



PARTICULATE EMISSION TEST SURVEY

FOR

DUNLOP OIL & MARINE LTD

Project No : 77390-03 (1)

9 December 2014

Global Surface Coatings Covered



ENVIRONMENTAL SERVICES TEST REPORT

Project No. 77390-03 (1)
Test Dates 12 November 2014
Report Date 9 December 2014
Client Dunlop Oil & Marine Ltd
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FAO Chris Allen

Work requested Particulate Emission Test Survey

A handwritten signature in black ink, appearing to read 'T. Sullivan', is positioned above the printed name.

Work carried out by T. Sullivan
Environmental Services

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Approved by T.J. Glazier, A. Miller
Approved Signatory

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PARTICULATE EMISSION TEST SURVEY

1.0 Introduction

This report presents the test procedures, results, conclusions and recommendations of the test survey carried out on 12 November 2014 by Tim Sullivan MCERTS Accreditation No. MM03456.

Dunlop Oil & Marine Ltd have asked PRA to carry out particulate emission testing of the two dust release points. The Bag Filtration Unit which serves LEV 07 (Banbury Mixer & experimental lab), LEV 40 (bulk carbon black hoppers) and LEV's 1, 2, 38 & 39 (powder weighing and Banbury Mixer downchute) and the Banbury Mixer release point. An isocyanate emission concentration measurement was also taken at the face extract of the PU coating process for hoses.

This test survey will enable Dunlop Oil & Marine Ltd to check their compliance against the particulate emission limits given in process guidance note PG6/28 (11) "Guidance for Rubber" revised 2013.

2.0 Test Procedures

2.1 Location of Sampling Ports

A description of the sampling port location at each release point is given in table 1. Diagrams of the stacks and sampling ports are shown in appendix 1.

Table 1 Sample point locations

Release Point	Test Parameters
1. Bag Filtration Unit	Particulate emission
2. Banbury Mixer	Particulate emission
3. PU Coating Process	Isocyanate emission

2.2 Flow

The gas velocity at release point 2 (Banbury Mixer) was measured using an ellipsoidal nose pitot tube and calibrated micromanometer in accordance with ISO 10780 "Measurement of velocity and volume flowrate of gas streams in ducts".

The gas velocity at the exit grill of release point 1 was too turbulent to measure using a pitot tube and micromanometer, therefore a rotating vane anemometer was used to give an indication of the gas velocity.

The gas temperature was measured using a calibrated digital temperature indicator and K type probe. The temperature was measured at the same sampling points as the flow measurements.

2.3 Particulate Emission

The particulate emission was measured using a gravimetric filter technique in accordance with BS ISO 9096 : 2003 "Manual determination of mass concentration of particulate matter."

For release point 1 (bag filtration unit) the flow did not meet the criteria stated in BS ISO 9096. However indicative flow measurement was taken using a hand held rotating vane anemometer.

For release point 2 (Banbury Mixer) the angle of gas flow was less than 15° with respect to the duct axis, no negative gas flow was found, the minimum pitot static reading was greater than 5 Pa and the ratio of the highest and lowest pitot static readings was less than 3:1. The temperature across the ducts did not vary by more than 5 % from the mean temperature. Therefore the flow in the sampling plane met the criteria stated in BS ISO 9096.

For release point 1 (bag filtration unit) the duct area was between 0.38 and 1.50 m² therefore nine point cumulative sampling at 0.25D, 0.50D and 0.75D along three sample lines was used.

For release point 2 the duct diameter was between 0.35 and 0.70 m therefore five point cumulative sampling at 0.113D, 0.50D and 0.887D along two stack diameters would normally be used. However because the working platform only gave access one side of the duct, it was decided to carry out five point sampling at 0.059D, 0.211D, 0.50D, 0.789D and 0.941D along a single stack diameter. It is considered that this sampling procedure would provide representative sample of the particulate emission.

The particulate sampling train (J.S. Holdings Stack Sampler) was checked for leaks under pressure (i.e. the sampling train was assembled, the sample pump was switched on, the nozzle of the probe was covered and the flow rate was checked to ensure a stable vacuum was maintained). The test showed the sample train was leak free.

The sampled gas was extracted at a rate that ensured the gas velocity at the sampler nozzle was equal to the gas velocity in the stack at the point of sampling (i.e. isokinetic sampling).

One particulate concentration determination was taken for each of the release points in order to sample for longer and try to ensure a measurable weight gain on the filter.

The uncertainty in the particulate concentration due to deviations from BS ISO 9096 was estimated using guidelines given by the Source Testing Association.

