp**	: .0
Sampled by	: L WINN	**Cylinder Type**	
Formation	:		

COMPONENT	MOL %	GPM @ 14.696(PSIA)
Methane	93.7714	0.000
Ethane	3.5098	0.936
Propane	0.3751	0.103
Iso-Butane	0.0185	0.006
Normal-Butane	0.0454	0.014
Iso-Pentane	0.0044	0.002
Hexanes++	0.0079	0.003
Nitrogen	1.9320	0.000
Carbon-Dioxide	0.3324	0.000
TOTAL	**99.9968**	**1.065**

Compressibility Factor (Z) @ 14.696 PSIA @ 60 DEG. F = 0.9979

Real Gravity: 0.588 **Ideal Gravity:** 0.587

BTU @ (PSIA)	**@14.65**	**@14.696**	**@14.73**	**@15.025**
GPM	1.061	1.065	1.067	1.088
Ideal BTU Dry	1018.11	1021.31	1023.67	1044.17
Ideal BTU Sat	1000.29	1003.49	1005.85	1026.35
Real BTU Dry	1020.27	1023.48	1025.86	1046.45
Real BTU Sat	1002.70	1005.91	1008.28	1028.88

Comments:

JW MEASUREMENT
Chain of Custody Record

Work Order #

Page 1 of 1

Client Name:	JOHN ZINK COMPANY
Address 1:	11920 EAST APACHE
Address 2:	TULSA, OK 74116
Phone:	918-234-1804
Contact:	LEON LONGACRE
Email:	LEON.LONGACRE@JOHNZINK.COM
Project:	
Site Name:	
Site Location:	
Invoice To:	

REQUESTED ANALYSIS

SAMPLE ID	Cylinder#	Gas Analysis - C6 Plus	Gas Analysis - Extended	Liquid Analysis - C6 Plus	Liquid Analysis - Extended	Other	Other	Other	Other
1 03501	4818	X							
2 03501	4789	X							
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

Customer Remarks:

Laboratory Remarks:

SAMPLE COLLECTED BY: [illegible] 9-23-10 11:20

WITNESSED BY: [illegible] 9/23/10

J-W Measurement Company

Tulsa, OK
W2.METRONGAS.COM
918-827-5770

Customer	: 035 - JOHN ZINK COMPANY LLC	**Date Sampled**	: 9/23/2010
Station ID	: 03501	**Date Analyzed**	: 9/24/2010
Cylinder ID	: 4818	**Effective Date**	: 10/01/2010
Producer	: JOHN ZINK COMPANY LLC	**Line Pressure**	:
Lease	: NAT TEST	**Cyl Pressure**	: 40.00
Area	: TULSA	**Temp**	: .0
Sampled by	: L WINN	**Cylinder Type**	
Formation	:		

COMPONENT	MOL %	GPM @ 14.696(PSIA)
Methane	93.8128	0.000
Ethane	3.6351	0.970
Propane	0.3681	0.101
Iso-Butane	0.0141	0.005
Normal-Butane	0.0443	0.014
Normal-Pentane	0.0085	0.003
Hexanes++	0.0104	0.004
Nitrogen	1.8115	0.000
Carbon-Dioxide	0.2954	0.000
TOTAL	**100.0000**	**1.097**

Compressibility Factor (Z) @ 14.696 PSIA @ 60 DEG. F = 0.9979

Real Gravity: 0.588 **Ideal Gravity:** 0.587

BTU @ (PSIA)	**@14.65**	**@14.696**	**@14.73**	**@15.025**
GPM	1.093	1.097	1.099	1.121
Ideal BTU Dry	1020.67	1023.87	1026.24	1046.80
Ideal BTU Sat	1002.81	1006.01	1008.38	1028.94
Real BTU Dry	1022.85	1026.07	1028.44	1049.09
Real BTU Sat	1005.23	1008.45	1010.83	1031.47

Comments:

JW MEASUREMENT
Chain of Custody Record

Work Order #

Page 1 of 1

Client Name:	JOHN ZINK COMPANY
Address 1:	11920 EAST APACHE
Address 2:	TULSA, OK 74116
Phone:	918-234-1804
Contact:	LEON LONGACRE
Email:	LEON.LONGACRE@JOHNZINK.COM
Project:	
Site Name:	
Site Location:	
Invoice To:	

REQUESTED ANALYSIS

SAMPLE ID	Cylinder#	Gas Analysis - C6 Plus	Gas Analysis - Extended	Liquid Analysis - C6 Plus	Liquid Analysis - Extended	Other	Other	Other	Other
1 03501	4776	X							
2 03501	4754	X							
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

Customer Remarks:

Laboratory Remarks:

SAMPLE COLLECTED BY: [signature] 9-27-10 11:21

WITNESSED BY: [signature] 9/27/10 11:21

J-W Measurement Company

Tulsa, OK
W2.METRONGAS.COM
918-827-5770

Customer	: 035 - JOHN ZINK COMPANY LLC	**Date Sampled**	: 9/27/2010
Station ID	: 03501	**Date Analyzed**	: 9/27/2010
Cylinder ID	: 4754	**Effective Date**	: 10/01/2010
Producer	: JOHN ZINK COMPANY LLC	**Line Pressure**	:
Lease	: NAT TEST	**Cyl Pressure**	: 40.00
Area	: TULSA	**Temp**	: .0
Sampled by	: L WINN	**Cylinder Type**	
Formation	:		

COMPONENT	MOL %	GPM @ 14.696(PSIA)
Methane	93.6768	0.000
Ethane	3.7635	1.004
Propane	0.3535	0.097
Iso-Butane	0.0178	0.006
Normal-Butane	0.0435	0.014
Iso-Pentane	0.0047	0.002
Normal-Pentane	0.0058	0.002
Hexanes++	0.0053	0.002
Nitrogen	1.8516	0.000
Carbon-Dioxide	0.2772	0.000
Oxygen	0.0004	0.000
TOTAL	**100.0000**	**1.127**

Compressibility Factor (Z) @ 14.696 PSIA @ 60 DEG. F = 0.9979

Real Gravity: 0.588 **Ideal Gravity:** 0.587

BTU @ (PSIA)	**@14.65**	**@14.696**	**@14.73**	**@15.025**
GPM	1.123	1.127	1.129	1.152
Ideal BTU Dry	1021.11	1024.32	1026.69	1047.25
Ideal BTU Sat	1003.25	1006.45	1008.82	1029.38
Real BTU Dry	1023.29	1026.51	1028.89	1049.55
Real BTU Sat	1005.67	1008.89	1011.27	1031.92

Comments:

JW MEASUREMENT
Chain of Custody Record

Work Order #

Page 1 of 1

Client Name:	JOHN ZINK COMPANY
Address 1:	11920 EAST APACHE
Address 2:	TULSA, OK 74116
Phone:	918-234-1804
Contact:	LEON LONGACRE
Email:	LEON.LONGACRE@JOHNZINK.COM
Project:	
Site Name:	
Site Location:	
Invoice To:	

REQUESTED ANALYSIS

SAMPLE ID	Cylinder#	Gas Analysis - C6 Plus	Gas Analysis - Extended	Liquid Analysis - C6 Plus	Liquid Analysis - Extended	Other	Other	Other	Other
1 03501	4691	X							
2 03501	4817	X							
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

Customer Remarks:

Laboratory Remarks:

SAMPLE COLLECTED BY: [illegible] 9-28-10 11:20

WITNESSED BY: [illegible] 9-28-10

J-W Measurement Company

Tulsa, OK
W2.METRONGAS.COM
918-827-5770

Customer	: 035 - JOHN ZINK COMPANY LLC	**Date Sampled**	: 9/28/2010
Station ID	: 03501	**Date Analyzed**	: 9/29/2010
Cylinder ID	: 4817	**Effective Date**	: 10/01/2010
Producer	: JOHN ZINK COMPANY LLC	**Line Pressure**	:
Lease	: NAT TEST	**Cyl Pressure**	: 0.00
Area	: TULSA	**Temp**	: .0
Sampled by	: LWINN	**Cylinder Type**	
Formation	:		

COMPONENT	MOL %	GPM @ 14.696(PSIA)
Methane	93.9737	0.000
Ethane	3.4597	0.923
Propane	0.3896	0.107
Iso-Butane	0.0167	0.005
Normal-Butane	0.0554	0.017
Iso-Pentane	0.0109	0.004
Normal-Pentane	0.0145	0.005
Hexanes++	0.0141	0.006
Nitrogen	1.7470	0.000
Carbon-Dioxide	0.3182	0.000
TOTAL	**100.0000**	**1.068**

Compressibility Factor (Z) @ 14.696 PSIA @ 60 DEG. F = 0.9979

Real Gravity: 0.588 **Ideal Gravity:** 0.587

BTU @ (PSIA)	**@14.65**	**@14.696**	**@14.73**	**@15.025**
GPM	1.065	1.068	1.071	1.092
Ideal BTU Dry	1021.05	1024.26	1026.63	1047.19
Ideal BTU Sat	1003.19	1006.39	1008.76	1029.32
Real BTU Dry	1023.23	1026.45	1028.83	1049.48
Real BTU Sat	1005.61	1008.83	1011.21	1031.86

Comments:

JW MEASUREMENT
Chain of Custody Record

Work Order #

Page 1 of 1

Client Name:	JOHN ZINK COMPANY
Address 1:	11920 EAST APACHE
Address 2:	TULSA, OK 74116
Phone:	918-234-1804
Contact:	LEON LONGACRE
Email:	LEON.LONGACRE@JOHNZINK.COM
Project:	
Site Name:	
Site Location:	
Invoice To:	

REQUESTED ANALYSIS

SAMPLE ID	Cylinder#	Gas Analysis - C6 Plus	Gas Analysis - Extended	Liquid Analysis - C6 Plus	Liquid Analysis - Extended	Other	Other	Other	Other
1 03501	4712	X							
2 03501	4799	X							
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

Customer Remarks:

Laboratory Remarks:

SAMPLE COLLECTED BY: [signature] 9-29-10 11:15

WITNESSED BY: [signature] 9/29/10 11:15 am

J-W Measurement Company

Tulsa, OK
W2.METRONGAS.COM
918-827-5770

Customer	: 035 - JOHN ZINK COMPANY LLC	**Date Sampled**	: 9/29/2010
Station ID	: 03501	**Date Analyzed**	: 9/30/2010
Cylinder ID	: 4799	**Effective Date**	: 10/01/2010
Producer	: JOHN ZINK COMPANY LLC	**Line Pressure**	:
Lease	: NAT TEST	**Cyl Pressure**	: 42.00
Area	: TULSA	**Temp**	: .0
Sampled by	: L WINN	**Cylinder Type**	
Formation	:		

COMPONENT	MOL %	GPM @ 14.696(PSIA)
Methane	93.4638	0.000
Ethane	3.7681	1.005
Propane	0.4759	0.131
Iso-Butane	0.0277	0.009
Normal-Butane	0.0739	0.023
Iso-Pentane	0.0105	0.004
Normal-Pentane	0.0107	0.004
Hexanes++	0.0180	0.008
Nitrogen	1.8332	0.000
Carbon-Dioxide	0.3183	0.000
TOTAL	**100.0000**	**1.184**

Compressibility Factor (Z) @ 14.696 PSIA @ 60 DEG. F = 0.9978

Real Gravity: 0.591 **Ideal Gravity:** 0.590

BTU @ (PSIA)	**@14.65**	**@14.696**	**@14.73**	**@15.025**
GPM	1.180	1.184	1.186	1.210
Ideal BTU Dry	1024.51	1027.72	1030.10	1050.73
Ideal BTU Sat	1006.58	1009.79	1012.17	1032.80
Real BTU Dry	1026.72	1029.95	1032.33	1053.05
Real BTU Sat	1009.03	1012.26	1014.65	1035.38

Comments:

PROPANE ANALYSIS

TULSA REFINING COMPANY, *3333 Southwest Blvd.*, **Tulsa, Oklahoma, 74107, 918-584-5025**

Report Date:

Sample #	AB36845		
Collected on:	**08/31/10**		
Collection Time	**04:45**		
Analyte	**Result**	**Analysis Date**	**Analyst**
RVP	179	08/31/10	BWANZER
CU CORR LPG	1	08/31/10	BWANZER
MOISTURE	PASS	08/31/10	BWANZER
GC WT%		08/31/10	BWANZER
Propylene	0.358	08/31/10	BWANZER
Methane	0.055	08/31/10	BWANZER
Ethane	0.596	08/31/10	BWANZER
Propane	98.918	08/31/10	BWANZER
Isobutane	0.072	08/31/10	BWANZER
Total WT%	99.999	08/31/10	BWANZER
GC LV%		08/31/10	BWANZER
Propylene	0.348	08/31/10	BWANZER
Methane	0.093	08/31/10	BWANZER
Ethane	0.847	08/31/10	BWANZER
Propane	98.648	08/31/10	BWANZER
Isobutane	0.065	08/31/10	BWANZER
Total LV%	100.001	08/31/10	BWANZER
Propane	98.648	08/31/10	BWANZER
Butane & heavier	0.065	08/31/10	BWANZER
S.G. LPG	0.506	08/31/10	BWANZER
API LPG	148	08/31/10	BWANZER
DENSITY @ 60F	4.214	08/31/10	BWANZER
RVP LPG	179.3	08/31/10	BWANZER
MON LPG	97	08/31/10	BWANZER

Matrix = LPG
Holly Sales Terminal
Propane Finished Tank

STR-PROPANE

†

CARBON DIOXIDE ANALYSIS

PRAXAIR

AIRGAS MID SOUTH
31 NORTH PEORIA STREET
TULSA, OK 74120

PRAXAIR, INC.

1-800-PRAXAIR

Praxair Number: 5535676
LIQUID CARBON DIOXIDE

BUSINESS CONFIDENTIAL

Lot Number:	CD	561	092010	TK207	1346
	Product ID	Fill Location	Date (Of Fill)	Trailer Number	Time (Of Fill)

Component	Specification		Analytical Result
ACET	0.2	PPM	<0.05 PPM LDL
APEAR	Normal	-	NORMAL
ASSAY	99.9	%	99.997%
C6H6	20	PPB	<5 PPB LDL
H2O	20	PPM	<0.5 PPM LDL
ODOR	None	-	NONE
TASTE	None	-	NONE
THC	20	PPM	<1.0 PPM LDL
TSULF	0.1	PPM	<0.025 PPM LDL

MEETS AND CONFORMS TO ALL REQUIREMENTS CALLED FOR IN THE ISBT GUIDELINES AND PRAXAIR BEVERAGE SPECS. ASSAY RESULT IS FROM THE BATCH TANK

Daniel J. Kerr
Authorized PRAXAIR Representative

LDL=Lower Detection Limit
of Analyzer
COC-4 - C204

MISCELLANEOUS DOCUMENTS

GUEST LIST

No.	First Name	Last Name	Organization
1	Scott	Herndon	Aerodyne
2	Ed	Fortner	Aerodyne
3	William	Brooks	Aerodyne
4	Jon	Franklin	Aerodyne
5	Ezra	Wood	Aerodyne
6	Jody	Wormhoudt	Aerodyne
7	Berk	Knighton	Montana State Univ.
8	Vincent	Torres	Univ. of Texas
9	Edward	Michel	Univ. of Texas
10	Dave	Allen	Univ. of Texas
11	Pete	Breitenbach	Univ. of Texas
12	Jim	Barufaldi	TRC
13	Jarrod	Hoskinson	TRC
14	Mike	Kearney	TRC
15	Jean-Philippe	Gagnon	Telops
16	Simon	Savary	Telops
17	Russ	Nettles	TCEQ
18	David	Furry	LSI
19	Josh	Furry	LSI
20	Eric	Anderson	LSI
21	Korey	Garcia	LSI
22	Kobey	Garcia	LSI
23	Bob	Spellicey	IMACC
24	Curtis	Laush	IMACC
25	Mark	Sloss	IMACC
26	Eban	Thoma	US EPA
27	Edgar	Thompson	US EPA
28	Brian	Dickens	US EPA
29	Jeffrey	Mercier	Sandia National Laboratory
30	Pajo	Vujkovik-Cvijin	Spectral Sciences
31	Raphael	Panfili	Spectral Sciences
32	Jeremey	Pitz	Air Force
33	Kevin	Gross	Air Force
34	Lucy	Randel	Industry Professionals for Clean Air
35	Steve	Smith	TXOGA
36	Bruce	Davis	TCC
37	Scott	Evans	TXOGA

~~S Vernon Cook 777FCA8244~~ OK

COMPREHENSIVE FLARE STUDY
ATTENDANCE SHEET

Last Name	First Name	Radio Serial No.	9/13	9/14	9/15	9/16	9/17	9/20	9/21	9/22	9/23	9/24	9/27	9/28	9/29	9/30	10/1
Adams	Dustin																
Afflerbach	Neal																
Allen	Dave					✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
Anderson	Eric	[illegible]		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		
Barufaldi	Jim	[illegible]		✓	✓	✓	✓	✓	✓	✓	✓						
Brault	Louis																
Breitenbach	Pete	777FCA8253	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓
Brewer	Ralph																
Brooks	William	[illegible]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Brymer	David																
Craft	Elena																
Dagenais-Pérusse	Yves																
Davis	Bruce				✓	✓	✓										
Dickens	Brian								✓								
Dombrowski	Hugues																
Durrnberger	Cyril																
Edgar	Thomas																
Eldridge	Bruce																
Evans	Scott				✓	✓	✓										
Farley	Vincent																
Fortner	Ed		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					
Franklin	Jon		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Furry	David			✓	✓												
Furry	Josh			✓	✓	✓	✓										
Gagnon	Jean-Philippe	~~777FCA8173~~ OK		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		
Garcia	Korey			✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Garcia	Kobey							✓	✓	✓	✓		✓	✓	✓	✓	✓
Giroux	Jean																
Grey	Peyton																
Gross	Kevin			✓	✓	✓	✓	✓	✓	✓							
Harley	Jacob																
Herndon	Scott		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hoskinson	Jarrod	[illegible]		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		
Janysek	Cody																
Kearney	Mike			✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		
Kimura	Yosuke																
Knighton	Berk		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Laush	Curtis	[illegible]		✓	✓		✓			✓	✓		✓	✓	✓		

R=Radio checked out
O=Radio checked in

CHEN DANIEL
VAID HITESH
SINGH KANWAR

✓ ✓
✓ ✓
✓ ✓

JOHN ZINK COMPANY

COMPREHENSIVE FLARE STUDY
ATTENDANCE SHEET

Last Name	First Name	Radio Serial No.	9/13	9/14	9/15	9/16	9/17	9/20	9/21	9/22	9/23	9/24	9/27	9/28	9/29	9/30	10/1
Lopez	Michael																
MacDonald	Ryan																
McDonald-Buller	Elena																
McGaughey	Gary																
Mercier	Jeffrey		✓	✓	✓	✓	✓				✓	✓					
Michel	Edward	[redacted]	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		
Morphew	James																
Mulvey	Terri																
Murray	David																
Nettles	Russ		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Orwick	Steve																
Panfili	Raphael	[redacted]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					
Pitz	Jeremey	[redacted]		✓	✓	✓		✓	✓	✓							
Randall	Lucy	[redacted]						✓	✓	✓	✓						
Rios	Tim																
Savary	Simon			✓	✓	✓	✓	✓	✓	✓	✓						
Sloss	Mark			✓	✓		✓	✓	✓	✓			✓	✓	✓		
Smith	Denzil																
Smith	Steve	[redacted]											✓	✓	✓		
Spellicey	Bob		!	✓			✓	✓	✓	✓							
Spinhirne	Jarett																
Stanzione	Maria																
Sullivan	Dave																
Thoma	Eban				✓	✓											
Thomas	Jim																
Thompson	Edgar				✓	✓											
Tiemann	Steve																
Torres	Vincent	[redacted]	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Tremblay	Pierre																
Trevino	Jorge																
Tullos	Erin																
Vallières	Alexandre																
Villemaire	André																
Vujkovik-Cvijin	Pajo				✓	✓	✓										
Williams	Dave																
Wood	Ezra		✓	✓	✓	✓	✓										
Wormhoudt	Jody							✓	✓	✓	✓	✓					

Radio Transaction

R=Radio checked out
O=Radio checked in

JOHN ZINK COMPANY

JOHN ZINK

Job No.

For

Page 1 of 2

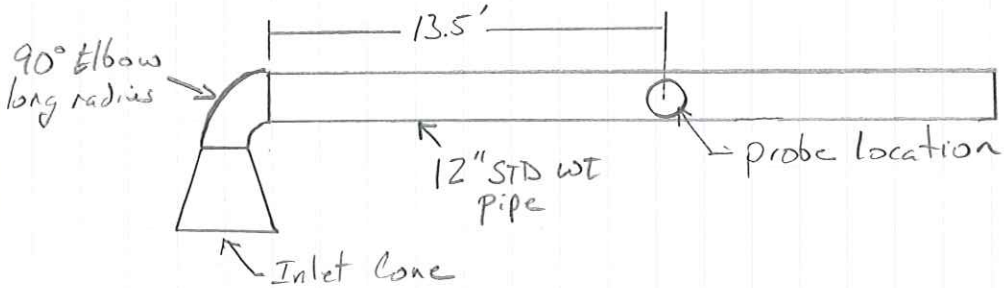
Location

Date 3 Jan 11

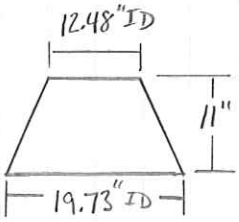
Subject Sample Collector Volume

By ZKC

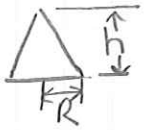
Calculate the volume from the sample collector inlet to the sample collector probe location.