2.4 Isocyanate Emission

The isocyanate concentration was measured in accordance with OSHA 42 “Di-isocyanates in air”. The exhaust gas was drawn through a 25 mm glass fibre filter impregnated with 1-(2-pyridyl) piperazine reagent using a sampling pump at a flow rate of 2 litres per minute. The filter was then analysed for MDI (methylenediphenyl-di-isocyanate) by a UKAS accredited laboratory using high performance liquid chromatography.

3.0 Results

This section presents a summary of the test results. All test results are reported at reference conditions 273 K and 1013 m.bar without correction for water vapour.

The measurements were carried out under what was considered typical production conditions.

The methods for calculating the gas velocity, volume flow, particulate concentration, and isocyanate concentration are shown in appendix 2. The test data is shown in appendix 3.

3.1 Flow

The gas velocity and volume flow for each release point are shown in table 2.

Table 2 Flow

Release Point	Date	Gas Velocity (m/s)	Volume Flow at STP (m ³ /h)
1. Bag Filtration Unit	12 November – 11.15	9.42	12110
2. Banbury Mixer	12 November – 13.40	10.11	9219

3.2 Particulate Emission

3.2.1 Release Point 1 – Bag Filtration Unit

The particulate concentration measured at release point 1 is shown in table 3.

Table 3 Particulate emission concentration

Test No.	Date/Time	% Isokinetic	Sampling Period (mins)	Weight of Particulate (mg)	Volume Sampled (m ³)	Particulate Conc. (mg.m ⁻³)
1	12 November 11.30	108	54	0.2	0.8286	0.2 ± 0.4

3.2.2 Release Point 2 – Banbury Mixer

The particulate concentration measured at the Banbury Mixer extract duct is shown in table 4.

Table 4 Particulate emission concentration

Test No.	Date/Time	% Isokinetic	Sampling Period (mins)	Weight of Particulate (mg)	Volume Sampled (m ³)	Particulate Conc. (mg.m ⁻³)
1	12 November 14.00	103	50	1.6	0.7734	2.1 ± 0.5

3.2.3 Particulate Blank

The blank particulate concentration is shown in table 5.

Table 5 Blank Particulate emission concentration

Test No.	Date	Weight of Blank (mg)	Average Volume Sampled (m ³)	Blank Particulate Conc. (mg.m ⁻³)
1	12 November	0.1	0.8010	0.1

3.3 Isocyanate Emission

The isocyanate measurement taken at the face extract of the PU coating process for hoses is shown in table 6.

Table 6 Isocyanate concentration

Test No.	Date & Time	Weight of Isocyanate (µg)	Volume sampled (litres)	Isocyanate Concentration (mg.m ⁻³)
1	12 November 11.05	< 0.07	168.8	< 0.0004

4.0 Conclusions

The particulate emission concentration (0.2 mg.m⁻³) from release point 1 – Bag Filtration Unit - is below the emission limit of 10 mg.m⁻³ for the storage, handling or mixing of carbon black as set out in process guidance note PG6/28 (11) “Guidance for Rubber”.

The particulate emission concentration (2.1 mg.m⁻³) from release point 2 - Banbury Mixer is below the emission limit of 50 mg.m⁻³ for any source other than carbon black.

The isocyanate emission concentration (< 0.0004 mg.m⁻³) for the PU coating process is below the emission limit of 0.1 mg.m⁻³.

APPENDIX 1

Diagram I.0 Sampling Points for Bag Filtration Unit

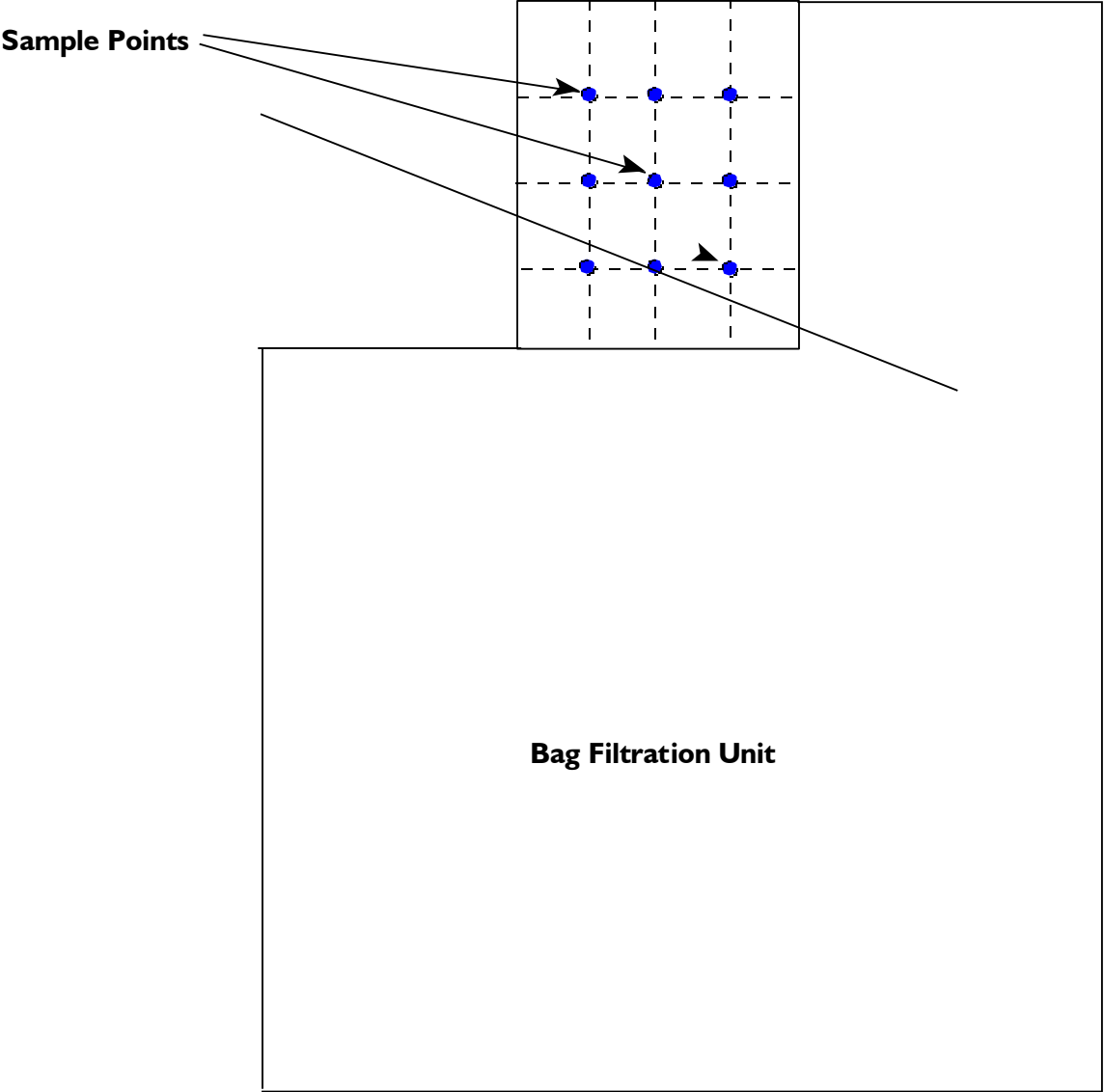