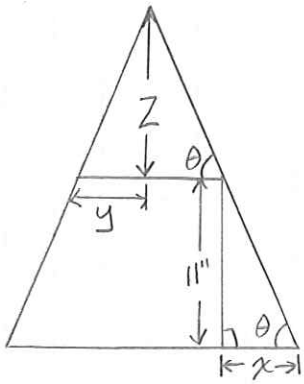
1) Calculate volume of inlet cone



Volume of cone



$= \frac{1}{3}\pi R^2 h$



Calculate θ in order to calculate Z

$x = \frac{19.73 - 12.48}{2} = 3.625''$

$\tan\theta = \frac{11}{3.625} \quad \theta = 71.76°$

$y = \frac{12.48}{2} = 6.24''$

$\tan 71.76 = \frac{Z}{6.24} \quad Z = 18.935$

JOHN ZINK

Job No. _____

For _____ Page 2 of 2

Location _____ Date _____

Subject _____ By _____

Volume of a cone with $R = \frac{19.73}{2} = 9.865''$

and $h = 18.935 + 11 = 29.935$ is:

$$\frac{\pi}{3}(9.865)^2(29.935) = 3050.7 \text{ in}^3$$

Volume of a cone with $R = 6.24$ and $h = 18.935$ is:

$$\frac{\pi}{3}(6.24)^2(18.935) = 772.1 \text{ in}^3$$

Cone volume $= 3050.7 - 772.1 = 2278.6 \text{ in}^3 \Rightarrow \underline{\underline{1.32 \text{ ft}^3}}$

2) Calculate volume of elbow:

90° Elbow, std wt., long radius

Volume: $\frac{2\pi^2 R r^2}{4}$ $r = 6''$ $R = 12''$

Volume $= 2132 \text{ in}^3 \Rightarrow \underline{\underline{1.23 \text{ ft}^2}}$

3) Calculate volume of pipe
12" STD wt. pipe, 13.5' long, ID = 1 ft

$$\frac{\pi(1\text{ft})^2}{4} \times 13.5' = \underline{\underline{10.6 \text{ ft}^3}}$$

4) Sum the three volumes
$1.32 + 1.23 + 10.6 = \boxed{13.15 \text{ ft}^3}$

JOHN ZINK

Job No.

For

Page 1 of 3

Location

Date 3 Jan 11

Subject Transport Time from flow meters to Flare Exit

By ZLK

Steam Flare

Volume between flow meters and flare tip exit = 234 ft^3

Case 1

Fuel Flow = 2342 lb/hr
Fuel Mol. Wt. = 29.7
Fuel Temp. = 80°F
Fuel Press. ≈ Atmospheric (assume 14.36 psia)

Convert flow rate into moles/sec:

$$\frac{2342\ lb/hr}{29.7\ lb/mol} \times \frac{1\ hr}{3600\ SEC} = 0.0219\ \frac{mol}{SEC}$$

Standard temp. = 68°F
Standard Pressure = 14.696 psia

Determine volume of 1 mole of material at standard conditions:

Universal Gas Constant = $1545.3\ \frac{ft\text{-}lb_f}{lb_m\text{-}mole\text{-}°R}$

$$1545.3\ \frac{ft\text{-}lb_f}{lb_m\text{-}mole\text{-}°R} \times \frac{(460+68)°R}{14.696\ lb_f/in^2} \times \frac{ft^2}{144\ in^2} = 385.6\ \frac{ft^3}{lb\ mole}$$

Convert mole flow rate to Standard Cubic Feet (SCF)

$$0.0219\ \frac{moles}{SEC} \times \frac{385.6\ ft^3}{mole} = 8.446\ \frac{SCF}{SEC}$$

JOHN ZINK

Job No.

For

Page 2 of 3

Location

Date

Subject

By

Adjust the volume flow rate to actual pressure and temperature of the gas:

$$8.446 \frac{SCF}{SEC} \times \frac{14.696 \text{ psia}}{14.36 \text{ psia}} \times \frac{(460+80)^\circ R}{(460+68)^\circ R} = 8.84 \frac{ACF}{SEC}$$

ACF = Actual Cubic Foot

$$\text{Time Required to fill } 234 ft^3 = \frac{234 ft^3}{8.84 \frac{ft^3}{SEC}} = \underline{\underline{26.5 \text{ SEC.}}}$$

Case 2)

Fuel Flow = 1850 lb/hr
Fuel Mol. Wt = 29.7
Fuel Temp. = 80°F
Fuel Press = 14.36 psia

$$\text{Time to Fill } 234 ft^3 = \underline{\underline{33.5 \text{ SEC}}}$$

Calculation of transport time from flow meters to TRC fuel sample connection.

Utilize a system volume of $75 ft^3$ for the calc.

Case 1 $\frac{75 ft^3}{8.84 ft^3/SEC} = \underline{\underline{8.5 \text{ SEC}}}$ from flow meters to TRC sample port.

JOHN ZINK

Job No.

For

Page 3 of 3

Location

Date

Subject

By

Air Flare

Volume between flow meters and Flare tip exit = 210 ft^3

Case 1)

Fuel Flow = 937 lb/hr
Fuel Mol. Wt. = 29.7
Fuel Temp. = 80°F
Fuel Press. = 14.36 psia

Time to fill 210 ft^3 = 59.4 SEC

Case 2)

Fuel Flow = 359 lb/hr
Fuel Mol. Wt. = 30.9
Fuel Temp. = 80°F
Fuel Press. = 14.36 psia

Time to fill 210 ft^3 = 161.2 SEC

Calculation of transport time from flow meters to TRC fuel sample connection.

Utilize a system volume of 75 ft^3 for the calc.

Case 1 $\frac{75\ ft^3}{3.57\ ft^3/SEC}$ = 21.2 SEC from flow meters to TRC fuel sample port

JOHN ZINK

Job No.

For

Page 1 of 1

Location

Date 30 Jan 11

Subject Transport Time from Sample Collector Inlet to Probe

By ZLK

Volume from sample collector inlet to sample probe = 13.15 ft^3
(From sample collector volume calc.)

With eductor set to 100%, flow through the sample collector = 1963 ft^3/min (from velocity profile testing)

Time for a particle to travel from the inlet to the sample probe is:

$$\frac{13.15\,ft^3}{1963\,ft^3/min} \times \frac{60\,SEC}{min} = \underline{\underline{0.402\ SEC}}\ (100\%\ \text{Eductor})$$

With the eductor set to 60%, flow through the sample collector = 1420 ft^3/min.

Time for a particle to travel from the inlet to the sample probe is:

$$\frac{13.15\,ft^3}{1420\,ft^3/min} \times \frac{60\,SEC}{min} = \underline{\underline{0.56\ SEC}}\ (60\%\ \text{Eductor})$$

JOHN ZINK

Job No.

For

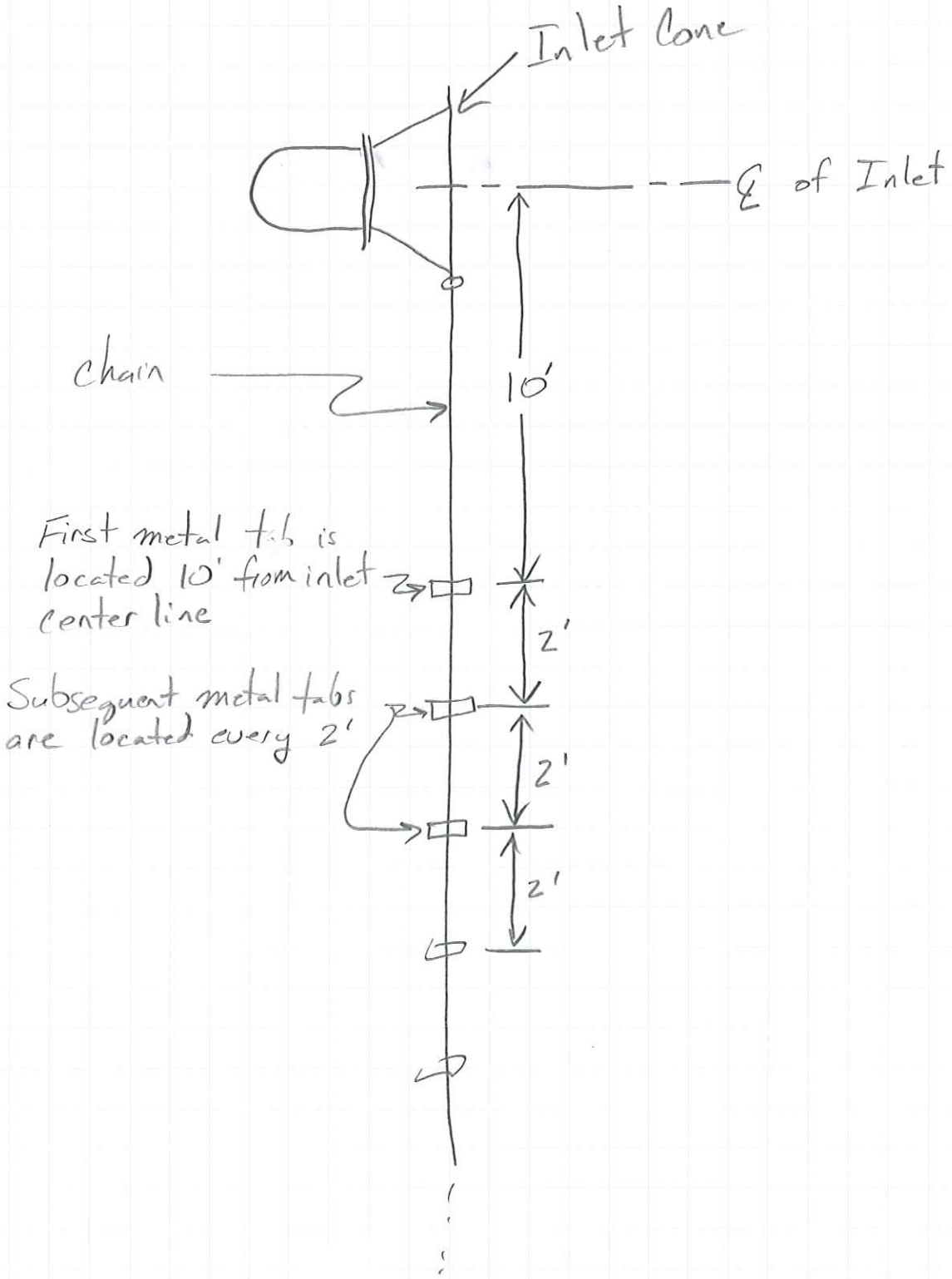
Page

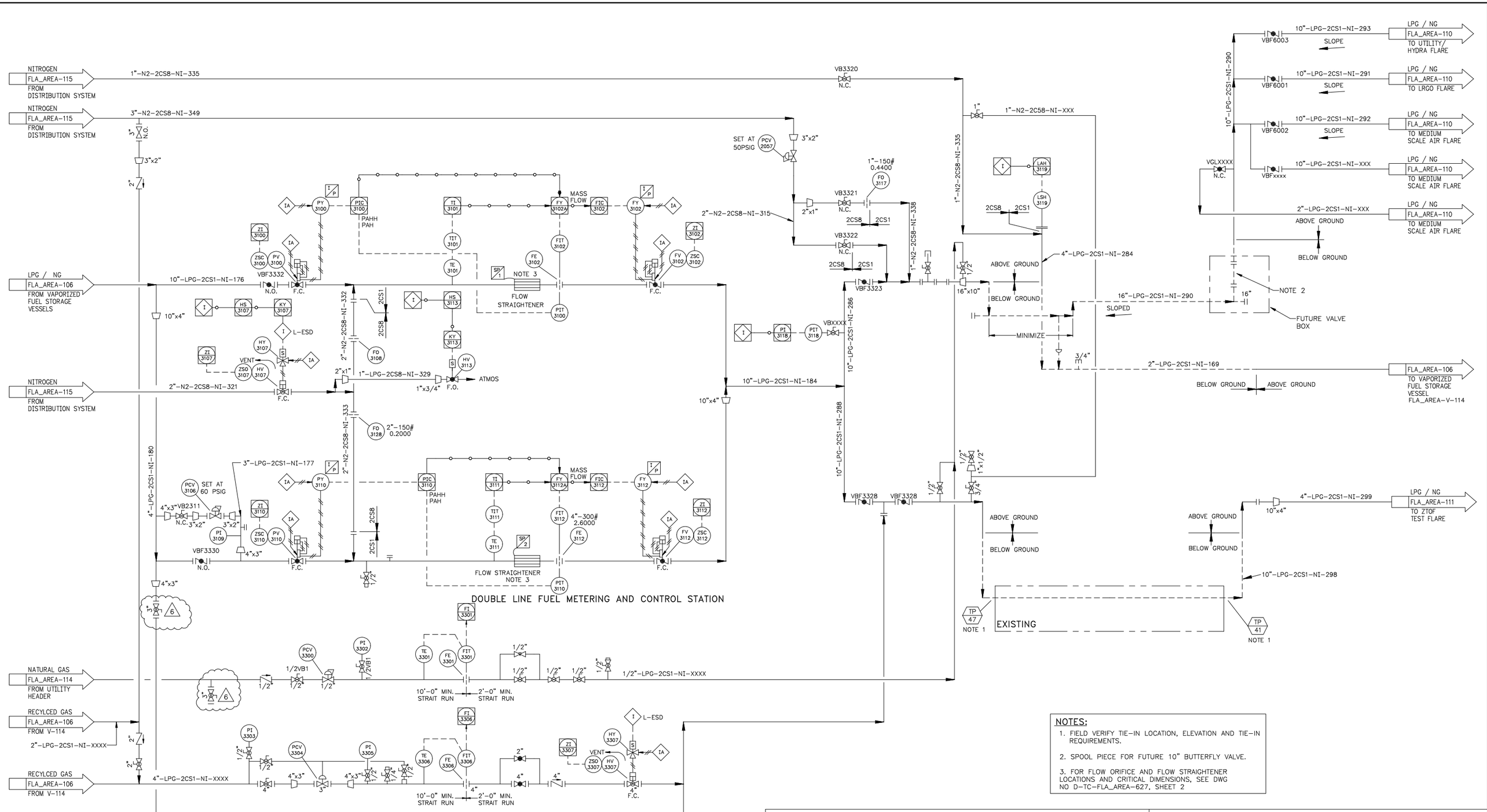
Location

Date 29 Nov 10

Subject Sample Collector Elevation Measurement Chain

By ZLK





NOTES:

1. FIELD VERIFY TIE-IN LOCATION, ELEVATION AND TIE-IN REQUIREMENTS.
2. SPOOL PIECE FOR FUTURE 10" BUTTERFLY VALVE.
3. FOR FLOW ORIFICE AND FLOW STRAIGHTENER LOCATIONS AND CRITICAL DIMENSIONS, SEE DWG NO D-TC-FLA_AREA-627, SHEET 2

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FOR: JOHN ZINK COMPANY LLC
USER: JOHN ZINK COMPANY LLC

NO.	REVISION DESCRIPTION	BY	CK.	APP.	DATE
6	REVISED	BN	ZK	ZK	6-8-10
5	REVISED PIPING	BN	ZK	ZK	3/25/10
4	REVISED PER TEST CENTER MODIFICATION	DHC			2/11/09
3	GENERAL REVISIONS (JOHN ZINK)	KH			8/23/02
2	ADDED FLOW STRAIGHTENERS & RELOCATED PRESSURE TRANSMITTERS	JHK	HS	HS	5/13/02
1	ISSUED FOR DESIGN "SAVED UNDER PROJECT 01-153"	CTT	HS	HS	11/30/01
0	PHASE I - ISSUED FOR DESIGN	CTT	KAG	HS	5/25/01

JOBSITE: TULSA, OK
R&D TEST FACILITY
S.O. NO. -
P.O. NO. -
DR. JHZ DATE: 10/15/99
CK. KAG DATE: 12/14/00
APP. HS DATE: 12/14/00

JOHN ZINK®
JOHN ZINK COMPANY LLC
R&D TEST FACILITY, CALL 1-918-234-5800 FAX (918) 234-5895

FLARE TEST FACILITY UPGRADE
FUEL METERING AND CONTROL STATIONS
PIPING AND INSTRUMENTATION DIAGRAM

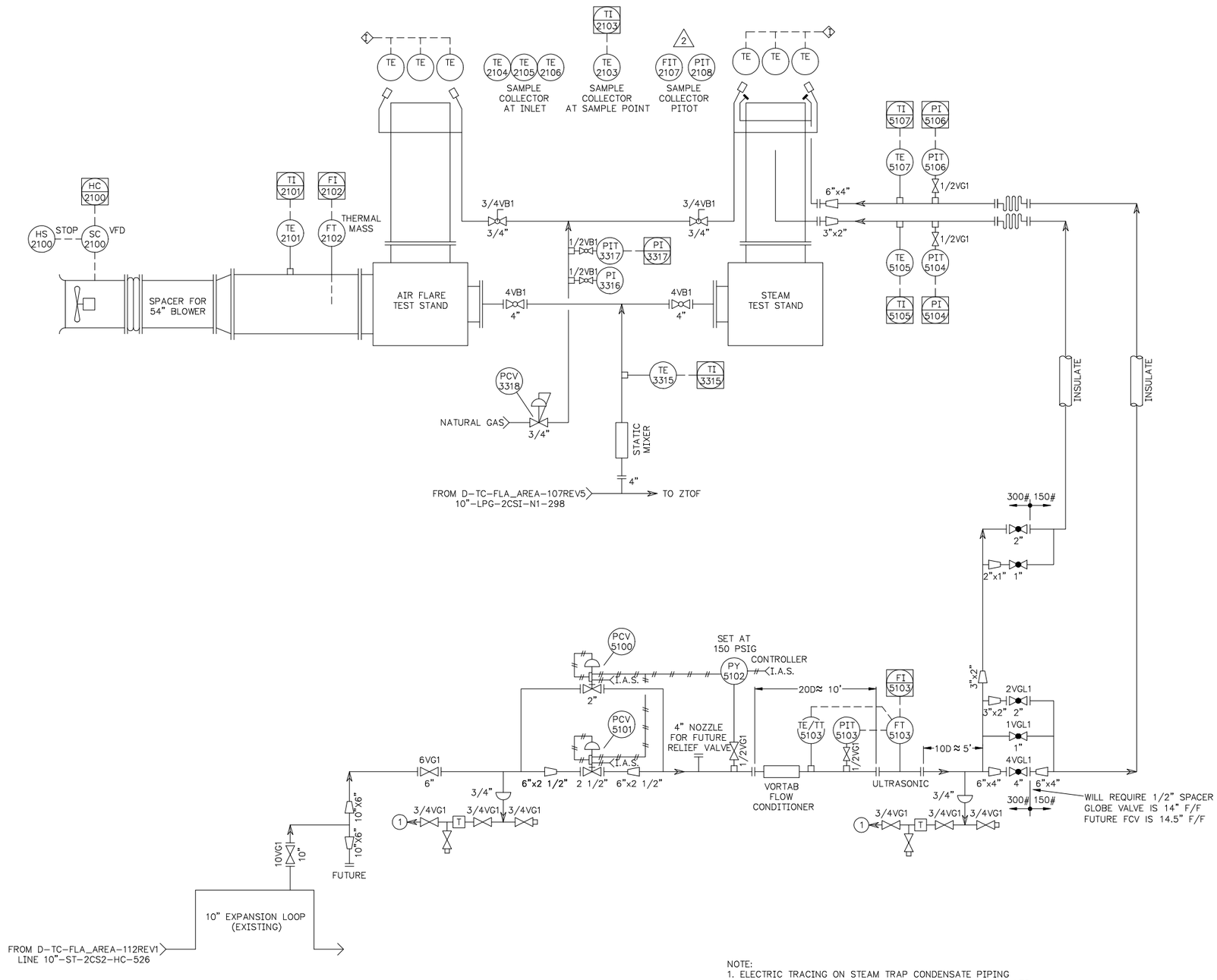
CERTIFIED
DATE:

DRAWING NUMBER D-TC-FLA_AREA-107
REV. 6
SCALE NONE
SHEET 1 of 1

UNIFIELD ENGINEERING TM

JOB NO: 01-832
ACAD FILE: D-TC-FLA_AREA-107
PLOT DATE: 5/13/2002 07:17:40

BASE NUMBER | APPROVAL



NOTE:
1. ELECTRIC TRACING ON STEAM TRAP CONDENSATE PIPING SHALL EXTEND THROUGH STEAM TRAP PIPING AND DRIP LEG TO CONNECTION POINT ON MAIN STEAM HEADER.