Diagram 2. Sample Point for Banbury Mixer

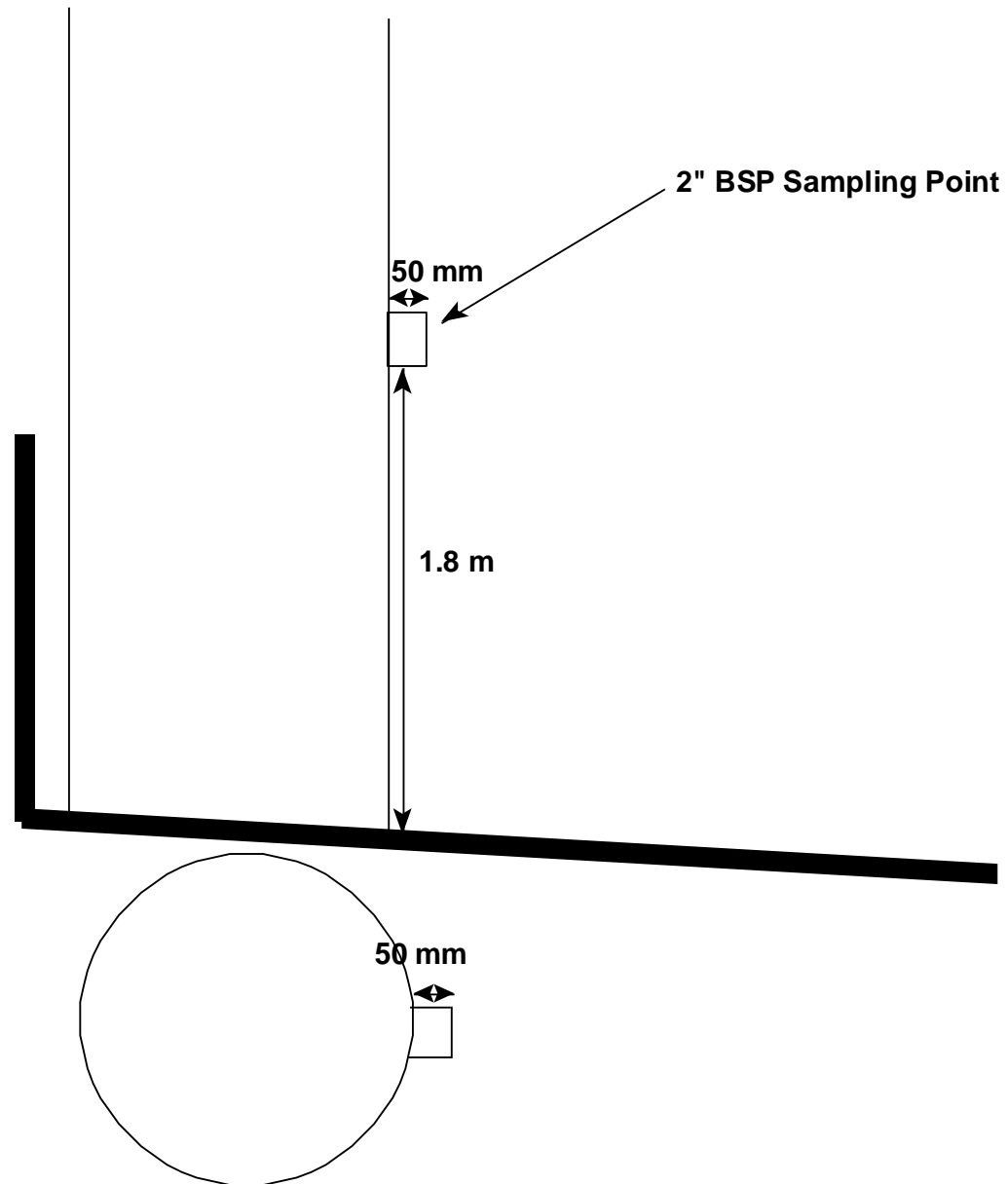
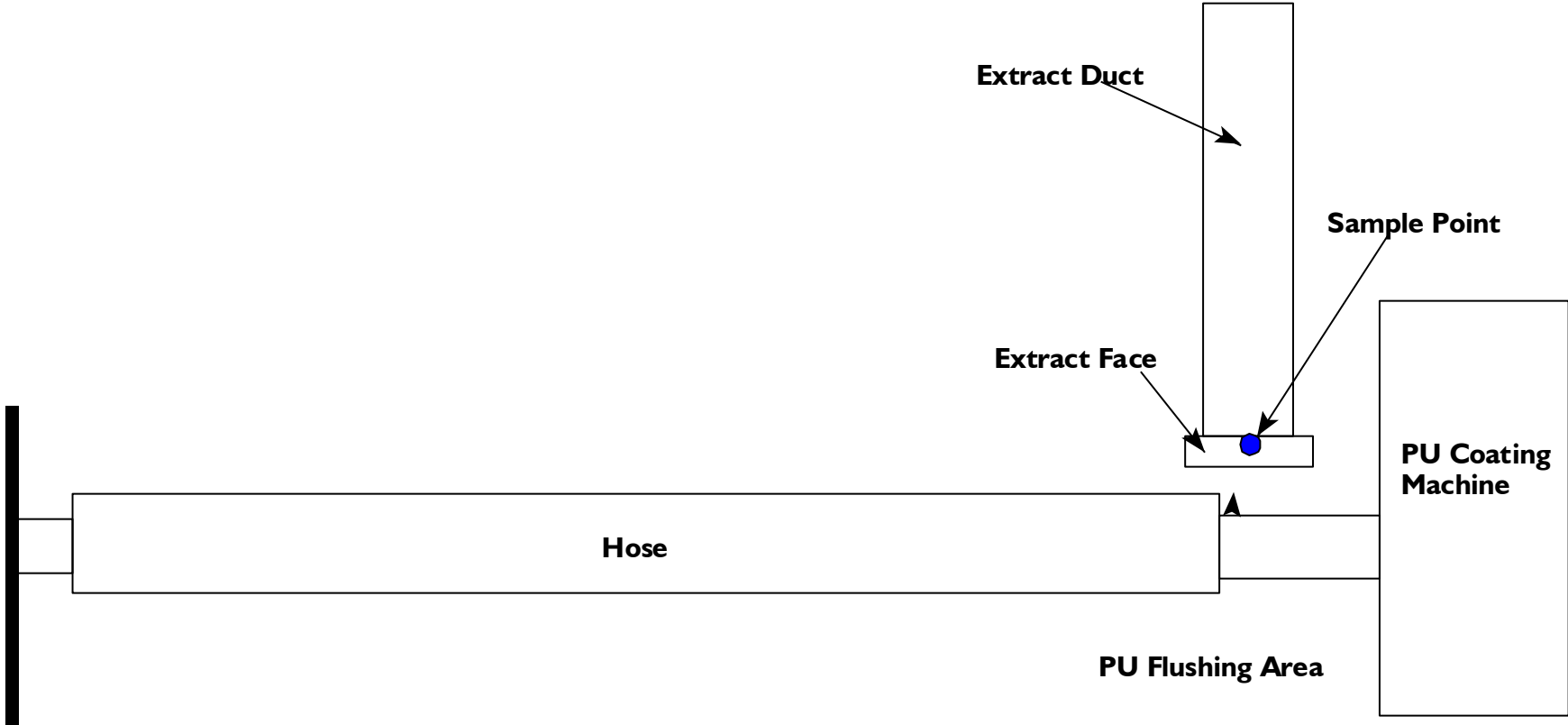


Diagram 3.0 Sampling Point for PU Coating Process



APPENDIX 2

Calculations

1.0 Gas Flow Calculations

i) Gas velocity at S.T.P (273 K and 1013 m.bar)

$$V_{STP} = 1.29 \times \sqrt{H_v}$$

where V_{STP} = gas velocity at STP (m/s)
 K_p = pitot correction factor
 = 0.996
 1.29 = gas density at 273 K and 1013 m.bar
 H_v = mean velocity pressure (Pa)

ii) Actual gas velocity (V_A)

$$V_A = V_{STP} \times \sqrt{\frac{T}{273} \times \frac{1013}{0.01(H_s) + B}}$$

where V_{STP} = gas velocity at STP (m/s)
 T = temperature of gas in duct (K)
 H_s = static pressure (Pa)
 B = atmospheric pressure (m.bar)

iii) Actual Gas Flowrate (Q)

$$Q = V_A \times A \times 3600$$

where Q = gas flowrate (m³/h)
 V_A = actual gas velocity (m/s)
 A = X sectional area of vent (m²)

iv) Gas flowrate at STP (Q_{STP})

$$Q_{STP} = Q \times \frac{273}{T} \times \frac{B}{1013}$$

where Q = gas flowrate at STP (m³/h)
 T = temperature of gas in stack (K)
 B = barometric atmospheric pressure (m.bar)

2.0 Particulate Emission Concentration

2.1 Weight of Particulate

a) weight of particulate on filter = $(F_2 - F_1) - (C_2 - C_1)$

where F_2 = final weight of test filter (g)

F_1 = initial weight of test filter (g)

C_2 = final weight of control filter (g)

C_1 = initial weight of control filter (g)

b) weight of particulate in washings = $(E_2 - E_1) - (C_2 - C_1)$

where E_2 = final weight of evaporated washing + dish (g)

E_1 = initial weight of dish (g)

C_2 = final weight of control dish (g)

C_1 = initial weight of control dish (g)

c) total weight of particulate = a + b

2.2 Volume Sampled

a) registered volume sampled (V_R) = $M_2 - M_1$

where M_2 = final gas meter reading (m^3)

M_1 = initial gas meter reading (m^3)

b) true volume sampled (V_T) = $V_R \times (100 \times R_E)$

where V_R = registered volume (m^3)

R_E = gas meter correction factor

= 0.988

c) true volume sampled to STP = $V_T \times \frac{273}{T} \times \frac{B}{1013}$

where V_T = true volume sampled (m^3)

273 = standard temperature (K)

T = gas temperature in stack (K)

1013 = standard atmospheric pressure (m.bar)

B = atmospheric pressure (m.bar)

2.3 Particulate Concentration

$$\text{mg.m}^{-3}_{(\text{particulate})} = \frac{W_t}{V}$$

where W_t = total weight of particulate captured
 V = true volume of gas sampled corrected to STP

2.4 Isokinetic Sampling

$$\% \text{ Isokinetic} = \frac{\text{gas velocity at nozzle (m/s)}}{\text{gas velocity at sample point in duct (m/s)}} \times 100$$

a) gas velocity at nozzle = $\frac{V_T}{A_N \times T_S}$ (m/s)

where V_T = true volume of gas sampled at actual temperature & pressure. (m^3)
 A_N = nozzle area (m^2)
 T_S = sampling time (secs)

b) gas velocity at sample point in duct

$$= 1.29 \times \sqrt{H_V} \times \sqrt{\frac{T}{273} \times \frac{1013}{B}}$$

where 1.29 = gas density at 273 K and 1013 m.bar
 $\sqrt{H_V}$ = mean square root of the velocity pressure (Pa)
 T = temperature of gas in duct (K)
 B = atmospheric pressure (m.bar)