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NO.	REVISION DESCRIPTION	BY	CK.	APP.	DATE
2	REVISED PER ENGINEERING	BN		ZK	8-9-10
1	REVISED PER ENGINEERING	BN		ZK	6-8-10

FOR: JOHN ZINK COMPANY LLC
USER: JOHN ZINK COMPANY LLC
JOBSITE: TULSA, OK
R & D TEST FACILITY
S.O. NO. 9105010
P.O. NO.
DR. Beth DATE: 3-25-10
CK. DATE:
APP. ZK DATE:
CERTIFIED DATE:

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JOHN ZINK COMPANY LLC
PARTS AND SERVICE, CALL 1-800-755-4252 FAX (918) 234-5705

FLARE TEST FACILITY UPGRADE
FUEL METERING AND CONTROL STATIONS
PIPING AND INSTRUMENT DIAGRAM

DRAWING NUMBER D-TC-FLA_AREA-120 REV 2
SCALE NONE

BASE NUMBER | APPROVAL

TRC Quality Assurance Documentation

Channel A Inlet

		Area		
Methane	Calibration Gas Value (%)	Inj. 1	Inj. 2	Inj. 3
	0.083	476	394	429
	4.99	23655	23053	23138
	40.10	181210	182658	181694

		Area		
Ethane	Calibration Gas Value (%)	Inj. 1	Inj. 2	Inj. 3
	0.01	81	119	124
	5.013	45626	45438	45186

		Area		
Propylene	Calibration Gas Value (%)	Inj. 1	Inj. 2	Inj. 3
	0.494	7127	7055	7084
	49.57	650040	641823	645524
	98.01	1304506	1277206	1278618

Channel B Exhaust

		Area		
Methane	Calibration Gas Value (ppm)	Inj. 1	Inj. 2	Inj. 3
	2.20	427	4147	3524
	50.60	34353	34270	34658
	101.00	59294	59624	60139
	829.40	456107	456434	456030

		Area		
Ethane	Calibration Gas Value (ppm)	Inj. 1	Inj. 2	Inj. 3
	2.00	2351	2181	2308
	50.00	55296	55431	55495
	99.90	108933	109256	108934

		Area		
Propylene	Calibration Gas Value (ppm)	Inj. 1	Inj. 2	Inj. 3
	0.494	7127	7055	7084
	49.57	650040	641823	645524
	98.01	167558	166985	168690

9/16/2010

Channel A Inlet A.M.					% Drift
Component					
Cal. Gas Value (%)	5.01	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		45535	45228	44868	0.45%
Cal. Gas Value (%)	40.10	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
					#DIV/0!
Cal. Gas Value (%)	49.57	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		645524	650040	641823	0.00%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

Channel B Exhaust A.M.					% Drift
Component					
Cal. Gas Value (%)	50.60	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		34658	34270	34353	0.00%
Cal. Gas Value (%)	50.00	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		55495	55430	55296	0.00%
Cal. Gas Value (%)		Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
					#DIV/0!
Cal. Gas Value (%)		Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
					#DIV/0!

Channel A Inlet P.M.					% Drift
Component					
Cal. Gas Value (%)	4.99	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
					#DIV/0!
Cal. Gas Value (%)	49.57	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		636975	635004	635684	1.53%
Cal. Gas Value (%)	49.57	Area			
		Inj. 1	Inj. 2	Inj. 3	
					#DIV/0!
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

Channel B Exhaust P.M.					% Drift
Component					
Cal. Gas Value (%)		Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
					#DIV/0!
Cal. Gas Value (%)		Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
					#DIV/0!
Cal. Gas Value (%)	99.98	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		167912	166760	167957	0.12%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

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Channel A Inlet A.M.					% Drift
Component					
Cal. Gas Value (%)	5.01	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		45535	45228	44868	0.45%
Cal. Gas Value (%)	40.10	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		178884	176393	173307	3.11%
Cal. Gas Value (%)	49.57	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		636840	639518	637377	1.22%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

Channel B Exhaust A.M.					% Drift
Component					
Cal. Gas Value (%)	101.00	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		64396	63451	64059	7.18%
Cal. Gas Value (%)	99.90	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		109140	109612	109312	0.29%
Cal. Gas Value (%)	99.98	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		165337	165088	166708	1.21%
Cal. Gas Value (%)	829.40	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		472889	474765	475247	3.97%

Channel A Inlet P.M.					% Drift
Component					
Cal. Gas Value (%)	4.99	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		22626	22224	21827	4.54%
Cal. Gas Value (%)	49.57	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		633493	621515		1.63%
Cal. Gas Value (%)	49.57	Area			
		Inj. 1	Inj. 2	Inj. 3	
					#DIV/0!
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

Channel B Exhaust P.M.					% Drift
Component					
Cal. Gas Value (%)	101.00	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		62637	62378	63167	1.94%
Cal. Gas Value (%)	99.90	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		110471	110532	110243	0.95%
Cal. Gas Value (%)	99.98	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		165892	166288		0.99%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

9/20/2010

Channel A Inlet A.M.					% Drift	Channel B Exhaust A.M.					% Drift
Component						Component					
Cal. Gas Value (%)		Area				Cal. Gas Value (%)	101.00	Area			
		Inj. 1	Inj. 2	Inj. 3		Methane		Inj. 1	Inj. 2	Inj. 3	
								65390	66204		
Cal. Gas Value (%)		Area				Cal. Gas Value (%)	99.90	Area			
		Inj. 1	Inj. 2	Inj. 3		Ethane		Inj. 1	Inj. 2	Inj. 3	
								114284	114282		
Cal. Gas Value (%)	49.57	Area				Cal. Gas Value (%)	99.98	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3		Propylene		Inj. 1	Inj. 2	Inj. 3	
		664704	653512	653968				648238	647598	646230	
Cal. Gas Value (%)		Area				Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3				Inj. 1	Inj. 2	Inj. 3	

Channel A Inlet P.M.					% Drift	Channel B Exhaust P.M.					% Drift
Component						Component					
Cal. Gas Value (%)	4.99	Area				Cal. Gas Value (%)	101.00	Area			
Methane		Inj. 1	Inj. 2	Inj. 3		Methane		Inj. 1	Inj. 2	Inj. 3	
		22511	22887	22438				62330	62589	62376	5.11%
Cal. Gas Value (%)	5.013	Area				Cal. Gas Value (%)	99.90	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3		Ethane		Inj. 1	Inj. 2	Inj. 3	
		44591	44531	44452				114425	114645	114511	0.21%
Cal. Gas Value (%)	49.57	Area				Cal. Gas Value (%)	99.98	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3		Propylene		Inj. 1	Inj. 2	Inj. 3	
		648238	647598	646230	1.53%			171136	171076	170587	
Cal. Gas Value (%)		Area				Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3				Inj. 1	Inj. 2	Inj. 3	

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Channel A Inlet A.M.					% Drift
Component					
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	
Cal. Gas Value (%)	49.57	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		650050	652503	652065	0.65%
Cal. Gas Value (%)	98.01	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		1261966	1260054	1291495	1.21%

Channel B Exhaust A.M.					% Drift
Component					
Cal. Gas Value (%)	50.60	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		34266	33917	33279	1.76%
Cal. Gas Value (%)	50.00	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		57801	57266	57497	3.82%
Cal. Gas Value (%)	99.90	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		114188	113764	114052	0.46%
Cal. Gas Value (%)	829.40	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		472889	474765	475247	

Channel A Inlet P.M.					% Drift
Component					
Cal. Gas Value (%)	4.99	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		22607	22769	22526	0.10%
Cal. Gas Value (%)		Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
Cal. Gas Value (%)	49.57	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		649880	650740	649649	0.22%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

Channel B Exhaust P.M.					% Drift
Component					
Cal. Gas Value (%)	101.00	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		63070	63994	64926	2.51%
Cal. Gas Value (%)	99.90	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		114145	113771	113702	0.09%
Cal. Gas Value (%)	99.98	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		171563	174020	175196	1.56%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

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Channel A Inlet A.M.					% Drift
Component					
Cal. Gas Value (%)	4.99	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		22813	22609	22653	
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	
Cal. Gas Value (%)	49.57	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		650050	652503	652065	0.00%
Cal. Gas Value (%)	98.01	Area			
		Inj. 1	Inj. 2	Inj. 3	
		1261966	1260054	1291495	

Channel B Exhaust A.M.					% Drift
Component					
Cal. Gas Value (%)	101.00	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		66462	64515	64924	2.04%
Cal. Gas Value (%)	99.90	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		113545	112758	113479	0.54%
Cal. Gas Value (%)	99.98	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		170578	170798	173739	1.09%
Cal. Gas Value (%)	829.40	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		479879	482306		

Channel A Inlet P.M.					% Drift
Component					
Cal. Gas Value (%)	4.99	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		22617	22681	22792	0.02%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	
Cal. Gas Value (%)	49.57	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		651857	651476	647648	0.19%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

Channel B Exhaust P.M.					% Drift
Component					
Cal. Gas Value (%)	101.00	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		64637	65249	64745	0.93%
Cal. Gas Value (%)	99.90	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		114201	114464	113839	0.90%
Cal. Gas Value (%)	99.98	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		171683	171644	172026	0.05%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

9/23/2010

Channel A Inlet A.M.					% Drift
Component					
Cal. Gas Value (%)	4.99	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		22694	22955	23041	0.90%
Cal. Gas Value (%)	40.10	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		179390	179114	179601	
Cal. Gas Value (%)	49.57	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		645417	647005	648152	0.53%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

Channel B Exhaust A.M.					% Drift
Component					
Cal. Gas Value (%)	829.40	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		483322	482111	482714	0.34%
Cal. Gas Value (%)	99.90	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		113040	113901	113204	0.35%
Cal. Gas Value (%)	99.98	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		170599	170226	170389	1.84%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

Channel A Inlet P.M.					% Drift
Component					
Cal. Gas Value (%)	4.99	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		23068	22721	22934	0.05%
Cal. Gas Value (%)	5.013	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		44591	44531	44452	0.00%
Cal. Gas Value (%)	49.57	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		645417	647005	648152	0.00%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

Channel B Exhaust P.M.					% Drift
Component					
Cal. Gas Value (%)	101.00	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		64454	65713	66823	1.21%
Cal. Gas Value (%)	99.90	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		113843	113279	113502	0.06%
Cal. Gas Value (%)	99.98	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		170599	170226	170389	0.00%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

9/27/2010

Channel A Inlet A.M.					% Drift
Component					
Cal. Gas Value (%)	4.99	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		23543	22992	22674	1.67%
Cal. Gas Value (%)	40.10	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		179266	179938	180823	0.36%
Cal. Gas Value (%)	49.57	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		657916	655355	654054	0.84%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

Channel B Exhaust A.M.					% Drift
Component					
Cal. Gas Value (%)	829.40	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		486628	484284	483624	0.78%
Cal. Gas Value (%)	99.90	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		110685	110617	110793	2.83%
Cal. Gas Value (%)	99.98	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		171091	170940	170608	1.56%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

Channel A Inlet P.M.					% Drift
Component					
Cal. Gas Value (%)	4.99	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		22694	22955	23041	0.75%
Cal. Gas Value (%)	5.013	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		44812	45019		0.88%
Cal. Gas Value (%)	49.57	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		666364	662635	661635	1.18%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

Channel B Exhaust P.M.					% Drift
Component					
Cal. Gas Value (%)	829.40	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		488683			0.79%
Cal. Gas Value (%)	99.90	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		112453	112752	112888	1.85%
Cal. Gas Value (%)	99.98	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		170599	170226	170389	0.28%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

9/28/2010

Channel A Inlet A.M.					% Drift
Component					
Cal. Gas Value (%)	4.99	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		22935	22837	23009	0.62%
Cal. Gas Value (%)	40.10	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
Cal. Gas Value (%)	49.57	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		665921	666073	659440	2.07%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

Channel B Exhaust A.M.					% Drift
Component					
Cal. Gas Value (%)	829.40	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		486186	489234	485937	1.25%
Cal. Gas Value (%)	99.90	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		111416	113901	113204	1.07%
Cal. Gas Value (%)	99.98	Area			
Propane		Inj. 1	Inj. 2	Inj. 3	
		161416	153753	170422	6.76%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

Channel A Inlet P.M.					% Drift
Component					
Cal. Gas Value (%)	4.99	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		22713	23199	22968	0.14%
Cal. Gas Value (%)	5.013	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		44591	44531	44452	0.87%
Cal. Gas Value (%)	49.57	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		645417	647005	648152	2.55%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

Channel B Exhaust P.M.					% Drift
Component					
Cal. Gas Value (%)	829.40	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		482537	482475	483542	0.88%
Cal. Gas Value (%)	99.90	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		111487	112487	113028	0.29%
Cal. Gas Value (%)	99.98	Area			
Propane		Inj. 1	Inj. 2	Inj. 3	
		165846	167835	168370	3.39%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

9/29/2010

Channel A Inlet A.M.					% Drift
Component					
Cal. Gas Value (%)	4.99	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		23068	22934	22721	0.23%
Cal. Gas Value (%)	40.10	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
Cal. Gas Value (%)	49.57	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		654403	654055	667358	1.82%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

Channel B Exhaust A.M.					% Drift
Component					
Cal. Gas Value (%)	829.40	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		484575	490355	493931	0.51%
Cal. Gas Value (%)	99.90	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		111416	113901	113204	0.16%
Cal. Gas Value (%)	99.98	Area			
Propane		Inj. 1	Inj. 2	Inj. 3	
		165639	165413	165440	2.24%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

Channel A Inlet P.M.					% Drift
Component					
Cal. Gas Value (%)	4.99	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		23454	23217	23156	1.61%
Cal. Gas Value (%)	5.013	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		45376	45567		2.13%
Cal. Gas Value (%)	49.57	Area			
Propylene		Inj. 1	Inj. 2	Inj. 3	
		665897	665814	665242	1.07%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

Channel B Exhaust P.M.					% Drift
Component					
Cal. Gas Value (%)	829.40	Area			
Methane		Inj. 1	Inj. 2	Inj. 3	
		483568	486903	488276	0.69%
Cal. Gas Value (%)	99.90	Area			
Ethane		Inj. 1	Inj. 2	Inj. 3	
		113560	112763	112631	0.29%
Cal. Gas Value (%)	99.98	Area			
Propane		Inj. 1	Inj. 2	Inj. 3	
		170017	170066	167496	2.23%
Cal. Gas Value (%)		Area			
		Inj. 1	Inj. 2	Inj. 3	

Telops Report

Comprehensive Flare

Study Project

Final Report

Presented to: The University of Texas at Austin,
Center for Energy & environmental Resources (CEER)

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Prepared, reviewed, or approved by		Function	Signature	Date
P	Jean-Philippe Gagnon	Scientist		18 February 2011
R	Simon Savary	Engineer		
A	Martin Chamberland	Vice-President		

100-2600, avenue St-Jean-Baptiste, Québec (Québec), Canada, G2E 6J5, Tel (418) 864-7808, Fax (418) 864-7843

DOCUMENT CHANGE RECORD

Date	Version	Reason for change	By	Approbation
15 October 2010	a	Draft Report	JGA	MCH
17 January 2011	b	Final Report	JGA	MCH
18 February 2011	c	Added table 3 summarizing calibration start/stop times	JGA	

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1 INTRODUCTION

1.1 Context (extract from QAPP)

The TCEQ contracted National Physical Laboratory (NPL), based in the United Kingdom, to perform differential absorption lidar (DIAL) measurements on industrial emissions sources located in a refinery and a storage terminal near Houston during 2007.

Measurements focused on those industrial sources that are difficult to measure using conventional sampling techniques. Specifically, the study involved:

Identifying potentially under-reported industrial emissions sources,

Conducting remote sensing measurements of these sources,

Collecting process and operational data from these sources, and

Comparing emissions determined using conventional EPA-approved determination methods to the remote sensing measurements.

NPL submitted a final report to EPA in 2008. An independent third party is currently comparing remote sensing measurements to conventionally determined emissions. Although these results are still being analyzed, based upon the preliminary total volatile organic compounds (VOC) measurements, flare emissions may potentially be under-reported when emissions are determined using EPA or TCEQ material balance calculation methods. Additionally, preliminary results indicate flare destruction and removal efficiency (DRE) may be reduced during certain operating conditions, such as combusting small volumes of waste gas, and during flare air- or steam-assist operations. These preliminary results indicate the need to conduct a study that determines the relationship between flare design, operation, and DRE.

The purpose of this study is to measure flare flue gas and collect required process and operational data in a semi-controlled environment to determine the relationship between flare design, operation, and DRE. The ambient air conditions, i.e., temperature, humidity, wind speed and wind direction will not be controlled. Direct measurement techniques of flare emissions as well as remote sensing measurement techniques, will be employed in the semi-controlled environment. Analysis of collected process and operational data will permit comparisons between traditional flare material balance emissions determinations, process stream and air measurements, and the emissions rates and concentrations measured by the direct and remote sensing technologies.

The TCEQ anticipates that the results of the controlled tests will be broadly applicable and provide insight to operational conditions that may impact flare VOC, DRE and flare combustion efficiency (CE), such as steam- and air-assist rates or waste gas volumetric flow rates.

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1.2 Purpose of work

The Hyper-Cam is a lightweight and compact passive imaging radiometric spectrometer. The Hyper-Cam couples a Fourier-transform spectrometer (FTS) to a focal plane array detector to produce a datacube, a complete spectrum for every pixel in the 2-D image. The Hyper-Cam offers user selectable, ultra-high (from 0.25 to 150 cm^{-1}), spectral resolution. Moreover, the Hyper-Cam uses a stable frequency reference to produce an error-free spectral axis and provide high-fidelity spectral calibration.

Fourier-transform spectrometers (FTS) such as the Hyper-Cam are well-suited instruments to perform passive, remote-sensing measurements. The Hyper-Cam's unique imaging capabilities bring forward new powerful possibilities in several fields of study. The Hyper-Cam coupled to detail physical modeling and novel processing techniques allow for the identification and quantification of distant turbulent gas emissions as well as bringing a whole new way of looking at the phenomenon.

1.3 Scope of document

This document contains the first release of the draft report on the comprehensive flare study project. The data acquisition methodology is presented in section 2.1. The processing and analysis algorithms are discussed in section 2.2. The results and a discussion of the results are presented in sections 3 and 4 respectively.

1.4 Reference documents

RD1 P. Tremblay, K. C. Gross, V. Farley, M. Chamberland, A. Villemaire, and G. P. Perram, *Understanding and Overcoming Scene-Change Artifacts in Imaging Fourier-Transform Spectroscopy of Turbulent Jet Engine Exhaust*, Imaging Spectrometry XIV, Proceedings of SPIE, Vol. 7457, 2009

RD2 P. Tremblay, S. Savary, M. Rolland, A. Villemaire, M. Chamberland, V. Farley, L. Brault, J. Giroux, J.-L. Allard, É. Dupuis, T. Padia, *Standoff gas identification and quantification from turbulent stack plumes with an imaging Fourier-transform spectrometer*, Advanced Environmental, Chemical, and Biological Sensing Technologies VII, Proceedings of SPIE, Vol. 7673, 2010

RD3 Subcontractors Steam Flare Test Point Times.xls

RD4 Subcontractors Air Flare Test Point Times.xls

1.5 Acronyms

BTU	British Thermal Unit
CDR	Critical Design Review
DRE	Destruction and Removal Efficiency
FFT	Fast Fourier Transform

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FPA	Focal Plane Array
MCT	Mercury Cadmium Telluride
RE	Removal Efficiency
SCF	Standard cubic foot
TNG	Tulsa Natural Gas

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2 METHOD

In this section, the data acquisition method will be discussed beginning with the details of the flare study geographical location and Telops' on-site experimental setup (section 2.1.1). Telops Hyper-Cam sensor will be presented in the following section (2.1.2). Section 2.1.3 presents the variables within this experimental campaign as well as the basis for the elaboration of the flare study test plan. A data log summary and completeness percentages can be found in section 2.1.4. Lastly, section 2.2 summarizes the different processing steps involved in the calculation of the DRE from the measured raw data.

2.1 Data acquisition

2.1.1 Physical setup

The flare study project took place at the John Zink R&D facility in Tulsa Oklahoma between September 16th and September 29th 2010. An aerial view of the experimental site is shown in Figure 1. Due to wind conditions, the type of flare in operation and equipment from other participants, the location of Telops' sensor changed during the length of the flare study in order to maintain an ideal view of the observed flare. Pins labeled "P1" to "P4" on Figure 1 indicate the position of Telops equipment at the John Zink facility. Table 1 lists for each position, the date for which the particular location was occupied and the distance from the flare in operation.

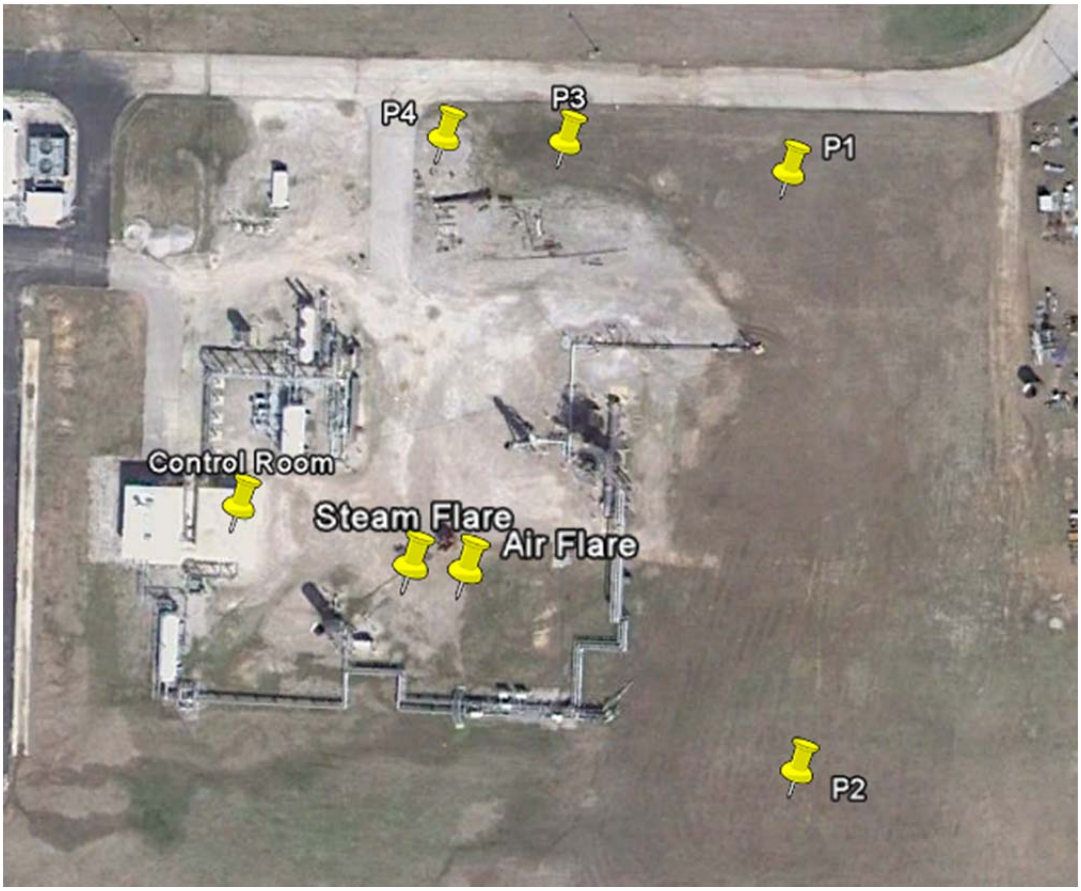

Figure 1 Aerial view of the John Zink test facility (taken from Google Earth). Pins labeled P1 to P4 indicate the location of Telops' sensor during the measurement campaign.