3.0 Blank Concentration

3.1 Weight of Particulate

a) weight of particulate on blank filter = $(B_2 - B_1) - (C_2 - C_1)$
 where B_2 = final weight of blank filter (g)
 B_1 = initial weight of blank filter (g)
 C_2 = final weight of control filter (g)
 C_1 = initial weight of control filter (g)

b) weight of particulate in blank washings = $(W_2 - W_1) - (C_2 - C_1)$
where W_2 = final weight of evaporated blank washing + dish (g)
 W_1 = initial weight of dish (g)
 C_2 = final weight of control dish (g)
 C_1 = initial weight of control dish (g)

c) total weight of blank particulate (M_B) = a + b

3.2 Volume Sampled

a) average volume sampled (V_A) = $\frac{V_1 + V_n}{n}$
where V_1 = volume of gas sampled corrected to STP for test 1 (m^3)
 V_n = volume of gas sampled corrected to STP for test n (m^3)

3.3 Blank Particulate Concentration

Blank Concentration ($mg.m^{-3}$) = $\frac{M_B}{V_A}$

where M_B = mass of blank (μg)
 V_A = average volume sampled at STP from daily tests (m^3)

4.0 Isocyanate Concentration

Concentration ($mg.m^{-3}$) = $\frac{M}{V_{STP}}$

where M = mass of isocyanate (μg)
 V_{STP} = volume sampled at STP (litres)

APPENDIX 3

Test Data

1. FLOW MEASUREMENTS

Dunlop Oil & Marine Ltd

Project No : 77390-03 (1)

1.1 Release Point 1 - Bag Filtration Unit

Date:	12/11/2014
Time:	11.15
Gas temperature (K)	300
Atmospheric pressure (m.bar)	994
Duct Dimensions (m)	0.8 x 0.5
Area (m ²)	0.4000

	Face Velocity (m/s)		Average Face Velocity (m/s)
11.6	7.4	8.0	9.42
10.6	10.5	10.3	
7.9	10.1	8.4	

Gas flowrate (m ³ /h)	13562
Gas flowrate at STP (m ³ /h)	12110

1. FLOW MEASUREMENTS

Dunlop Oil & Marine Ltd

Project No: 77390-03 (1)

1.2 Release Point 2 - Banbury Mixer

Date:	12/11/2014
Time:	13.40
Gas temperature (K)	299
Atmospheric pressure (m.bar)	994
Static pressure (m.bar)	0.45
Duct Dimensions (m)	0.6
Area (m ²)	0.2827

Distance Along Sample Line	Vel. Pressure Hv (Pa)	Sqrt Hv	Average Sqrt Hv (Pa)	Gas Velocity. (m/s)
0.059D	42	6.48	7.45	10.11
0.211D	44	6.63		
0.500D	53	7.28		
0.789D	70	8.37		
0.941D	72	8.49		

Gas flowrate (m ³ /h)	10290
Gas flowrate at STP (m ³ /h)	9219

2. PARTICULATE EMISSION: VOLUME SAMPLED

Dunlop Oil & Marine Ltd

Project No : 77390-03 (1)

Standard Temperature (K) = 273
 Standard Pressure (m.bar) = 1013

2.1 Release Point 1 - Bag Filtration Unit

Test	Date	Time	Temp K	Pressure m.bar	Initial Gas Meter m3	Final Gas Meter m3	Sampled Volume m3	True Volume m3	Volume at STP m3
1	12-Nov	11.30	300	994	750.0440	750.9832	0.9392	0.9279	0.8286

2.2 Release Point 2 - Banbury Mixer

Test	Date	Time	Temp K	Pressure m.bar	Initial Gas Meter m3	Final Gas Meter m3	Sampled Volume m3	True Volume m3	Volume at STP m3
1	12-Nov	14.00	308	995	750.9874	751.8865	0.8991	0.8883	0.7734

3. PARTICULATE EMISSION: WEIGHT COLLECTED

Dunlop Oil & Marine Ltd

Project No: 77390-03 (1)

3.1 Release Point 1 - Bag Filtration Unit

Test	Date	Time	Weight on Filter (mg)	Weight on Control (mg)	Particulate on Filter (mg)	Particulate in Washing (mg)	Total Collected (mg)
1	12-Nov	11.30	0.0	-0.1	0.1	0.1	0.2

3.2 Release Point 2 : Banbury Mixer

Test	Date	Time	Weight on Filter (mg)	Weight on Blank Filter (mg)	Particulate on Filter (mg)	Particulate in Washing (mg)	Total Collected (mg)
1	12-Nov	14.00	0.6	-0.1	0.7	0.9	1.6

3.3 Blank 1

Test	Date	Time	Weight on Filter (mg)	Weight on Blank Filter (mg)	Particulate on Filter (mg)	Particulate in Washing (mg)	Total Collected (mg)
1	12-Nov	15.05	0.0	-0.1	0.1	0.0	0.1

4. PARTICULATE EMISSION: CALCULATION OF % ISOKINETIC SAMPLING

Dunlop Oil & Marine Ltd

Project No : 77390-03 (1)

Standard Temperature (K) 273
 Standard Pressure (m.bar) 1013

4.1 Release Point 1 - Bag Filtration Unit

Test 1 12-Nov-14 11.30
 Temp = 300
 Press = 994

	Velocity pressure (Pa)	Nozzle Size	Nozzle Area (m2)	Sampling Flowrate (litres/min)	Time Sampled (secs)	Initial gas meter (m3)	Final gas meter (m3)	Sampled Volume (m3)	True Volume (m3)	Velocity at nozzle (m/s)	SQRT Hv (Pa)	Velocity in Duct (m/s)	% isokinetic
Test 1	47.6	0.006	2.827E-05	16.5	3240	750.0440	750.9832	0.9392	0.9279	10.13	6.90	9.42	108

4.2 Release Point 2 - Banbury Mixer

Test 1 12-Nov-14 14.00
 Temp = 308
 Press = 995

Sample Point	Velocity pressure (Pa)	Nozzle Size	Nozzle Area (m2)	Sampling Flowrate (litres/min)	Time Sampled (secs)	Initial gas meter (m3)	Final gas meter (m3)	Sampled Volume (m3)	True Volume (m3)	Velocity at nozzle (m/s)	SQRT Hv (Pa)	Velocity in Duct (m/s)	% isokinetic
Test 1	55.9	0.006	2.827E-05	16.8	3000	750.9874	751.8865	0.8991	0.8883	10.47	7.48	10.21	103

5.0 Uncertainty calculation for EN 13284 Determination of low range mass concentration of dust, Manual Gravimetric Method

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5.1 Bag Filter- Test 1

Measurement Equation

$$c = \frac{m}{V} f_c$$

Limit value (ELV)	10	mg.m ⁻³	Reference oxygen		% by volume
Measured concentration	0.20	mg.m ⁻³ (at reference conditions)			

Measured Quantities	Symbol	Value	Standard uncertainty	Units	Uncertainty as percentage	Uncertainty at lv	Requirement of std
Sampled Volume	V _m	0.9279	uV _m	0.001 m ³	0.11		<=2%
Sampled gas Temperature	T _m	300	uT _m	2 k	0.67		<=1%
Sampled gas Pressure	ρ _m	99.4	uρ _m	1 kPa	1.01		<=1%
Sampled gas Humidity	H _m	0	uH _m	1 % by volume	1.00		<=1%
Oxygen content	O _{2,m}		uO _{2,m}	0.1 % by volume	#DIV/0!		<=5%
Mass particulate	m	0.2	um	0.18 mg	91.05	1.82	<5% of limit value
Note - Sampled gas humidity, temperature and pressure are values at the gas meter							
Leak	L	2		%	2.00		<=2%
Uncollected Mass (Instack filter - no rinse)	UCM	0		mg	0		<=10%

Intermediate calculations

Factor for std conds uncertainty components	symbol	Value	sensitivity coeff	u (in units of fs)	Equation	Value
Factor for std conds	fs	0.89				
ρ _m		0.009		0.009	$f_s = \frac{(100 - H_m) \cdot 273 \cdot \rho_m}{100 \cdot T_m \cdot 101.3}$	
H _m		0.009		0.009		
T _m		0.003		0.006		
ufs				0.014		1.57
Corrected volume	V	0.83		uV	0.013 m ³	V = V _m f _s
Factor for O2 correction uncertainty components	symbol	Value	sensitivity coeff	u	Equation	Value
Factor for O2 correction	fc	1.00				
O _{2,m}		0.05		0.005	$f_c = \frac{21 - O_{2,ref}}{21 - O_{2,m}}$	
Factor for O2 Correction	ufc	1.00		0.005		0.48