Table 1

Position #	Date	Flare in Action	Distance from Active Flare (m)
P1	Sept. 15-17	Steam Flare	95
	Sept. 20-21		
P2	Sept. 22-23	Air Flare	66
P3	Sept. 27		77
P4	Sept. 28-29	Steam Flare	74

Figure 2 shows Telops measurement site (taken at P1) composed of; Hyper-Cam sensor, data acquisition and data processing computer systems. A view of the steam flare in operation from the Hyper-Cam's position is also shown in Figure 2.

Figure 2 Left: Telops' measurement site. Right : view of the steam flare from the Hyper-Cam's position.

Since the tips of both the air-assisted and steam-assisted flares were made from highly reflective materials, a black area was painted on both flares using a high temperature resistant, dull black paint (refer to Figure 3). This area served as our graybody surface to model the atmospheric layer between the sensor and the plume. More details about the atmospheric model are given in Section 2.2.

Figure 3 Air-assisted flare (left) and steam-assisted flare (center) illustrating the black painted area.

2.1.2 Instruments

The Hyper-Cam is a lightweight and compact passive imaging radiometric spectrometer. The Hyper-Cam is a passive sensor in the sense that it only collects photons from the infrared scene; no signal is emitted from the sensor. The spectral measurements are performed using a Fourier-transform spectrometer (FTS) coupled to a 320x256 pixels focal plane array detector. This instrument generates an interferogram for each pixel in the image. By applying the Fourier transform on every interferogram, a complete spectrum is obtained for each pixel in the image; the resulting measurement is called a datacube. An example of such a datacube measurement from the Hyper-Cam is presented in Figure 4.

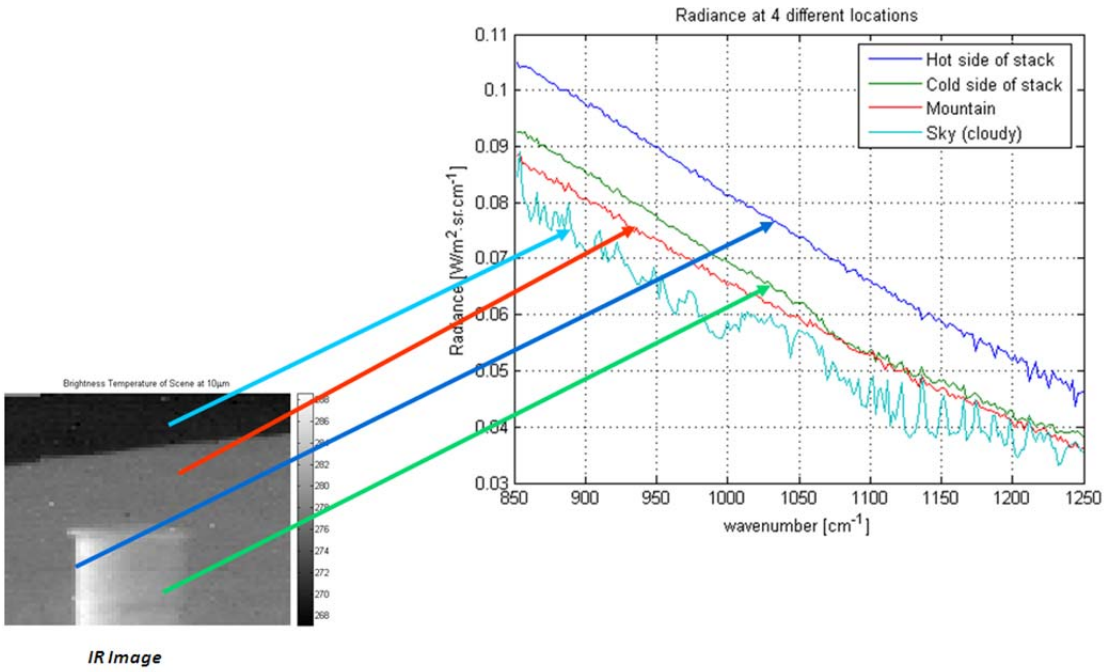

Figure 4 Example of a datacube generated by the Hyper-Cam. Infrared image of a smoke stack in the foreground, distant mountains at the back and cloudy sky in the upper portion of the image; graph showing the calibrated spectra of selected pixels within the datacube.

Because of its imagery capability, the Hyper-Cam is used in a starring configuration meaning that no image raster is necessary to generate the 2-D image. Every pixel of the Hyper-Cam has an instantaneous field-of-view of 0.35 mrad. A magnifying telescope can be installed on the sensor to increase the iFOV to 1.4 mrad. The instrument features two internal calibration blackbodies used to perform an end-to-end radiometric calibration of the infrared measurements. This field-portable sensor is shown in Figure 2.

The Hyper-Cam-LW used in this flare study project features a MCT focal plane array to provide a spectral response from 8µm to 12µm. The active area of the FPA can

be windowed and formatted to fit the desired image size and to decrease the acquisition time of a datacube. The spectral resolution is user selectable and ranges from 0.25 to 150 cm^{-1}. However, throughout the length of the flare study, a spectral resolution of 1 cm^{-1} was used since it is a good compromise between acquisition speed and fine resolution.

Having fixed the spectral resolution to 1cm^{-1}, the other main contributor to the acquisition speed is the size of the active area on the FPA. For reasons explained in section 2.2, the field of view of the Hyper-Cam must encompass several scene features such as; the plume itself, part of the stack and region of the sky devoid of plume gases. Moreover, since the processing method is based on statistical properties extracted from scene interferograms, the acquisition of several datacubes is necessary. Those two factors guided the selection of the ideal FPA window size and ultimately determined the sensor acquisition speed and thus the number of acquired datacubes within a given test sequence.

Different window sizes were used throughout the flare study, all carefully adjusted to contain all the features mentioned above and small enough to keep the acquisition speed as fast as possible. Thus, depending on the selected window sizes, the datacube rate varied from 1 to 0.33Hz (acquisition times of 1 to 3 seconds per datacube) leading to an average number of acquired datacubes per test sequence of 186.

Local meteorological data was also gathered by Telops during the flare study project. However, the wind sensor of our weather station broke down on September 21st. Local wind information is not directly used in the data processing algorithm but can be used to validate the results of the calculated plume speeds.

2.1.3 Experimental campaign

The experimental campaign consisted in the measurement of concentrations and visible emissions of hydrocarbons, carbon monoxide, particulates, flared gas heat content and flared gas exit velocity to help understand DRE and CE on a typical steam- and air-assisted flare tip rated at 937,000 and 144,000 pounds per hour respectively, but operated nominally at 0.25 and 0.1 % of rated design.

The flare test plan consisted in a number of test series for both the air-assisted (denoted Ax,y, where x and y are the test series numbering) and steam-assisted flares (denoted Sx,y) the differences between the test series (x in the test series nomenclature) being the waste gas flow and waste gas compositions settings.

The waste gas compositions (and lower heating values (LHV)) for the different test series varied within:

1. 100% Propylene, LHV = 2,183 Btu/scf

2. 20/80 ratio Tulsa natural gas (TNG) to propylene diluted with nitrogen to a LHV = 350 Btu/scf

3. 20/80 ratio Tulsa natural gas to propylene diluted with nitrogen to LHV = 600 Btu/scf

4. 20/80 ratio Tulsa natural gas to propane diluted with nitrogen to a LHV = 350 Btu/scf

5. 20/80 ratio Tulsa natural gas to propane diluted with nitrogen to LHV = 600 Btu/scf

The waste gas flow for the different test series on the steam-assisted flare burner were varied between:

1. 0.25% (nominally) of flare design capacity or 2,342 lb/hr

2. 0.1% (nominally) of flare design capacity or 937 lb/hr

The waste gas flow for the different test series on the air-assisted flare burner were varied between:

1. 0.65% (nominally) of flare design capacity or 937 lb/hr

2. 0.25% (nominally) of flare design capacity or 359 lb/hr

Within a given test series, the ratio of steam to waste gas or, in the case of the air-assisted flare the ratio of air to waste gas was varied from incipient smoke to snuff point. Data was collected at the incipient smoke point, the snuff point and at a number of mid-way points as shown in Figure 5. For most of the test series, data collection at those measurement points was repeated 2 or more times in random order to assess the repeatability of the results.

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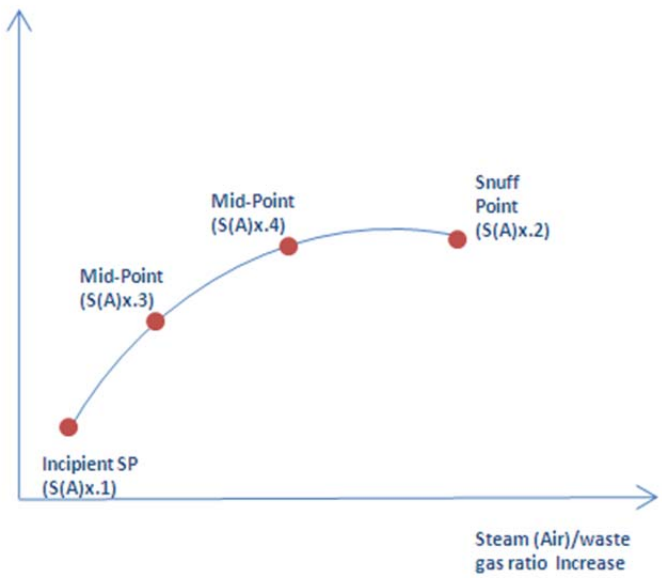

Figure 5 Graphical interpretation of the different measurement points within a given test series (x) (steam-assisted or air-assisted flare).

2.1.4 Data log summary

Table 2 summarises the data recorded by Telops for the different test series throughout the length of the flare study. The measurement start and stop time columns denote the time at which the Hyper-Cam acquisition was started and stopped. The measurement valid column denotes if valid data was recorded for each test series and repetition number. The Measurement Analysed column lists which test series that were selected for post-processing analysis to yield DRE numbers (motivation for this selection is clarified in section 3.1.1). Table 3 summarises the start and stop times of sensor calibration periods.

Table 2

Flare Type	Date	Measurement Start Time	Measurement Stop Time	Test Series	Repetition #	Measurement Valid	Measurement Analysed
Steam Flare	Thursday Sept. 16 2010	11h41	11h54	S1,3	**3**	yes	no
		12h00	12h10	S1,1	**2**	yes	no
		12h15	12h20	S1,2	**2**	yes	no
		14h43	14h46	S2,1	**1**	yes	no
		14h50	14h51	S2,1	**1**	yes	no
		15h03	15h10	S2,2	**1**	yes	no
		15h24	15h28	S2,3	**1**	yes	no
		15h39	15h41	S2,1	**2**	yes	no
		15h46	15h52	S2,3	**2**	yes	no
		16h05	16h12	S2,2	**2**	yes	no
		16h17	16h23	S2,1	**3**	no (3)	yes
		16h34	16h42	S2,3	**3**	yes	yes

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Flare Type	Date	Measurement Start Time	Measurement Stop Time	Test Series	Repetition #	Measurement Valid	Measurement Analysed
	Friday Sept. 17 2010	16h45	16h51	S2,2	**3**	yes	yes
		10h07	10h16	S3,1	**1**	yes	yes
		10h34	10h40	S3,5	**1**	yes	no
		10h42	10h50	S3,6	**1**	yes	no
		11h03	11h11	S3,7	**1**	yes	no
		11h22	11h38	S3,5	**2**	yes	yes
		11h43	11h53	S3,2	**1**	yes	yes
		14h05	14h17	S4,1	**1**	yes	yes
		14h20	14h29	S4,2	**1**	yes	no
		14h43	14h54	S4,3	**1**	yes	no
		15h00	15h09	S4,1	**2**	yes	no
		15h13	15h23	S4,2	**2**	yes	no
		15h36	15h46	S4,3	**2**	yes	yes
		15h59	16h02	S4,1	**3**	yes	no
		16h04	16h15	S4,2	**3**	yes	yes
		16h28	16h39	S4,3	**3**	yes	no
		16h52	17h03	S4,4	**1**	yes	no
	Monday Sept. 20 2010	08h41	8h45	Sky_Bng_AM	**-**	yes	-
		08h56	09h07	S6,1	**1**	yes	no
		09h29	09h41	S6,2	**1**	yes	no
		09h53	10h01	S6,4	**1**	yes	no
		10h12	10h15	S6,3	1	yes	no
		10h45	10h54	S1,5	1	yes	yes
		11h01	11h11	S1,6	1	no (3)	yes
		11h18	11h34	S1,7	1	yes	no
		11h43	11h51	S1,8	1	yes	yes
		12h04	12h06	S1,9	1	yes	no
		12h10	12h12	S1,1	1	yes	no
		12h32	12h42	Sky_Bng_Noon	-	yes	-
		14h15	14h25	S6,3	1	yes	no
		14h32	14h39	S6,1	2	yes	no
		14h42	14h51	S6,5	1	yes	no
		14h59	15h09	S6,3	2	yes	no
		15h18	15h28	S6,6	1	yes	no
		15h33	15h45	S6,4	2	yes	no
		15h53	16h01	S6,2	2	yes	no
		16h12	16h23	S6,1	3	no (3)	yes
		16h38	16h01	S6,3	3	yes	yes
		16h55	17h05	S6,4	3	yes	yes
		17h10	17h22	S6,2	3	yes	yes
		17h36	17h45	S6,1	4	no (3)	yes
		17h49	17h59	Sky_Bng_PM	-	yes	-
	Tuesday	08h14	08h19	Sky_Bng_AM	-	yes	-

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Flare Type	Date	Measurement Start Time	Measurement Stop Time	Test Series	Repetition #	Measurement Valid	Measurement Analysed
	Sept. 21 2010	08h41	08h48	S5,1	1	yes	no
		08h55	09h03	S5,2	1	yes	yes
		09h11	09h16	S5,3	1	yes	no
		09h23	09h31	S5,5	1	yes	no
		09h38	09h50	S5,6	1	yes	no
		09h57	10h05	S5,4	1	yes	no
		10h17	10h27	S5,1	2	yes	no
		10h33	10h42	S5,6	2	yes	no
		10h49	10h57	S5,3	2	yes	no
		11h07	11h17	S5,4	2	yes	no
		11h24	11h32	S5,1	3	yes	no
		11h39	11h47	S5,6	3	yes	yes
		11h58	12h06	S5,3	3	yes	yes
		12h14	12h24	S5,4	3	yes	yes
		Missed instrument in Calibration		S5,7	1	no (2)	no
		12h45	12h50	Sky_Bng_Noon	-	yes	-
		14h03	14h11	S4,5	1	yes	no
		14h21	14h30	S4,6	1	yes	no
		14h40	14h48	S4,7	1	yes	no
		14h52	15h01	S4,8	1	yes	yes
		15h04	15h12	S4,9	1	yes	yes
		15h17	15h25	S4,10	1	yes	yes
		15h47	15h56	S4,11	1	yes	no
		Missed instrument in Calibration		S4,12	1	no (2)	no
		17h18	17h23	Sky_Bng_PM	-	yes	-
Air Flare	Wednesday Sept. 22 2010	08h25	08h31	Sky_Bng_AM	-	yes	-
		Missed - Changing location		AB1	1	no (1)	no
		Missed - Changing location		AB2	1	no (1)	no
		Missed - Changing location		AS1	1	no (1)	no
		Missed - Changing location		AB3	1	no (1)	no
		Missed - Changing location		A1,1	1	no (1)	no
		Missed - Changing location		A2,1	1	no (1)	no
		Missed - Changing location		A2,3	1	no (1)	no
		Missed - Changing location		A2,4	1	no (1)	no
		10h42	10h48	A2,5	1	yes	no
		10h50	11h05	A2,1	2	no (3)	yes
		11h09	11h19	A2,5	2	yes	no
		11h21	11h30	A2,4	2	yes	no
		Missed instrument in Calibration		A2,1	3	no (2)	no
		11h42	11h52	A2,5	3	no (3)	yes
		11h55	12h01	A2,4	3	no (3)	yes
		12h13	12h18	Sky_Bng_Noon	-	yes	-
		14h14	14h40	A3,1	1	yes	no

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Flare Type	Date	Measurement Start Time	Measurement Stop Time	Test Series	Repetition #	Measurement Valid	Measurement Analysed
		14h57	15h05	A3,2	1	yes	no
		15h13	15h15	A3,3	1	yes	no
		15h20	15h29	A3,4	1	yes	no
		15h38	15h43	A3,5	1	yes	no
		15h45	15h52	A3,6	1	yes	no
		16h00	16h08	A3,2	2	yes	yes
		16h11	16h18	A3,1	2	yes	yes
		16h20	16h24	A3,6	2	yes	no
		16h29	16h37	A3,4	2	yes	yes
		16h39	16h47	A3,1	3	yes	no
		Missed – Instrument in Calibration		A3,6	3	no (2)	no
		17h03	17h08	A3,4	3	yes	no
		17h11	17h18	A3,2	3	yes	no
		17h18	17h28	A3,5	2	yes	no
		17h33	17h40	Sky_Bng_PM	-	yes	-
	Thursday Sept. 23 2010	09h28	09h39	Sky_Bng_AM	-	yes	-
		08h45	08h55	A4,2	1	yes	yes
		09h05	09h14	A4,1	1	yes	no
		09h19	09h24	A4,3	1	yes	no
		09h31	09h39	A4,4	1	yes	no
		09h41	09h48	A4,5	1	yes	no
		09h50	10h00	A4,1	2	yes	no
		10h01	10h09	A4,3	2	yes	no
		10h11	10h17	A4,4	2	yes	no
		10h24	10h30	A4,5	2	yes	no
		10h32	10h41	A4,1	3	yes	yes
		10h44	10h50	A4,3	3	yes	yes
		10h52	11h00	A4,4	3	yes	no
		11h05	11h16	A4,5	3	yes	yes
		11h24	11h28	A4,6	1	yes	no
		12h29	12h35	Sky,Bng,Noon	-	yes	-
		13h58	14h09	A6,1	1	yes	no
		14h10	14h17	A6,2	1	yes	yes
		14h19	14h32	A6,3	1	yes	no
		14h34	14h47	A6,4	1	yes	no
		14h49	14h56	A6,5	1	yes	no
		15h07	15h17	A6,6	1	yes	yes
		15h26	15h34	A6,1	2	yes	no
		15h37	15h46	A6,3	2	yes	no
		15h48	16h00	A6,4	2	yes	no
		16h02	16h07	A6,1	3	yes	no
		16h08	16h16	A6,3	3	yes	yes
		16h18	16h33	A6,4	3	yes	no

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Flare Type	Date	Measurement Start Time	Measurement Stop Time	Test Series	Repetition #	Measurement Valid	Measurement Analysed
		17h52	18h06	Sky_Bng_PM	-	yes	-
	Monday Sept. 27 2010	09h54	09h59	Sky_Bng_AM	-	yes	-
		10h13	10h20	A5,1	1	yes	no
		10h30	10h37	A5,2	1	yes	yes
		10h40	10h48	A5,3	1	yes	yes
		10h52	11h00	A5,4	1	yes	yes
		11h03	11h10	A5,5	1	yes	no
		11h15	11h23	A5,1	2	yes	yes
		11h25	11h31	A5,5	2	yes	no
		Missed – Instrument in Calibration		A5,3	2	no (2)	no
		Missed – Instrument in Calibration		A5,1	3	no (2)	no
		12h03	12h12	A5,5	3	yes	no
		12h14	12h21	A5,3	3	yes	no
		13h54	12h57	Sky_Bng_Noon	-	yes	-
		14h01	14h15	A7,1	1	yes	no
		14h18	14h25	A7,2	1	yes	yes
		14h27	14h35	A7,3	1	yes	yes
		14h36	14h46	A7,4	1	yes	yes
		14h50	14h58	A7,5	1	yes	no
		15h01	15h07	A7,1	2	yes	yes
		Missed – Instrument in Calibration		A7,2	2	no (2)	no
		15h26	15h31	A7,3	2	yes	no
		18h04	18h08	Sky_Bng_PM	-	yes	-
Steam Flare	Tuesday Sept. 28 2010	08h36	08h40	SB1	1	yes	no
		08h45	08h49	SB2	1	yes	no
		08h55	09h00	SS1	1	yes	no
		09h03	09h07	SB3	1	yes	no
		08h51	08h59	Sky_Bng_AM	-	yes	-
		09h26	09h33	S7,1	1	yes	yes
		09h40	09h47	S7,2	1	yes	yes
		09h54	10h01	S7,3	1	yes	yes
		10h12	10h16	S7,4	1	yes	yes
		10h07	10h26	S7,4	1	yes	no
		10h31	10h37	S7,5	1	yes	no
		10h45	10h51	S7,1	2	yes	no
		11h00	11h05	S7,6	1	yes	no
		11h11	11h16	S7,2	2	yes	no
		11h23	11h29	S7,3	2	yes	no
		11h34	11h40	S7,2	3	yes	no
		12h48	13h03	Sky_Bng_Noon	-	yes	-
		13h02	13h08	S8,1	1	yes	yes
		13h13	13h20	S8,2	1	yes	yes