Parameter	Value	Units	Sensitivity coeff	Uncertainty contribution	Uncertainty as %
Corrected Volume (standard conc)	V	0.83 m ³	0.24	0.00 mg.m ⁻³	1.57 %
Mass	m	0.20 mg	1.00	0.18 mg.m ⁻³	91.05 %
Factor for O2 Correction	fc	1.00	0.20	0.00 mg.m ⁻³	0.48 %
Leak	L	0.00 mg.m ⁻³	1.00	0.00 mg.m ⁻³	1.15 %
Uncollected mass	UCM	0.00 mg	1.00	0.00 mg.m ⁻³	0.00 %
Combined measurement uncertainty				0.18 mg.m⁻³	

Expanded uncertainty as percentage of measured value	182.14	% measured of value	expressed with a level of confidence of 95% (Using a coverage factor k=2)
Expanded uncertainty in units of measurement	0.36	mg.m ⁻³	
Expanded uncertainty as percentage of limit value	3.64	% ELV	

Note: Enter values into green boxes

5.0 Uncertainty calculation for EN 13284 Determination of low range mass concentration of dust, Manual Gravimetric Method

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5.2 Banbury Mixer- Test 1

Measurement Equation

$$c = \frac{m}{V} f_c$$

Limit value (ELV)	10	mg.m ⁻³	Reference oxygen		% by volume
Measured concentration	2.10	mg.m ⁻³ (at reference conditions)			

Measured Quantities	Symbol	Value	Standard uncertainty	Units	Uncertainty as percentage	Uncertainty at lv	Requirement of std
Sampled Volume	V _m	0.8883	uV _m	0.001 m ³	0.11		<=2%
Sampled gas Temperature	T _m	308	uT _m	2 k	0.65		<=1%
Sampled gas Pressure	ρ _m	99.5	uρ _m	1 kPa	1.01		<=1%
Sampled gas Humidity	H _m	0	uH _m	1 % by volume	1.00		<=1%
Oxygen content	O _{2,m}		uO _{2,m}	0.1 % by volume	#DIV/0!		<=5%
Mass particulate	m	1.6	um	0.18 mg	11.40	2.39	<5% of limit value
Note - Sampled gas humidity, temperature and pressure are values at the gas meter							
Leak	L	2		%	2.00		<=2%
Uncollected Mass (Instack filter - no rinse)	UCM	0		mg	0		<=10%

Intermediate calculations

Factor for std conds uncertainty components	fs	0.87					
	symbol	sensitivity coeff	u (in units of fs)				
	ρ _m	0.009	0.009				
	H _m	0.009	0.009				
	T _m	0.003	0.006				
	ufs		0.014			1.56	
Corrected volume	V	0.77	uV	0.012 m ³	$V = V_m f_s$	1.56	
Factor for O2 correction uncertainty components	fc	1.00					
	symbol	sensitivity coeff	u				
	O _{2,m}	0.05	0.005				
Factor for O2 Correction	ufc	1.00		0.005	$f_c = \frac{21 - O_{2,ref}}{21 - O_{2,m}}$	0.48	

Parameter	Value	Units	Sensitivity coeff	Uncertainty contribution	Uncertainty as %
Corrected Volume (standard conc)	V	0.77 m ³	2.72	0.03 mg.m ⁻³	1.56 %
Mass	m	1.60 mg	1.31	0.24 mg.m ⁻³	11.40 %
Factor for O2 Correction	fc	1.00	2.10	0.01 mg.m ⁻³	0.48 %
Leak	L	0.02 mg.m ⁻³	1.00	0.02 mg.m ⁻³	1.15 %
Uncollected mass	UCM	0.00 mg	1.31	0.00 mg.m ⁻³	0.00 %
Combined measurement uncertainty				0.24 mg.m⁻³	

Expanded uncertainty as percentage of measured value	23.15	% measured of value	expressed with a level of confidence of 95% (Using a coverage factor k=2)
Expanded uncertainty in units of measurement	0.49	mg.m ⁻³	
Expanded uncertainty as percentage of limit value	4.86	% ELV	

Note: Enter values into green boxes

6.0 ISOCYANATE MEASUREMENTS - VOLUMES SAMPLED

Dunlop Oil & Marine Ltd

Project No : 77390-03 (1)

Standard Temperature (K) = 273
Standard Pressure (m.bar) = 1013

6.1 PU Coating Process

Stack	Date	Pump	Temp K	Pressure m.bar	Flow Rate litres/minute	Sampling Time minutes	Actual Volume litres	Volume at STP litres
1	12-Nov	SKC 403825	292	994	2	92	184.00	168.80



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