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Flare Type	Date	Measurement Start Time	Measurement Stop Time	Test Series	Repetition #	Measurement Valid	Measurement Analysed
		13h26	13h33	S8,3	1	yes	yes
		13h40	13h46	S8,4	1	yes	yes
		14h00	14h06	S8,5	1	yes	no
		14h15	14h20	S9,5	1	yes	no
		14h25	14h30	S9,1	1	yes	yes
		14h37	14h44	S9,2	1	yes	yes
		14h54	15h01	S9,3	1	yes	yes
		15h13	15h20	S9,4	1	yes	yes
		15h27	15h35	S10,4	1	yes	yes
		15h39	15h47	S10,3	1	yes	yes
		15h53	15h59	S10,2	1	no (3)	yes
		16h04	16h11	S10,1	1	no (3)	yes
		16h18	16h25	S11,1	1	no (3)	yes
		16h32	16h38	S11,2	1	yes	yes
		16h46	16h53	S11,3	1	yes	yes
		17h02	17h13	S11,4	1	yes	yes
		18h14	18h22	Sky_Bng_PM	-	yes	-
	Wednesday Sept. 29 2010	09h18	09h25	Sky_Bng_AM	-	yes	-
		08h36	08h47	S12,1	1	yes	no
		08h53	09h00	S12,2	1	yes	no
		09h05	09h13	S12,3	1	yes	no
		09h23	09h28	S12,4	1	yes	yes
		09h34	09h41	S12,1	2	yes	yes
		09h47	09h52	S12,2	2	yes	yes
		09h58	10h04	S12,3	2	yes	yes
		10h11	10h18	S13,3	1	yes	yes
		10h27	10h44	S13,4	1	yes	no
		11h02	11h11	S13,4	2	yes	yes
		11h19	11h27	S13,5	1	yes	no
		11h34	11h43	S13,2	1	yes	yes
		11h54	12h00	S13,1	1	yes	yes
		12h06	12h13	S14,1	1	yes	yes
		12h21	12h30	S14,4	1	yes	yes
		12h38	12h44	S13,4	3	yes	no
		13h53	14h00	Sky_Bng_PM	-	yes	-

(1) Test series missed because sensor is changed to different location

(2) Test series missed because sensor is in calibration mode

(3) Problematic data set (investigation is on-going)

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Table 3

Day	Calibration Start Time	Calibration Stop Time	Day	Calibration Start Time	Calibration Stop Time
Thursday Sept. 16 2010	12h21	12h27	Tuesday Sept. 21 2010	08h48	08h54
	1H16	1h26		09h04	09h10
	1h42	1h51		09h32	09h37
	15h11	15h20		14h11	14h20
	15h29	15h38	Wednesday Sept. 22 2010	11h30	11h40
	15h53	15h54		12h01	12h13
	15h54	16h02		13h05	13h15
	16h23	16h33		14h40	14h50
	16h52	17h01	Thursday Sept. 23 2010	08h55	09h05
Friday Sept. 17 2010	10h07	10h33		09h14	09h19
	10h56	11h11		11h30	11h50
	11h12	11h21		14h56	15h07
	11h39	11h42		15h17	15h26
	11h54	11h56		16h33	16h43
	13h28	13h36	Monday Sept. 27 2010	11h33	11h39
	14h30	14h40		11h50	12h00
	14h55	14h59		12h21	12h31
	15h24	15h35		15h07	15h17
	15h48	15h57		15h31	15h41
	16h17	16h22	Tuesday Sept. 28 2010	08h40	08h50
	16h40	16h45		09h33	09h40
Monday Sept. 20 2010	09h08	09h14		09h47	09h54
	09h42	09h48		10h01	10h12
	10h02	10h08		10h51	11h00
	10h16	10h21		11h40	11h50
	10h54	11h00		13h46	14h00
	11h11	11h17		15h01	15h13
	11h35	11h42		16h38	16h46
	11h54	12h00		17h13	17h23
	12h14	12h19	Wednesday Sept. 29 2010	09h13	09h23
	14h26	14h32		10h18	10h27
	15h09	15h15		10h44	11h02
	15h47	15h52		12h44	12h54
	16h04	16h10			
	16h48	16h54			

The cause of the invalid measurements tagged as (1) of September 22nd was a combination of changes in wind direction and positioning of other equipment (crane lifting the collector, lift for positioning IMACC's retroreflector) on the experimental site which forced a repositioning of the Hyper-Cam so to keep field-of-view clear of obstacles. In that particular case, repositioning involved the selection of a new site, moving of all the equipment to the newly selected site and a re-initialization of the sensor. The operation took approximately 2 hours to complete.

The invalid measurements referenced in Table 2 as (2) were caused by the fact that the instrument was in calibration mode during the given test sequence. Among the parameters triggering a calibration of the Hyper-Cam are the internal temperature of the sensor and the integration time. The internal temperature of the sensor fluctuated within a day according to changes in the outside temperature. To maintain the highest of data quality, a variation of 1˚C in internal temperature of the sensor initiated a calibration. The fact that the intensity of the plume varied significantly within a test sequence, implied that the integration time was adjusted at each measurement point to avoid saturation within the interesting portion of the plume. Moreover, the acquisition of several datacubes (usually 64) of each of the two internal blackbody calibration units was necessary to allow averaging and increase signal-to-noise ratio. Depending on instrument settings, a calibration period took between 6-10 minutes to complete. Therefore, the internal temperature of the sensor, the integration time and the time taken

to perform calibration within the context of the flare study project explain why some tests segments were not acquired.

Some data sets were identified as problematic (tagged (3)) during the post-processing stages. For some of which, standard calibration and post-processing algorithms would detect erroneous data. Others, generated false features in the calculated spectra. The reasons causing those data sets to fail at some post-processing stages remains unexplained at this stage and investigation is still on-going.

Table 4 presents the total number of tests series performed over the course of the whole flare study project, the total number of valid test series and the total number of analysed test series (with problematic data sets removed). Two completeness percentages are presented. The acquisition percentage of completeness is defined as:

(Total Number of Valid Tests Series / Total Number of Tests series) x 100 (1).

Whereas the analysed percentage of completeness is defined as:

(Total Number of Analyzed Tests Series / Total Number of Tests series) x 100(2).

Table 4

Total Number of Tests series	Total Number of Valid Tests Series	Total Number of Analyzed Test Series	Completeness % (acquisition)	Completeness % (analyzed)
198	172	64	87	32

2.2 Data processing

This section summarises the data processing steps required for estimating the products quantities in the plume after combustion. Figure 6 shows a block diagram of the processing steps of the analysis, while Figure 7 depicts the physical layout of the measurement topology.

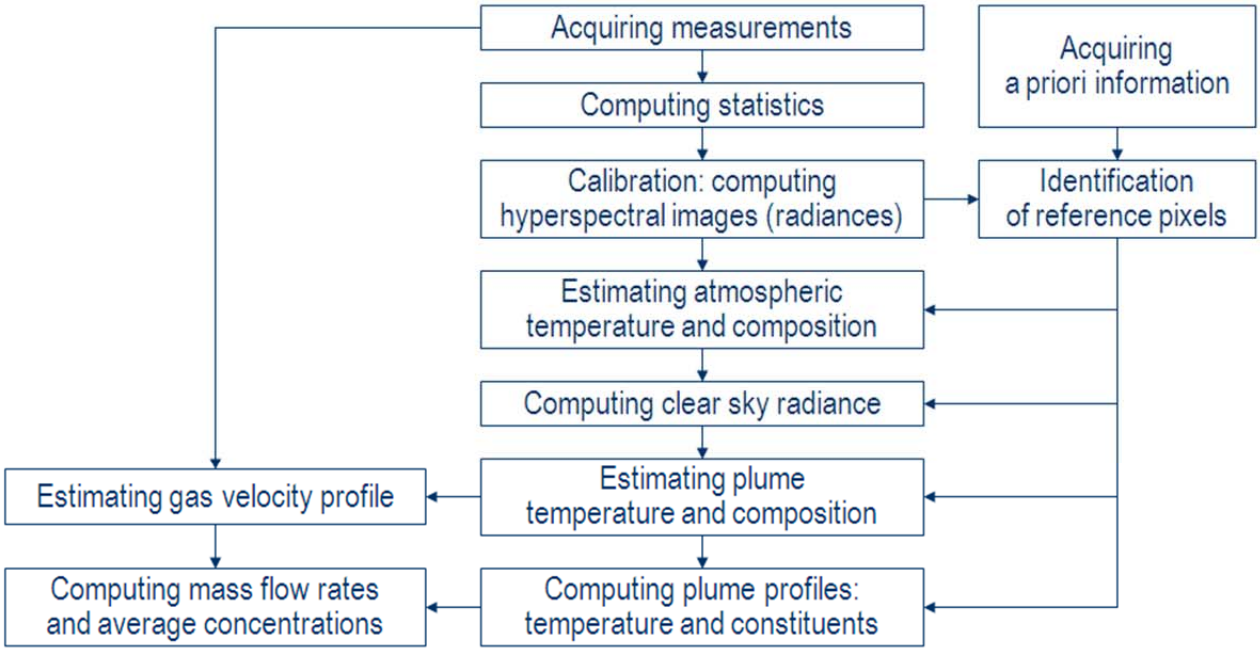

Figure 6 Flare emissions quantification processing steps

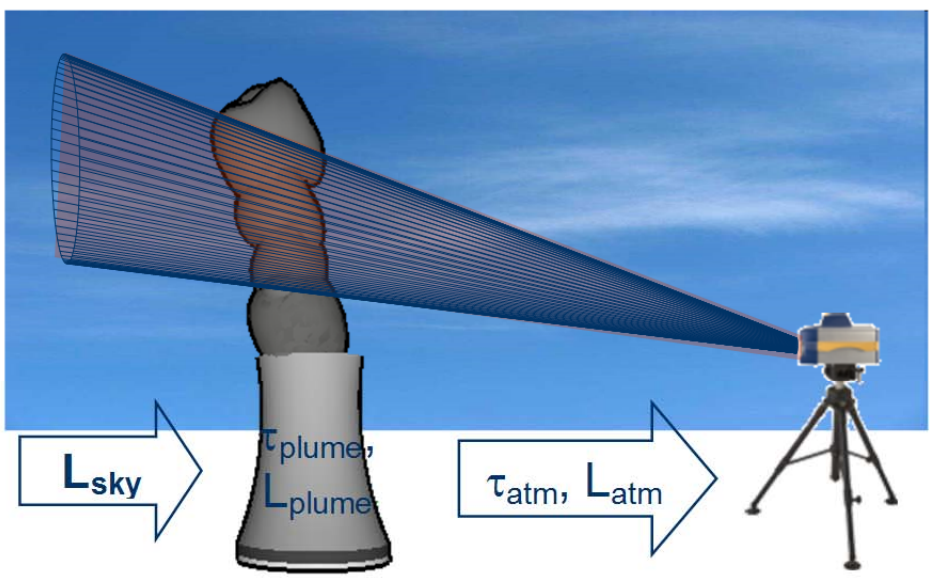

Figure 7 Measurement topology: the hyperspectral imager is looking at the smokestack end. It receives a global spectral radiance whose contributors are the background, the smoke and the atmospheric layer between the stack and the instrument.

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2.2.1 Acquiring measurements

For every point of a test series, the Hyper-Cam imager is acquiring interferograms in continuous. Acquiring many measurements allows for a better statistical representation of the scene. Blackbody reference measurements are also taken for subsequent radiometric calibration of the data collection.

2.2.2 Interferogram statistical analysis

First, before performing any high-level analysis of the measured hyperspectral data, the calibration of the measurement must take place. This calibration step compensates for the radiometric gain and offset of the instrument. Typically, one will average multiple scene measurement in order to increase the signal to noise ratio. However, due to the turbulent and dynamic nature of the plume in flare scenes, the mean scene is no longer representative of the scene. For such fluctuating scenes, Telops developed an adapted interferogram processing technique based on quantile analysis [RD1].

2.2.3 Radiometric calibration

The blackbody measurements are used to characterise the radiometric gain and offset of the instrument to calibrate a sequence of measurement. The calibrated data is in units of physical radiance [in $W/(m^2.sr.cm^{-1})$].

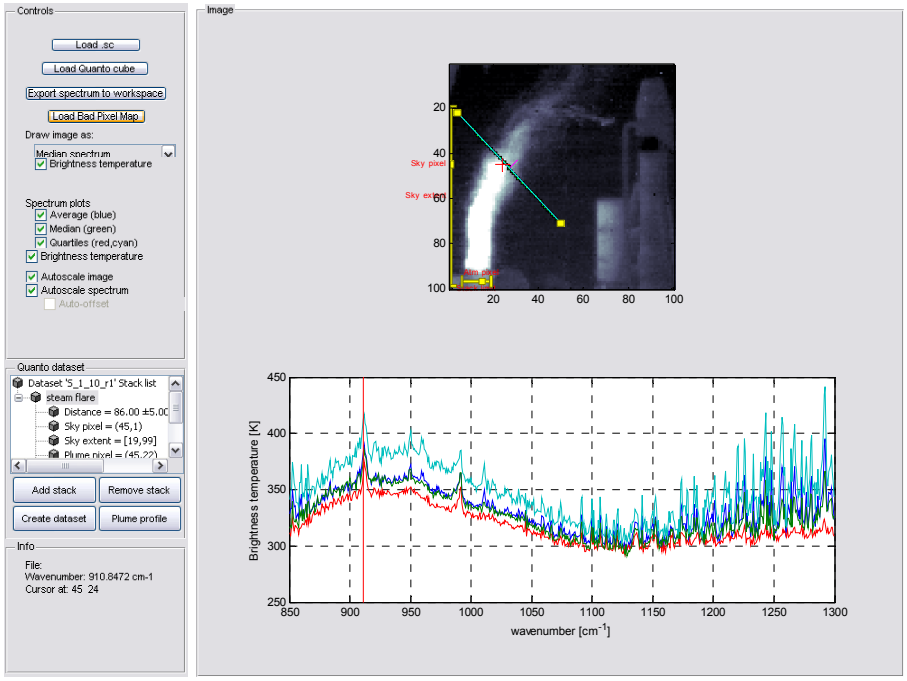
2.2.4 Dataset preparation (choose plume slice to be analysed)

Once the measurements are radiometrically calibrated, each scene must be prepared into a dataset (one per point in each test series). A dataset is used as an input to the quantification algorithms. It defines the following reference pixels:

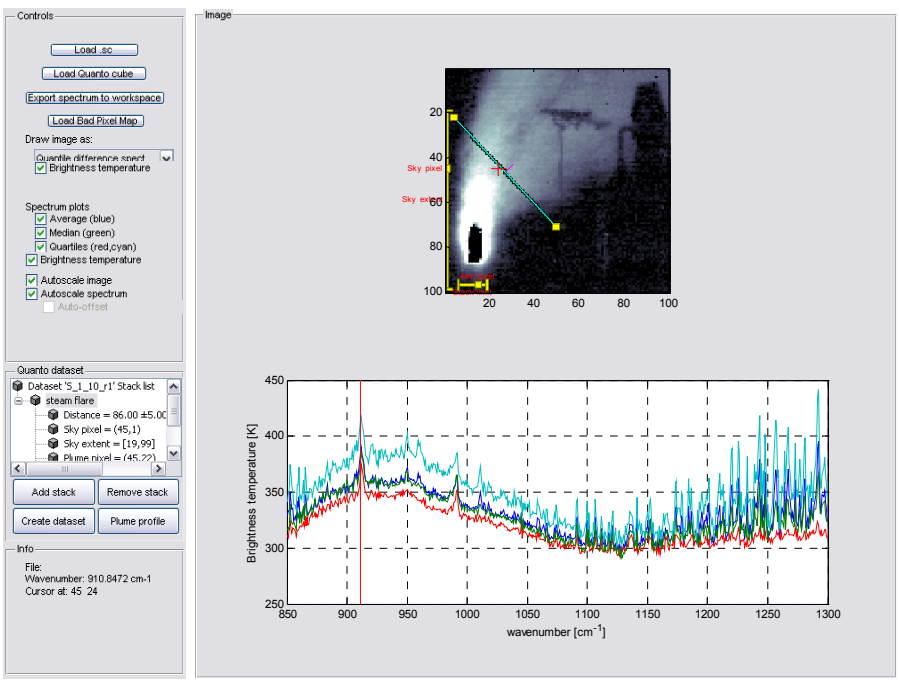
- A clear sky background, unpolluted by the plume gases;
- A reference pixel for determining the atmosphere between the flare and the instrument;
- The region of analysis of the plume: a line through which the plume flows that encompasses the whole extent of the plume. The line may be composed of multiple segments to compose with obstacles in the scene.

Without an imaging spectrometer, these many distinct parameters of a scene would be very tedious to measure and would require considerable logistics. The advantage of using an imager is to obtain all the required information of a given scene into one single measurement.

Telops developed a graphical tool to help choose and define these parameters from the calibrated scene data. This tool also shows the results of the statistical analysis, which are helpful for choosing the reference pixels. Figure 5 is an example of the different parameters in one dataset. This tool illustrates very well the worth of the imaging capabilities of Telops HyperCam.



(a)



(b)

Figure 8 Graphical tool for defining a quantification dataset (S1.10r1 shown). (a) shows the median scene (at 910 cm^{-1}). (b) shows the same band in fluctuation display mode, which helps localize the extent of the over the measurement duration. The plume slice for analysis is shown by the cyan line.

2.2.5 Running the physical model

Telops uses a physical radiometric model in its algorithms to determine the plume gas species and quantities. First, the atmospheric temperature and composition are estimated. The sky background and the atmospheric estimate are then used to estimate the temperature and composition of the plume. For more details, see [RD2].

The gas species mixture is chosen by the operator using *a priori* knowledge about the scene and by performing test runs of the model to identify the gas species that increase the quality of the model in regard to the measurements.

Applying this model to every pixel of the plume slice defined in the dataset preparation step yields a concentration profile for each identified species. Figure 9 shows an example of the propene profile from dataset S1.10r1.

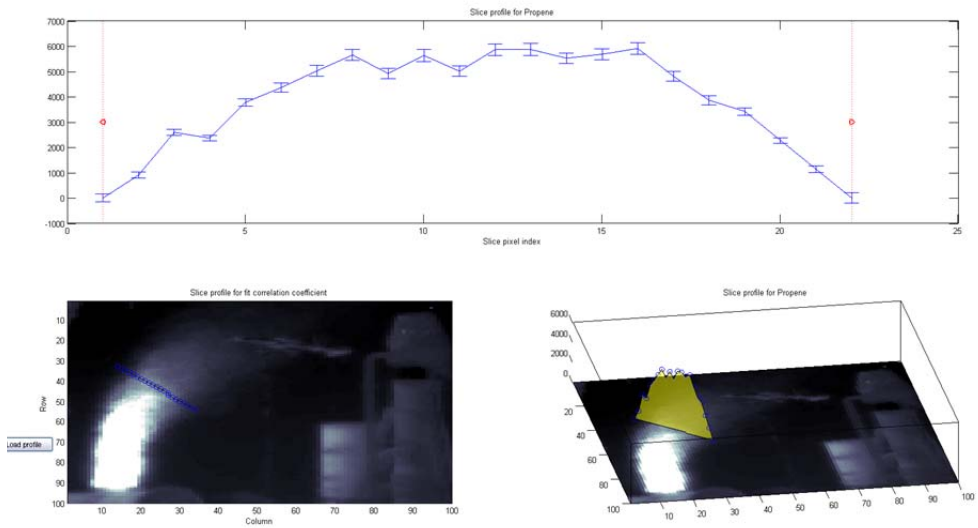


Figure 9 Propene concentration profile along the chosen slice for dataset S1.10r1. Units are in ppm·m. The upper figure is a 2D projection of the 3D profile at the lower-right.

2.2.6 Calculation of gas fluxes

Gas fluxes are computed by integrating the plume speed and concentration profiles along the line represented by the pre-defined plume slice. Figure 10 shows an example of the calculated plume velocities in the horizontal and vertical directions for the S1.10r1 dataset. The system of reference is given in the upper left corner. The 2-d infrared image along with the chosen plume slice is presented in the upper right corner. The two middle plots present the horizontal and vertical speed quartiles. The median horizontal and vertical speeds are plotted in the two lower graphs.

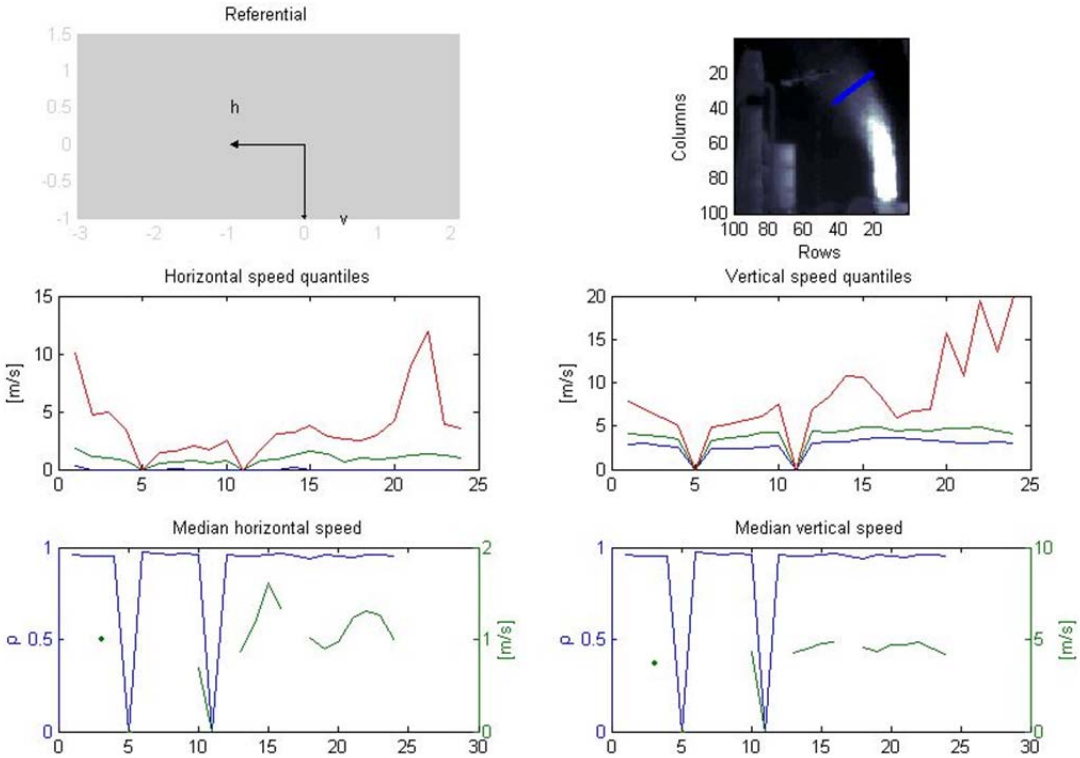


Figure 10 Output of the plume velocity determination algorithm along the chosen slice for dataset S1.10r1. The median horizontal and vertical speeds are plotted in the two lower graphs (green curve, right y-axes) whereas the blue curve (left y-axes) acts as a correlation factor.

2.2.7 Computation of the combustion efficiency

Combustion efficiencies for each of the datasets are calculated for each pixel of the pre-determined plume slice based on a ratio of carbon atoms defined as:

$$CE = \frac{Carbon\ burnt}{Carbon\ total} \quad (3).$$

$$CE = \frac{N_{CO_2}}{N_{CO_2}+N_{C_3H_6}+N_{CH_4}+N_{C_x}} \quad (4).$$

where $N_{CO_2}, N_{C_3H_6}$ and $N_{CH_4}$is the number of C atoms in CO_2, propene and methane. N_{C_x} is the number of carbon atoms in all of the other gases present in gas species mixture determined in section 2.2.5. Figure 11 shows an example of the calculated combustion efficiency from the S1.10r1dataset.

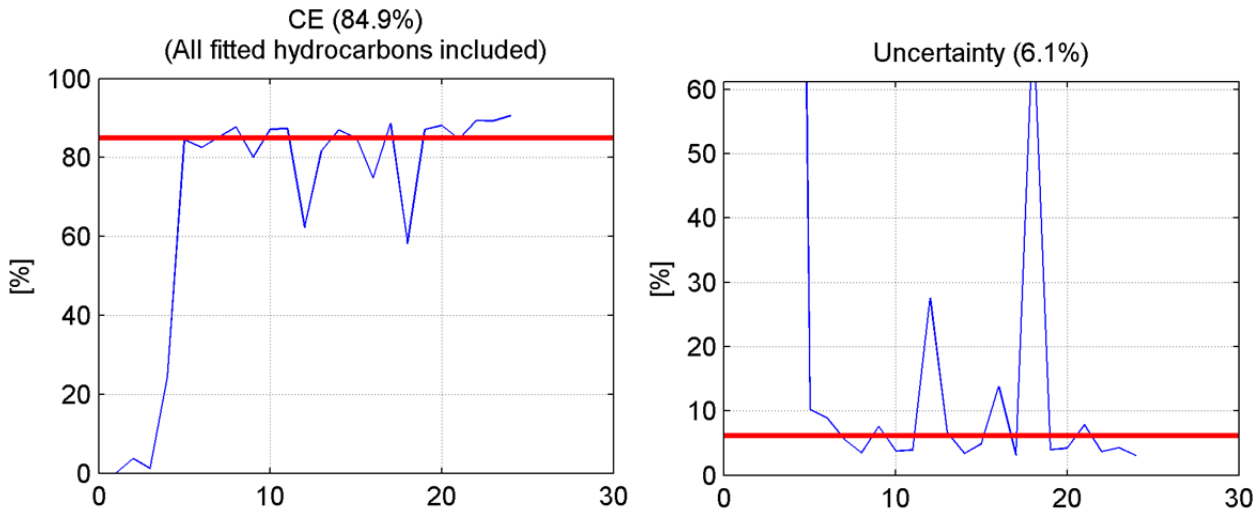


Figure 11 Combustion efficiency (left) and the combustion efficiency absolute uncertainty measure (right) along the plume slice for the S1.10r1dataset. The red curve indicate the median combustion efficiency.

3 RESULTS

Section 3.1.1 presents the adopted strategy to select a subset of the original dataset on which the processing and analysis was performed to yield gas flow and DRE results of section 3.1.2.

3.1.1 Data sampling

Over the course of the flare study project, 172 valid individual data sets (including repetitions) were collected amounting to more than 4TB of data. With several hours of processing time for each individual data set, it was clear that not all data sets could be processed and thoroughly analyzed in the prescribed schedule. Therefore, a strategy was put forward to select a data subset best representing the complete data set. The idea behind this strategy was to retain a minimum number of data points in order to decrease the number of analyzed data sets but still allow for a fair representation of the incipient-to-snuff point curve.

Figure 12 illustrates this data sampling strategy. For a given test series composed of 1 to two midway points, all data points (incipient, snuff and midway points) were selected for processing and analysis. However, in the case of test series comprising more than 2 midway points, along with incipient only one midway point was selected for processing and analysis.

Figure 12 Data sampling strategy in the case of a test series composed of 1 to 2 mid points (left) and a test series comprising more than 2 mid points (right). Green dots indicate the selected test points for processing and analysis whereas the red dots represent the test points left aside.

For each selected test point by the above method, a single repetition run was selected. The criteria for selecting the repetition run were:

- Exposure time (highest number of acquired datacubes)

- Quality of the acquired data (saturation levels in the plume)

By the above strategy, the original dataset composed of 172 test series was reduced to 64.

3.1.2 Result summary

To illustrate the type of results produced by our data processing algorithm, the results of dataset S4.3 run 2 are presented. The mass flow rates and combustion efficiencies for each of the selected datasets from the steam and air assisted flares are reported in RD3 and RD4 respectively.

The output of the application of the physical model to every pixel of the plume slice defined in the dataset preparation step yields a concentration profile for each identified gas species. The calculated plume temperature and propene concentration profiles for dataset S4.3 run 2 are presented in Figure 13 and Figure 14 respectively.

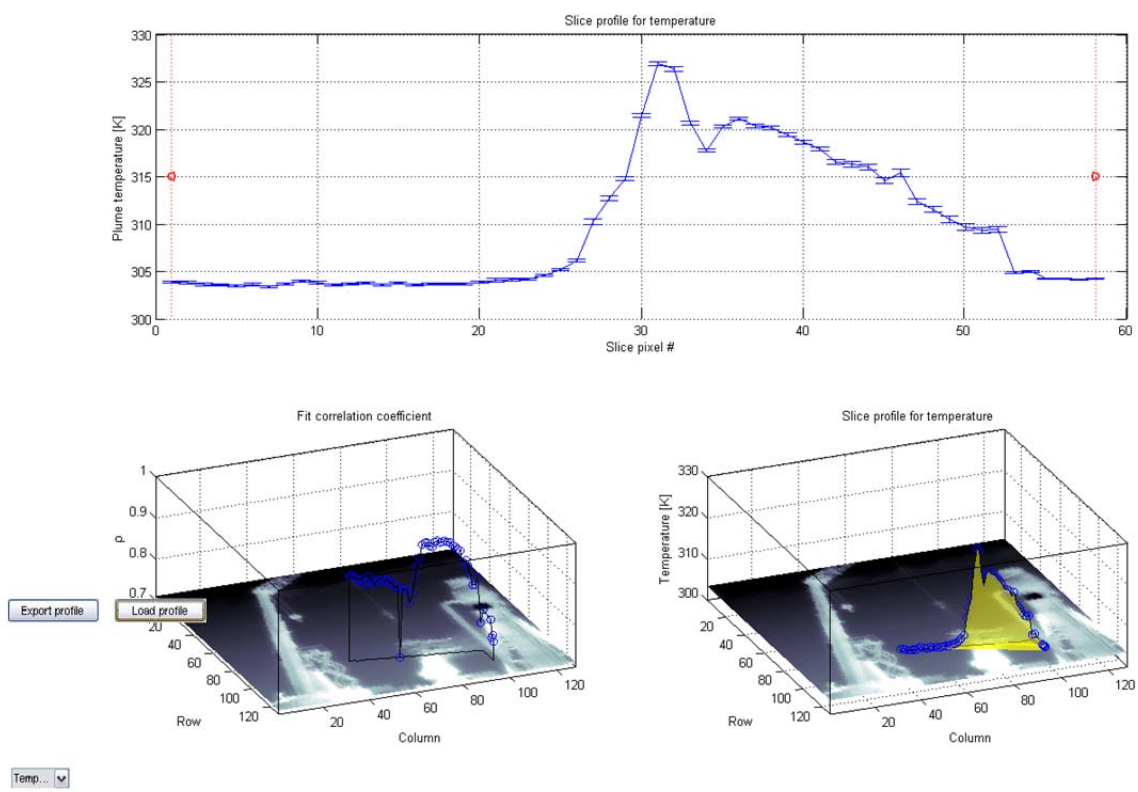


Figure 13 Plume temperature profile for experiment S4.3r2 (upper and lower right figures). A broadband IR image of the scene is underlaid.

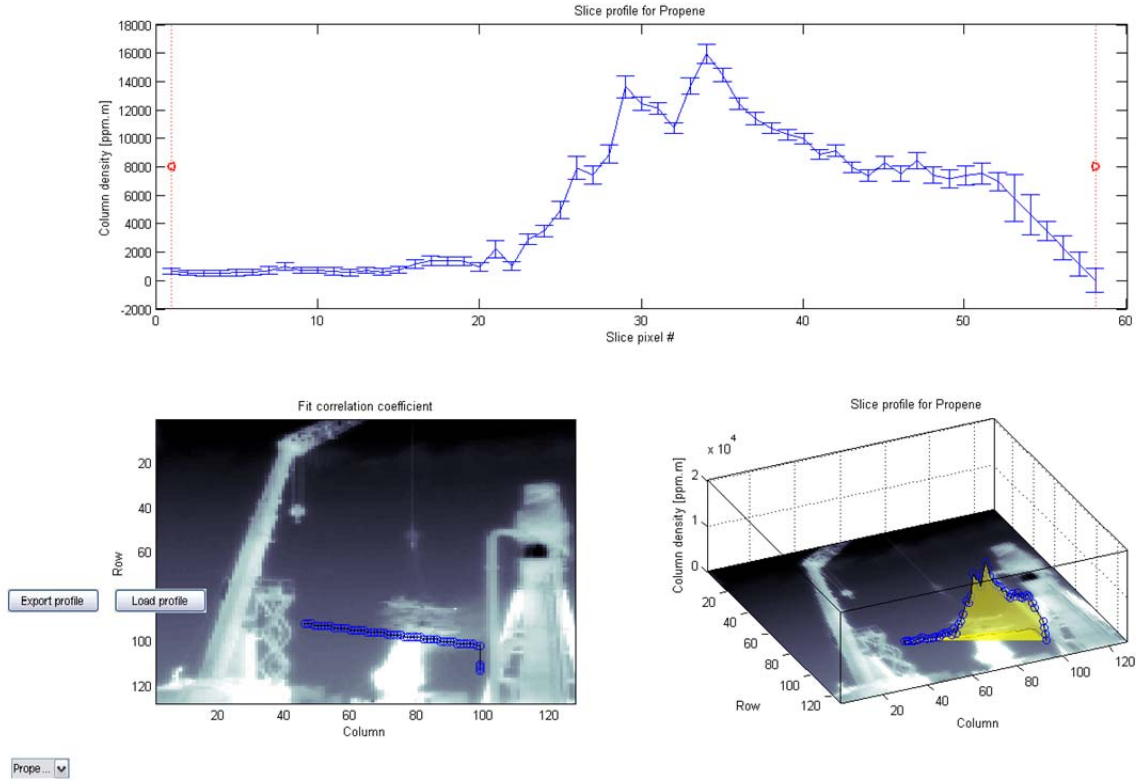


Figure 14 Propene concentration profile for experiment S4.3r2 (upper and lower right figures). A broadband IR image of the scene is underlaid.

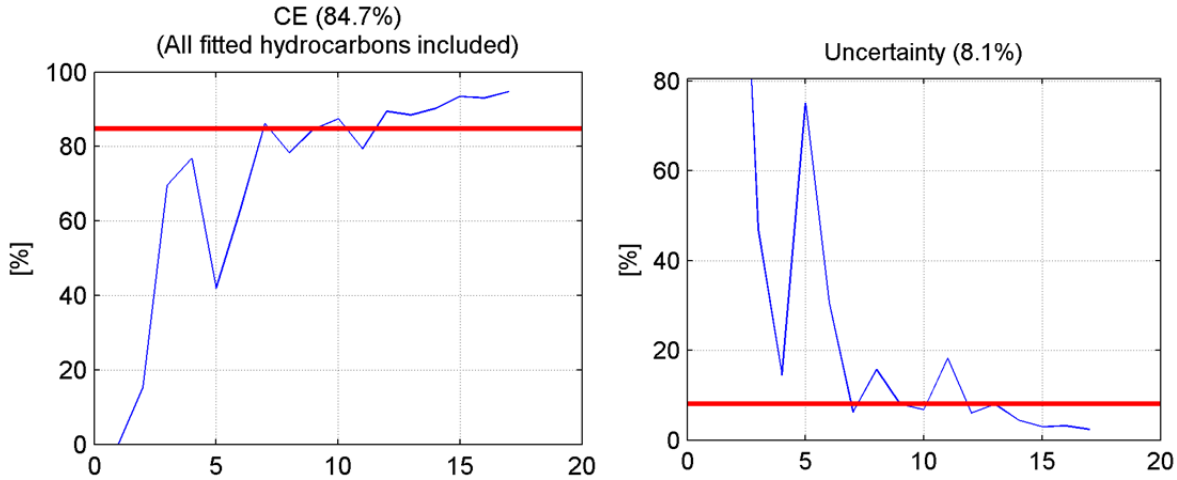


Figure 15 Combustion efficiency (CE) for pixels along the pre-determined plume slice for experiment S4.3r2 (blue curve). The red line indicates the median combustion efficiency.

The output of the plume velocity algorithm for experiment S4.3r2 is presented in Figure 16. From those plots we note that the horizontal plume velocity varies from 0.2 to 0.5 m/s whereas the vertical plume velocity varies from -3.3 to -5 m/s along the selected plume slice. Integrating the plume speed and concentration profiles along the plume slice leads to the calculated gas fluxes for experiment S4.3r2 (refer to Figure 17). The propene and methane mass flow rate from this table are reported in RD3. The target flow rate for S4.3r2 was 2342lbs/hr and the gas composition was 20/80 Tulsa natural gas and propylene.

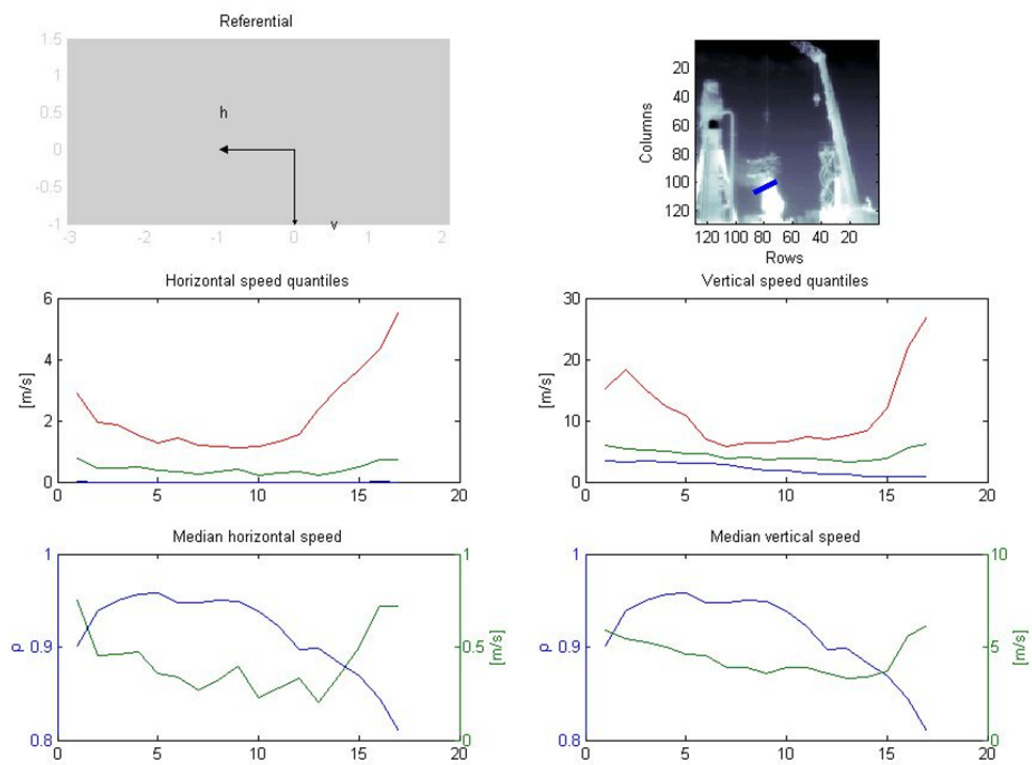


Figure 16 Output of the plume velocity algorithm for experiment S4.3r2.

Gas name	Mass flow rate [lb/h]	Uncertainty [lb/h]
H2O	44764	20211
CO2	16897	8242
Methane	232	108
Propene	874	386

Figure 17 Output of the gas fluxes for experiment S4.3r2.

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4 CONCLUSION AND DISCUSSIONS

As mentioned in the previous section, the mass flow rates and combustion efficiencies for each of the selected datasets from the steam and air assisted flares were reported in RD3 and RD4 respectively.

4.1 CE vs mass flow rates

It is important to mention that the CE is extracted directly from the concentration profiles resulting from the application of the physical model on the pre-determined plume slice. The mass flow rates however are obtained by integrating the plume speed and gas concentration profiles along the line represented by the pre-defined plume slice. The accuracy of the mass flow rates directly depends on the accuracy with which the plume velocities can be calculated. For some datasets, the calculated plume velocities vary greatly and are thus a great cause of error on the estimated mass flow rates (refer to section 4.2). Based on those facts, we feel that the combustion efficiency numbers are more representative than the mass flow rates.

4.2 Presence of objects in the FOV

An important source of disturbance is the presence of the collector in the field-of-view of the instrument. An example of this situation is presented in Figure 18. The presence of the collector in the FOV can lead to a number of different problems.

For some of the datasets, the configuration was such that some of the pixels on the selected plume slice have as background the collector instead of the sky. For such pixels, the physical model breaks down since it is based on the fact that the background consists of the sky radiance.

In some of the datasets, the presence of the collector forces the plume slice to be positioned a greater distance away from the flare (refer to Figure 18). Such a plume slice position is far from ideal since the intensity of the flare is lowered. Since the plume speed algorithm tracks intensity fluctuations in the recorded images (interferograms) for the pixels on the selected plume slice, lower intensity fluctuations can introduce significant errors in the calculated plume speed profile.

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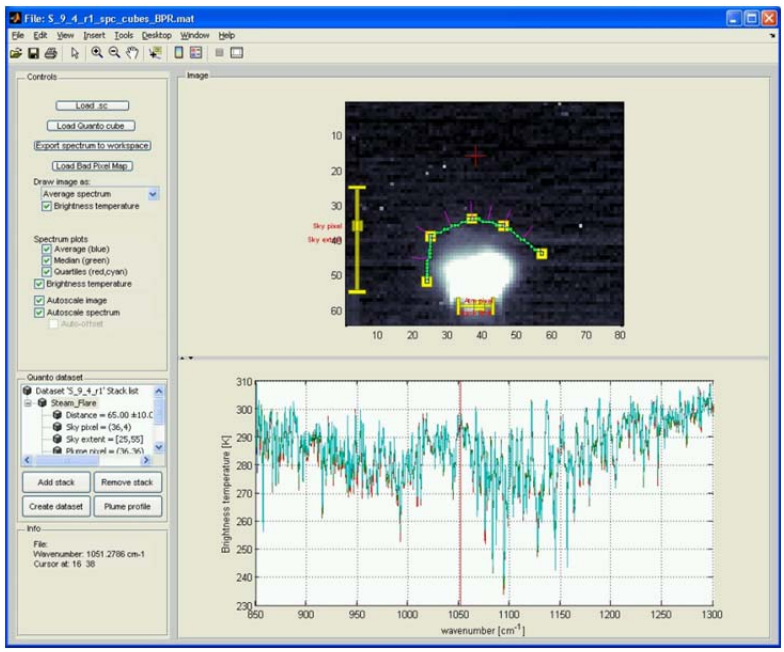

Figure 18 Example of a situation (S9.4 run1) where the position of the collector prevents an ideal positioning of the plume slice. Top: picture of the steam flare and the collector. Bottom: Corresponding IR image along with IR spectra and the selected plume slice (light blue curve).The collector is visible as the light gray cylinder extending to the right of the IR image.

4.3 Processing delays

It is a fact that the reporting of the mass flow rates and the CE numbers took longer than expected. Many factors are responsible for this time delay:

- Individual dataset preparation
- Atmospheric gas determination
- Plume gas determination

- Large amount of individual datasets
- Large amount of computer processing time
- Algorithm adaptations
- Human intervention in several processing steps

It is important to note that this algorithm applied to steam and air flares is at the experimental level. The preparation of all the datasets as well as the intermediate result validation steps are not automatic and require human intervention.

Moreover, the complete processing of a single dataset requires a couple of hours of computer processing time despite several significant improvements. Due to the scope of the project and the specifics of the experiment (objects in the FOV, large number of files to process), the adaptation of our original algorithm was mandatory. Without those adaptations, even longer computer processing time and more human interventions would have been required.

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PFTIR Quality Assurance Documentation

Daily Radiance Calibrations

As part of the quality assurance, the PFTIR is calibrated against a black body source daily. This calibration provides a function which converts the PFTIR voltages to radiance units in watts/cm^2/steradian/wavenumber. This function is derived by dividing the Planck function at the temperature of the black body by the measured black body spectrum. To eliminate the effects of the atmospheric gases, this measured spectrum is "smoothed" by generating a synthetic background following the contour of the spectrum but avoiding molecular absorptions. This process is discussed elsewhere in the document.

The radiance calibrations for each day of testing are plotted in Figure 1. The calibrations are relatively constant in the larger wavenumber analysis region (2000 cm^{-1} to 2500 cm^{-1}) but in the smaller wavenumber analysis region (900 cm^{-1} to 1200 cm^{-1}) they show variations. This region is influenced by ambient emissions and can show variations from day to day.

Pre-test FTIR Calibrations Of The Analytical Methodology

Prior to going to the field, the PFTIR was calibrated in the laboratory to assure that the analytical methodologies were returning accurate gas concentrations. This was accomplished using a "Hot Cell" calibrator. This calibrator operates by placing a 250 C hot-gas cell at the focal point of a 12" collimating telescope. Gas standards are then passed through the cell generating radiant emissions of the gases under known concentration, path length, and temperature conditions. The gas standards were diluted using mass flow controllers to provide a range of concentrations over the full range expected in the field.

The Figures below show the calibrations performed on CO, CO_2, C_2H_4, and C_3H_6. For the calibration runs (Figures 2 and 4), the slope of each curve is the calibration correction that was to be added to the analytical software. For the challenge runs (Figure 3 for CO and CO_2) the slope of the curves show the accuracy of the method after calibration. Values within 4% of the expected value were considered within experimental error.

The somewhat large corrections for C_2H_4 and C_3H_6 were the result of having only one reference standard for these gases at 185 C. Consequently, The US EPA funded the generation of high temperature references for both C_2H_4 and C_3H_6 allowing us to improve the analysis of these compounds. These spectra became available just after the completion of the TCEQ/UT testing. Figure 5 shows the results of analyzing the references using the method calibrated against the data of Figure 4. While the analysis method provided very linear response, C_2H_4 showed and error of 10.9% while C_3H_6 showed an error of 21.5%. This is in part due to the generated references spanning a much larger concentration range that the original data. Prior to doing the final analysis of the flare data, the new references were incorporated into the analysis method to expand the analysis range and to correct possible errors.

Long Term Stability Test For Determination of PFTIR Precision

To assess the stability of the PFTIR a long term stability test was performed. This consisted of monitoring a stable flame over a long enough period of time to determine the standard deviation of the PFTIR output. For the test performed here, the pilot flames of the steam assisted flare were monitored during a period when no fuel was being fed to the flare. These flames should be very stable, except for possible wind effects, so the test performed should put an upper bound on the standard deviation. The results of this test are shown in Figure 6. The average value of the combustion efficiency was 0.995 with a standard deviation of 0.0018. A standard deviation of 0.1% to 0.2% is consistent with long term stability tests performed in previous flare monitoring programs.

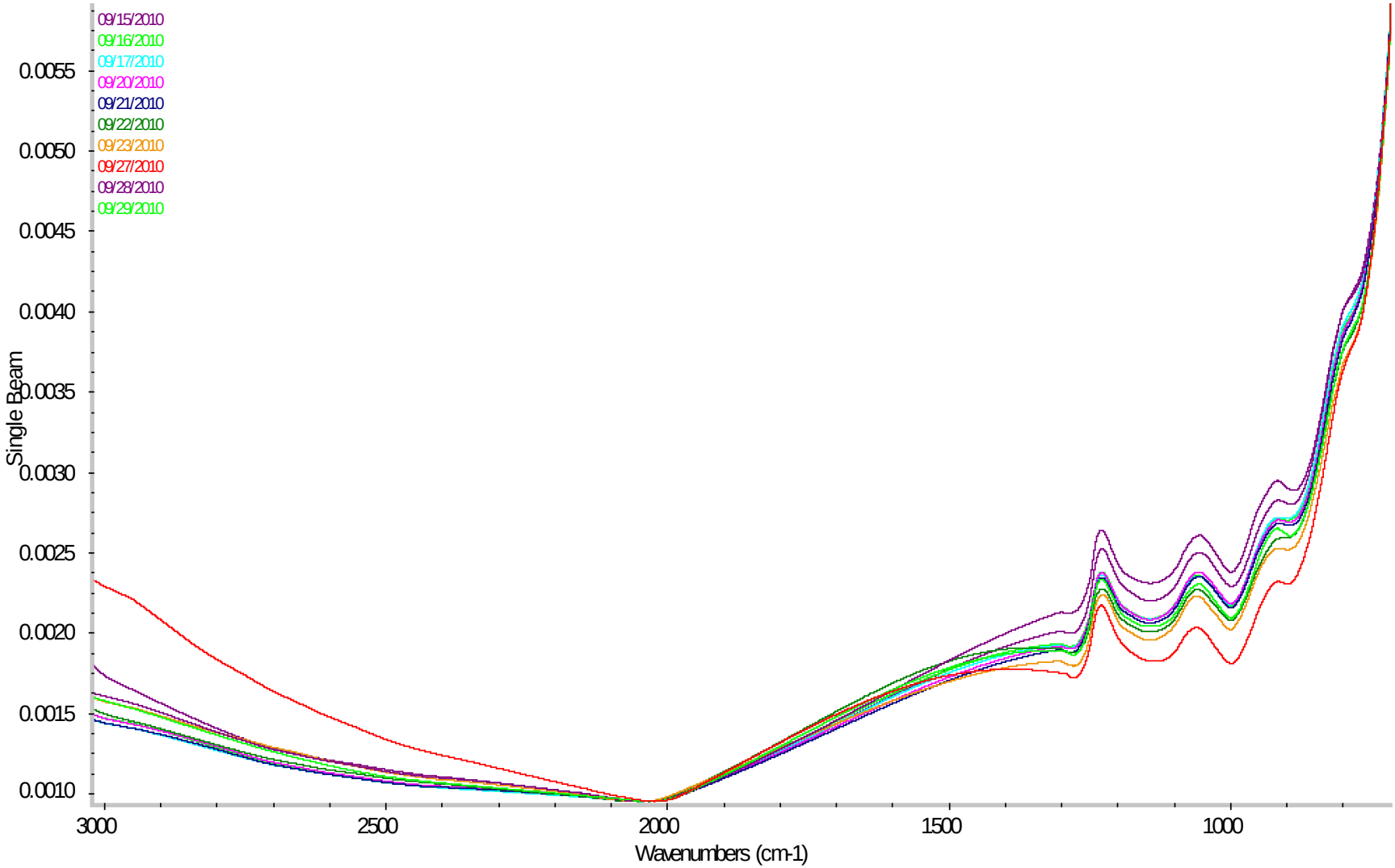
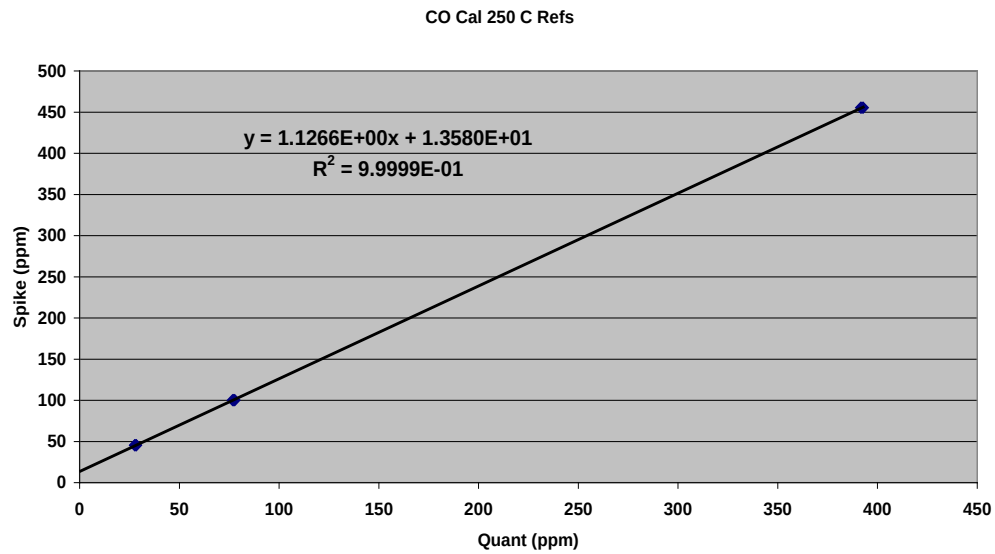


Figure 1 Plots of the Radiance Calibration functions derived from the daily black body measurements. The regions of analysis are from 2000 cm^{-1} to 2500 cm^{-1} for CO, and CO_2 and from 900 cm^{-1} to 1100 cm^{-1} for organics. The region from 1250 cm-1 to 2000 cm-1 passes through the opaque H_2O region in the air, so this region can have artificial effects. The greater variance in the small wavenumber regions is predominantly instrumental radiance.

Using 250 C refs for CO and Co2 No Cal Factors Dynamic Shift CO_H2O

CO Spike	CO Quant	CO2 Spike	CO2_765	CO2_1k	CO2_2k
455.5	392.2	14454	14829.6	14613.2	15906.7
455.5	391.6	14454	15309.1	16243	15769.98
455.5	392.8	14454	15423.2	15223.3	16457.8
100.2	77.35	127200	145447.9	138528.6	125526.98
100.2	77.82	127200	145081.8	139845.2	126253.4
100.2	76.63	127200	144612.26	139988.8	126031.8
100.2	77.28	127200	145929.5	139568.8	126949.7
45.5	28.26	144545.45	170584.2	162091.7	145746.4
45.5	27.55	144545.45	170598.2	163823.28	146042.57
45.5	28.42	144545.45	171107.8	162579.01	145623
45.5	27.79	144545.45	172539.98	163612.7	146655.8



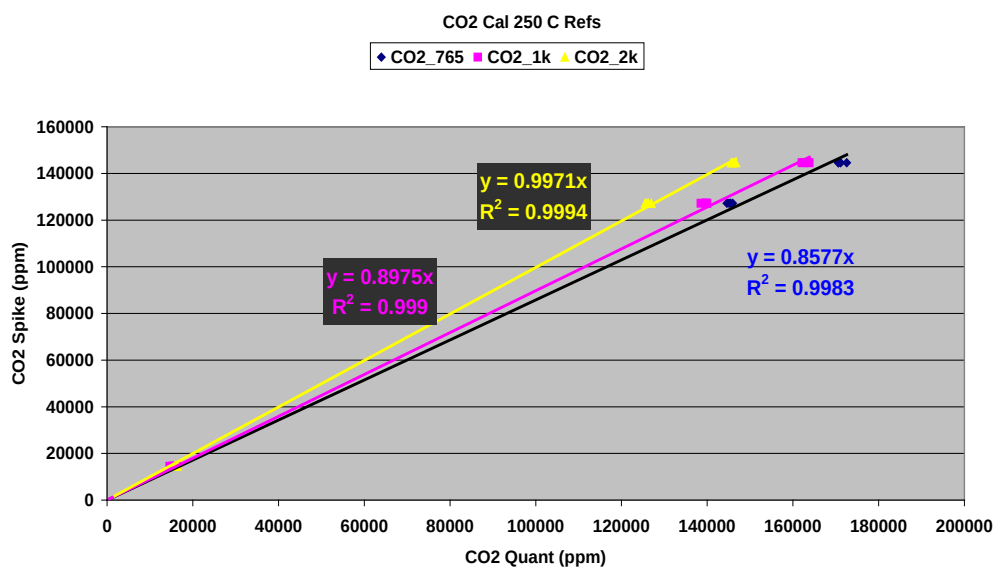
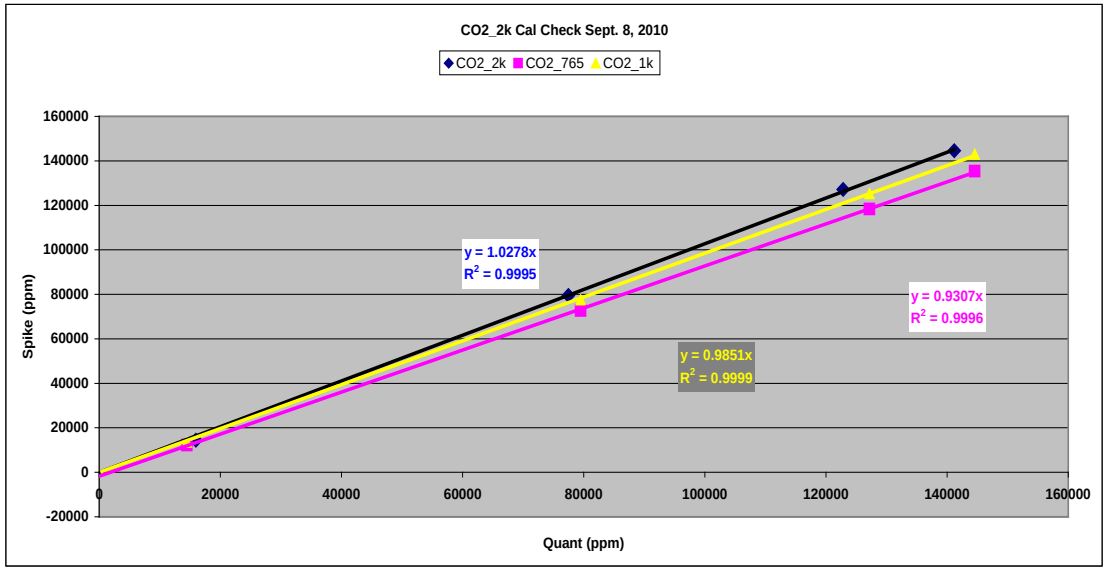


Figure 2 Pre-test calibration of PFTIR for CO and CO_2 at 250 C. Calibration performed Using 12" Collimator and Hot Cell source with 2% accuracy calibration gases.

Calibration Check Using Omnic collect of BOTH cal spectra and data spectra Data of Sept. 08, 2010

CO = 501 ppm CO2 = 159000 ppm

Test No.	CO2_2k	CO2_765	CO2_1k	CO
Test_1#1	15477.2	11764.1	12815.9	461.3
Test_1#2	15887.7	12246.2	13865.2	457.3
Test_1#3	16270.8	12617.7	14221.9	456.5
Test_1#4	16225.05	12429.4	13278.2	456.5
Ave	15965.19	12264.35	13545.3	457.9
Test_2#1	77260	72499.09	77013.3	264.5
Test_2#2	77520	73097.9	77456.3	264.4
Test_2#3	77877	73206	77621.2	263.3
Test_2#4	77179.3	72076.7	78050.3	265.1
Ave	77459.08	72719.92	77535.275	264.325
Test3#1	122679	117849.2	124957.1	111.1
Test3#2	122921	118821.2	125401.7	108.5
Test3#3	122859	118348.6	125323.1	110.1
Ave	122819.7	118339.7	125227.3	109.9
test_4#1	140599	135244.4	142242.8	55.3
test_4#2	140833	135238.3	143243.4	55.6
test_4#3	141587	135622.4	143230.9	54.9
test_4#4	141710	135381.8	143115	54.7
Ave	141182.3	135371.7	142958.03	55.125



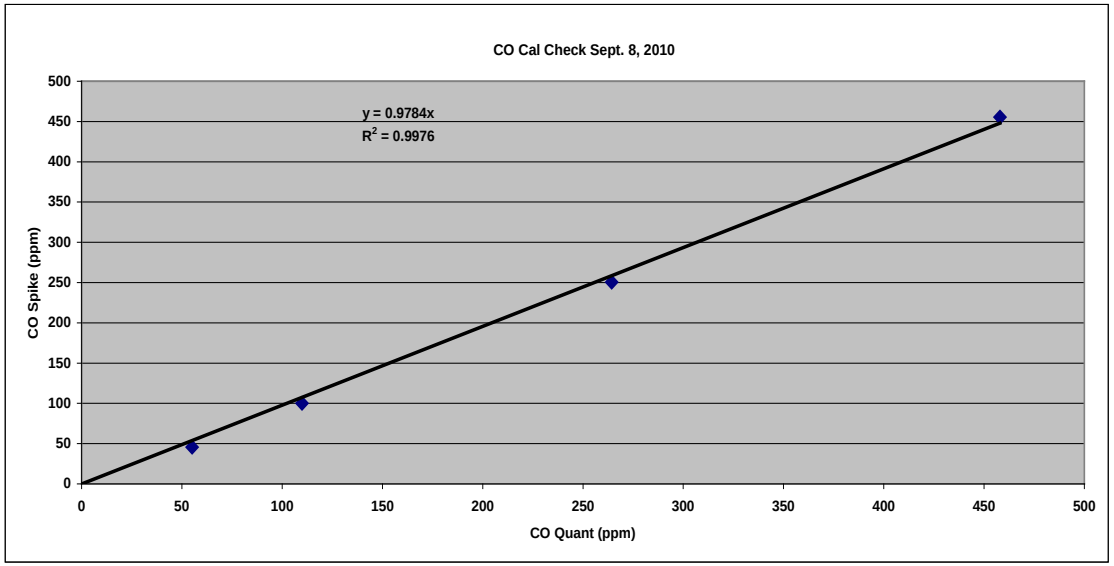
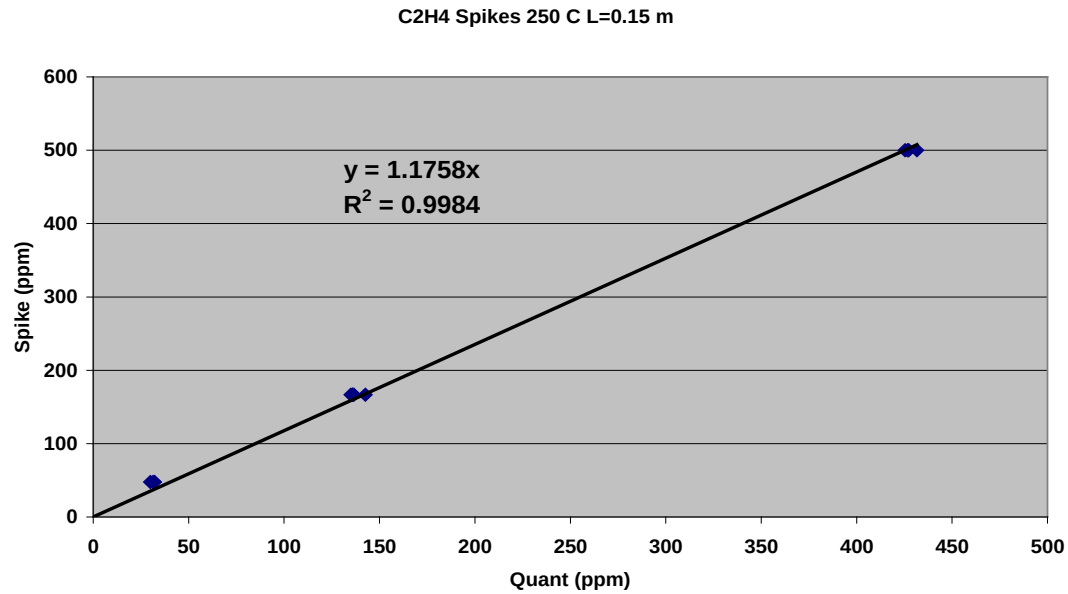


Figure 3 Pre-test *challenge* of PFTIR calibration for CO and CO_2 at 250 C. Challenge performed Using 12” Collimator and Hot Cell source with 2% accuracy calibration gases.

C2H4 = 1000 C3H6 = 1000 T=250 C L=0.15 m

Flows		Quant	Quant	Spike	Spike
C2-C3	N2	C2H4	C3H6	C2H4	C3H6
0.1	0.5	142.57	125.45	166.67	166.67
0.1	0.5	135.8	123.01	166.67	166.67
0.1	0.5	134.95	119.68	166.67	166.67
0.1	0.5	135.96	118.12	166.67	166.67
0.1	0.5	136.6	116.82	166.67	166.67
0.5	0.5	431.55	382.73	500.00	500.00
0.5	0.5	426.58	381.04	500.00	500.00
0.5	0.5	425.4	384.5	500.00	500.00
0.5	0.5	427.3	381.6	500.00	500.00
0.05	1	29.89	22.73	47.62	47.62
0.05	1	32.01	25.71	47.62	47.62
0.05	1	32.17	25.45	47.62	47.62
0.05	1	31.31	27.46	47.62	47.62



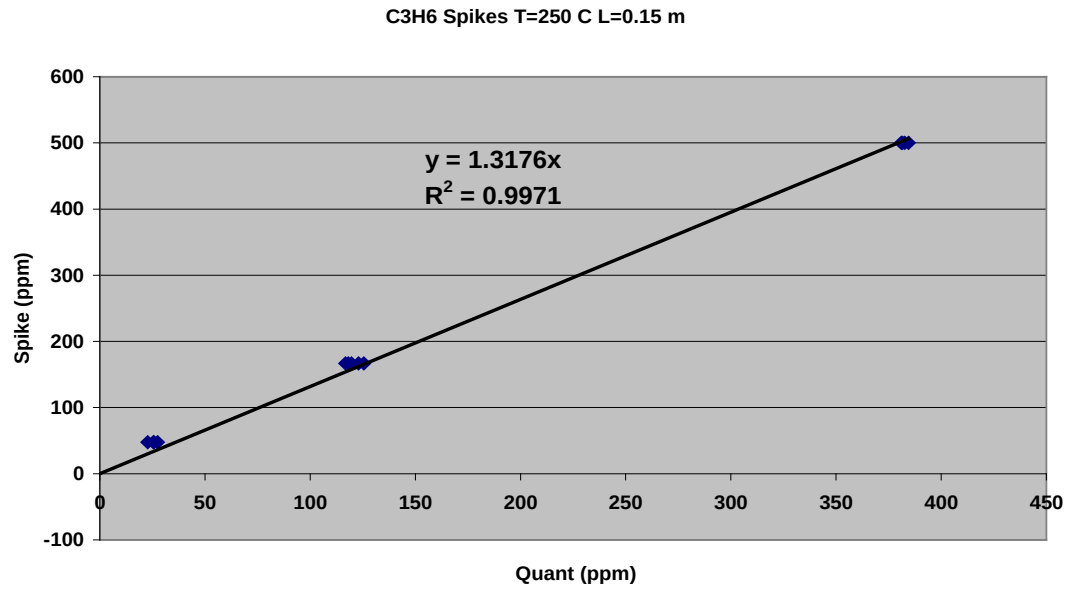
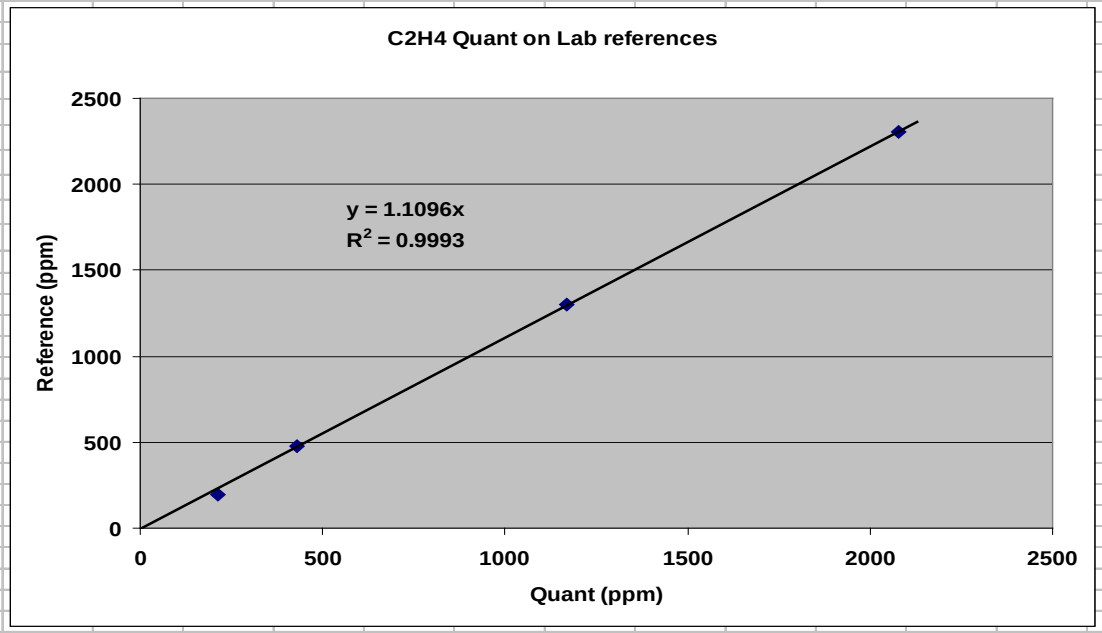


Figure 4 Pre-test calibration of PFTIR for C_2H_4 and C_3H_6 at 250 C. Calibration performed Using 12" Collimator and Hot Cell source with 2% accuracy calibration gases.

Laboratory generated C2H4 and C3H6 references at 250 C

Quant C2H4	Spike C2H4	Quant C3H6	Spike C3H6
1168	1304	934.9	1111
214	196	171.2	196
2079	2307	1687.2	2000
430	476	2809.3	3333
		400.7	476
		4046	5000



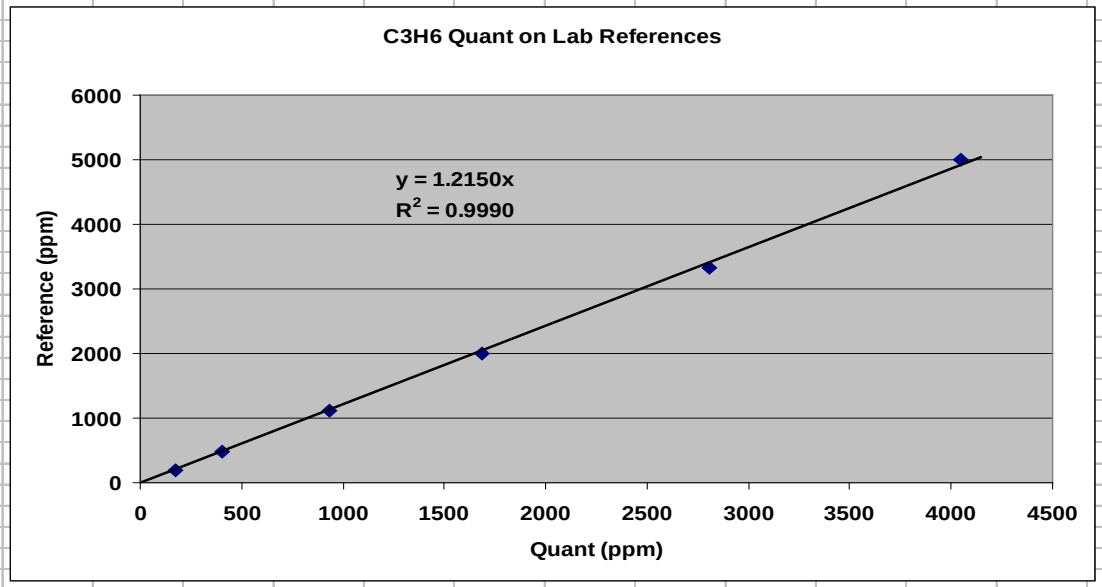


Figure 5 Calibration of analysis method for C_2H_4 and C_3H_6 using laboratory generated references. Generation of the C_2H_4 and C_3H_6 references was funded by US EPA in Research Triangle Park, NC. These were integrated into the analysis method after the TCEQ test and before the final data processing to improve the C2 and C3 quantization.

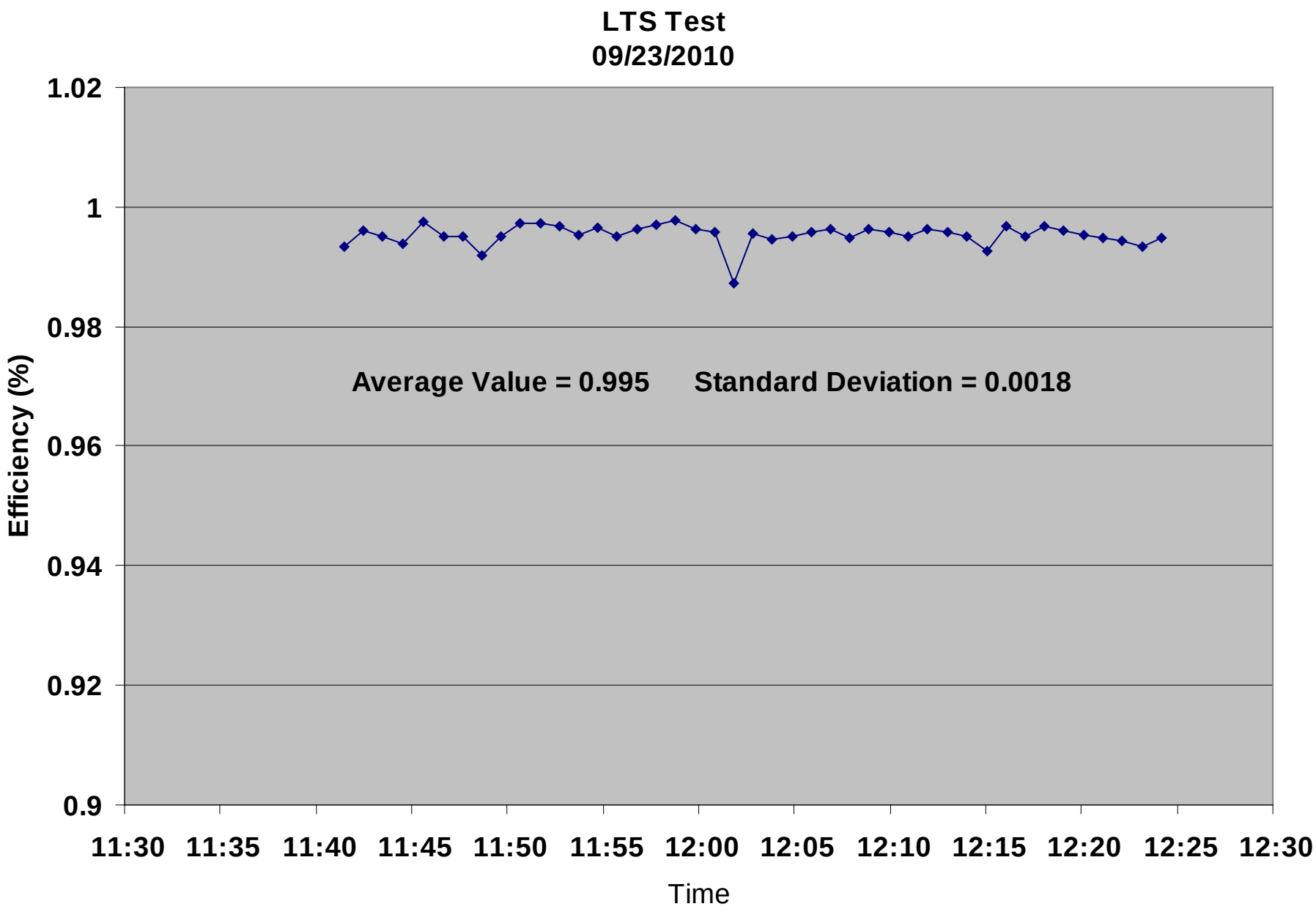


Figure 6 Long Term Stability (LTS) test run on 09/23/2010. This test was to determine the precision of the PFTIR when looking at a stable flame. In this case, the steam assisted flare pilot flames were used over a lunch break when no fuel was present. The standard deviation of 0.1% to 0.2% is consistent with what has been seen in other tests.

Daily Calibration Spectra For The Passive FTIR System

Calibration spectra were collected every morning using the source collimator shown in Figure 1. The spectra required consisted of the following:

- M_{ir} gathered with a standard IR source in the collimator. This spectrum is used to produce atmospheric transmission.
- M_n gathered with a liquid nitrogen cooled source in the collimator. This spectrum is used to produce atmospheric radiance combined with instrument radiance.
- M_{bb} gathered with a black-body source in the collimator. This spectrum used to calibrate the instrument in radiance units.

In addition to collecting data with the collimator, background spectra were collected throughout the day to account for the sky-background within the field-of-view of the PFTIR. These spectra are defined as M_b. Table 1 is a listing of the spectra gathered each day of testing. If the sky was variable, multiple background spectra were collected. The spectra used for reduction of each block of data are shown in the spreadsheet presenting the measured efficiencies.

Figure 1 Imacc Source Collimator for Calibration of the PFTIR.

Table 1

Calibration Spectra Collected Each Day of Testing

Calibration Spectra for 09/07/2010

Name	Date modified
Mb N2 flow 1.25 l_m.SPA	9/7/2010 11:57 AM
Mbb 150 scans T=250 C.SPA	9/7/2010 11:35 AM
Mn LN2 09-07-2010.SPA	9/7/2010 11:46 AM

Calibration Spectra for 09/08/2010

Name	Date modified
Mb #1 N2 T=250C.SPA	9/8/2010 9:15 AM
Mb #2 N2 T=250C.SPA	9/8/2010 9:15 AM
Mb #3 N2 T=250C.SPA	9/8/2010 9:15 AM
Mb #4 N2 T=250C.SPA	9/8/2010 9:15 AM
Mb AVE N2 T=250C.SPA	9/8/2010 12:29 PM
Mbb T=300 C PK-PK=16.18.SPA	9/8/2010 9:00 AM
Mir v=4.5 v pk-pk=11.45.SPA	9/8/2010 8:35 AM
Mn LN2 09-08-2010.SPA	9/8/2010 8:45 AM

Calibration Spectra for 09/15/2010

Name	Date modified
Ave_BKG_1702-1715.spa	9/19/2010 8:56 AM
Mb Sky Blue G=1 09-15-2010.SPA	9/15/2010 10:43 AM
Mbb T=275 C G=1.SPA	9/15/2010 10:43 AM
Mir V=4.0 G=1.SPA	9/15/2010 10:19 AM
Mn Ln2 G=1 10-15-2010.SPA	9/15/2010 10:25 AM

Calibration Spectra for 09/07/2010

Name	Date modified
bkg_2010-09-16_092910.SPA	9/16/2010 9:32 AM
bkg_ave_1417-1421.sgl	9/16/2010 2:23 PM
Mb sky blue G=1.SPA	9/16/2010 8:44 AM
Mbb T=275 C G=1.SPA	9/16/2010 8:29 AM
Mir V=4.5 G=1.SPA	9/16/2010 8:17 AM
Mn LN2 G=1.SPA	9/16/2010 8:22 AM

Calibration Spectra for 09/17/2010

Name	Date modified
AVE_BKG-1056-1057 09-17-2010.spa	10/25/2010 2:17 PM
AVE-BKG-1352-1353-1500-1501.sgl	10/26/2010 1:35 PM
BKG_AVE-1459-1501.sgl	9/17/2010 4:02 PM
Mb Sky partly cloudy.SPA	9/17/2010 9:15 AM
Mbb T=275 C G=1.SPA	9/17/2010 12:28 PM
Mir V=4.5 G=1 fog on mirror.SPA	9/17/2010 8:28 AM
MN LN2 G=1 collimator fogged.SPA	9/17/2010 8:33 AM

Calibration Spectra for 09/20/2010

Name	Date modified
Ave_Bkg_943-944-945.spa	9/20/2010 9:47 AM
Ave_Bkg_943-944-945-1018-1019-1020-1021.spa	10/27/2010 9:29 AM
Ave_Bkg_1018-1019-1020-1021.spa	9/20/2010 10:22 AM
Ave_Bkg_1018-1019-1020-1021-1213-1214.spa	10/27/2010 10:18 ...
ave_bkg-1113-1114.sgl	9/20/2010 11:24 AM
ave_bkg-1213-1214.sgl	9/20/2010 1:59 PM
ave_bkg-1358-1359.sgl	10/27/2010 11:28 ...
Mb blue sky G=1.SPA	9/20/2010 8:29 AM
Mbb T=275 C G=1.SPA	9/20/2010 7:53 AM
Mir V=4.5 G=1.SPA	9/20/2010 7:34 AM
Mn LN2 09-20-2010.SPA	9/20/2010 7:45 AM

Calibration Spectra for 09/21/2010

Name	Date modified
2010-09-21_100844.sgl	9/21/2010 10:08 AM
AVE_BKG-916-917.spa	9/21/2010 9:20 AM
AVE_BKG-917-934.spa	10/27/2010 1:32 PM
AVE_BKG-952-1008-1029.spa	10/27/2010 1:34 PM
AVE_BKG-1043-1059-1133.spa	10/27/2010 1:35 PM
AVE_BKG-1149-1208.spa	10/27/2010 1:36 PM
AVE_BKG-1354-1355.spa	10/27/2010 1:37 PM
AVE_BKG-1354-1355-1413-1433-1434-155...	10/27/2010 2:39 PM
BKG#2 partly cloudy G=1.SPA	9/21/2010 8:26 AM
Mb Sky Blue G=1.SPA	9/21/2010 8:11 AM
Mbb T=275 C G=1.SPA	9/21/2010 7:48 AM
Mir 4.5 v g=1.SPA	9/21/2010 7:35 AM
Mn LN2 G=1.SPA	9/21/2010 7:39 AM

Calibration Spectra for 09/22/2010

Name	Date modified
ave_bkg_924-925.SPA	9/22/2010 9:26 AM
ave_bkg_1104-1105.SPA	9/22/2010 11:07 AM
ave_bkg_1202-1203-1658-1659.SPA	9/26/2010 6:17 PM
ave_bkg_1259-1300.SPA	9/22/2010 1:01 PM
ave_bkg_1506-1553-1554-1648-1658-1659...	10/27/2010 4:59 PM
AVE-BKG-1027-thru-1442.sgl	10/27/2010 4:26 PM
Mb Blue Sky G=1 09-22-2010.SPA	9/22/2010 8:20 AM
Mbb T=275 C G=1.SPA	9/22/2010 8:13 AM
Mir V=6 G=1.SPA	9/22/2010 8:01 AM
Mn LN2 G=1.SPA	9/22/2010 8:01 AM

Calibration Spectra for 09/23/2010

Name	Date modified
AVE-BKG-0857-to-1617.sgl	10/28/2010 10:45 ...
Mb Part Cloudy Sky G=1 09-23-2010.SPA	9/23/2010 8:31 AM
Mbb T=300 C G=1.SPA	9/23/2010 8:13 AM
Mir V=5,5 G=1.SPA	9/23/2010 7:59 AM
Mn LN2 G=1.SPA	9/23/2010 8:04 AM

Calibration Spectra for 09/27/2010

Name	Date modified
AVE-BKG-1005-to-1415.sgl	10/29/2010 11:55 ...
AVE-BKG-1005-to-1604.sgl	10/29/2010 11:57 ...
Mb V=0,7 G=1 Clear Sky.SPA	9/27/2010 8:05 AM
Mb V=0,7 G=1 Plume BKG.SPA	9/27/2010 8:11 AM
Mbb 300C V=4,5 G=1.SPA	11/6/2010 10:02 AM
Mir V=4,2 G=1.SPA	9/27/2010 7:45 AM
Mn LN2 V=0,5 G=1.SPA	9/27/2010 7:51 AM

Calibration Spectra for 09/28/2010

Name	Date modified
Ave-Bkg-948-to-1133.sgl	10/29/2010 3:13 PM
Ave-Bkg-1324-to-1645.sgl	10/29/2010 3:15 PM
Mb V=0.7 G=1 Most clear.SPA	9/28/2010 8:07 AM
Mbb T=300C V=5,1 G=1.SPA	9/28/2010 8:00 AM
Mir V=5 G=1.SPA	9/28/2010 7:48 AM
Mn LN2 V= 0.7 G=1.SPA	9/28/2010 7:54 AM

Calibration Spectra for 09/07/2010

Name	Date modified
Ave-Bkg-916-to-1237.sgl	10/30/2010 9:22 AM
Mb V=0,8 G=1 Clear.SPA	9/29/2010 8:16 AM
Mbb T=300C V=5,4 G=1.SPA	9/29/2010 8:09 AM
Mir V=5 G=1.SPA	9/29/2010 7:52 AM
Mn LN2 V= 0.8 G=1.SPA	9/29/2010 7:58 AM

ImaccQuantfy - concentrations file
methodFile(s) = C:\FTIRMethods\ground flare\Combustion_250C.method

Timestamp	***Measured CO2***	***Expected CO2***
12/01/10 04:43 PM	13755.4	
Averages	***13755.4***	***13600***
12/01/10 04:31 PM	25032.5	
Averages	***25032.5***	***25000***
12/01/10 05:05 PM	4124.5	
Averages	***4124.5***	***4167***
12/01/10 04:58 PM	7331.3	
Averages	***7331.3***	***7143***

%Recovery

101.1

100.1

99.0

102.6