



COT bv
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REPORT

Testing of coating system
according to EN 10290 Type 2 Class B

Haarlem, 7th October 2013

Civil projects
Corrosionprotection
Laboratory

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1 INTRODUCTION

1.1 Commission

By commission of Welesgard Ltd., in Kiev, Ukraine, the Centrum voor Onderzoek en Technisch advies bv (COT) in Haarlem, The Netherlands, has tested the system WG Welepipe according to EN 10290, Type 2 Class B.

The tests has been offered in COT quotation, reference BA/MH LAB13-0048-OFF, dated January 31st 2013.

1.2 General information

Table 1: Sample information

COT sample number	Sample	Dimensions (mmxmmx mm)	Amount / Panel numbers	Batch number	Colour	Received
02-05-13/0176	Steel panels, coated with WG Welepipe	150 x 100 x 5 150 x 100 x 5* 150 x 150 x 5* 300 x 150 x 5 300 x 50 x 5	24x / 1-30 3x / 31-33 4x / 40-43 9x / 44-52 6x / 34-39	--	Grey	01-05-2013
28-05-13/0192	Free film WG Welepipe	200 x 100 x 1		--	Grey	28-05-2013
02-05-13/0175	WG Welepipe A WG Welepipe B		0.5 L 1 L	-- 120127248	Grey Amber	01-05-2013

*Sealed coating all sides

Table 2: Panel numbers and tests

Panel numbers	Test
All	Dry film thickness
All	Holiday detection
4-9	Adhesion – Resistance to removal
10-15	Adhesion – Pull off
40-43	Cathodic disbondment
34-39	Flexibility
1-3	Hardness
31-33	Immersion – tap water
46, 52, 22-30	Impact resistance
16-18, (7-9)	Indentation Resistance
4-9	Resistance to removal
44, 45, 47, 49-51	Specific electrical insulation resistance
19-21	Thermal Ageing



Table 3: Coding of used calibrated COT equipment

COT Equipment	Description of equipment
A006	Hydraulic Precision Adhesion Tester
D001	Shore D Meter
E009	Digital Thickness Meter, type D7 according ISO 2808
I003	Digital Insulation Resistance Tester
M012	Digital Multi Meter
O002 / O004	Thermostat regulated Ovens at 60 and 80 °C
P002	High voltage Holiday Detector
S023	Impact Equipment, with various diameter nubs and weights
S027	Digital Slide Gauge
S029	FT-IR Infra-red Scanner
T024	MTS M/2 Tensile strength Machine

2 PROCEDURE

Table 4: Tests carried out according to EN 10290 paragraph 7.2 to 7.17

Test	Method	Equipment	Information	Requirements
Dry Film Thickness (DFT)	ISO 2178	COT E009	Arithmetic mean of 5-10 readings	Class B: ≥ 1500 micron
Hardness Shore D	ISO 868	COT D001	--	Specified by manufacturer
Appearance and continuity	Section 7.4	--	Visual inspection	Uniform colour and appearance; No defects
Holiday detection	Annex B	COT P002	8 V/ μ m nominal DFT (e.g. 12 kV)	No holidays
Impact resistance	Annex C, Annex B	COT S023	25 mm nub, 1(+1) kg at -5 ± 3 °C	No perforation at impact: > 3 (J) x thickness (mm)
			at 23 ± 2 °C	> 5 (J) x thickness (mm)
Resistance to removal	Annex D	COT O002	at 23 ± 2 °C	\leq Rating 3
			at 23 ± 2 °C	\leq Rating 4
Adhesion Pull-off method	EN 24624	COT A006, COT O002	at 23 °C	> 7 MPa, No substrate/coating break
			at 60 °C, 23 °C	Results for information
Cathodic disbondment	Annex E	COT M012, COT S027	28 days, $\varnothing_{\text{cell}}$ 100 mm, 6 mm holiday, 3 % NaCl, 23 °C, -1.5 V, ref. Ag/AgCl	Radius of disbondment: Average ≤ 8 mm Maximum ≤ 10 mm
Specific electrical insulation resistance	Annex F	COT M012, COT I003	100 days at 23 ± 2 °C	$R_{s100} \geq 10^7 \Omega \cdot \text{m}^2$, When $R_{s70} \leq 10^8 \Omega \cdot \text{m}^2$: $R_{s100}/R_{s70} < 0.8$
			30 days at 60 ± 2 °C.	$R_{s30} \geq 10^4 \Omega \cdot \text{m}^2$
Indentation resistance	Annex H	Indentation gauge x2, COT O002	2.5 kg, at 23 ± 2 °C at 60 ± 2 °C	< 0.2 mm ≤ 30 % DFT
Thermal ageing	Annex J: EN 24624	COT A006, COT O004	100 days at 80 °C	Results for information
Flexibility	Annex K	COT T024, Mandrel	at 23 ± 2 °C at 0 ± 2 °C	Mandrel \varnothing ; no cracks mm, SG = 250 mm mm, SG = 250 mm
Elongation	ISO 527-1 ISO 527-3	COT T024	at 23 ± 2 °C, 1 mm/min specimen type 2	Elongation ≥ 10 %
Infra-red scan	FTIR - protocol	COT S029, 'Golden Gate' accessory	Cured product, Liquid samples	As manufacturer's FT-IR fingerprint scans

3 RESULTS

3.1 Minimum Dry Film Thickness of the coating system

The dry film thickness (DFT) has been determined of all panels with COT sample number 02-05-13/0176, the overall mean dry film thickness is $1852 \pm 102 \mu\text{m}$, all panels have DFT above the minimum dry film thickness of $1500 \mu\text{m}$.

Table 5: Dry film thickness (COT sample number 02-05-13/0176)

Test date: 13-05-2013

Panel no.	DFT (μm)			Panel no.	DFT (μm)			Panel no.	DFT (μm)		
	Mean	High	Low		Mean	High	Low		Mean	High	Low
1	1773 \pm 101	1915	1575	19	1876 \pm 64	1985	1785	37	1848 \pm 68	1975	1755
2	1901 \pm 56	1965	1795	20	1979 \pm 63	2095	1875	38	1690 \pm 67	1795	1565
3	1850 \pm 117	2065	1715	21	1774 \pm 96	1945	1625	39	1884 \pm 89	1985	1715
4	1821 \pm 98	2005	1695	22	1959 \pm 99	2105	1825	40	1818 \pm 62	1905	1705
5	1793 \pm 113	1975	1635	23	1798 \pm 66	1885	1665	41	1870 \pm 77	1955	1755
6	1755 \pm 97	1935	1635	24	1821 \pm 66	1895	1725	42	1852 \pm 51	1915	1575
7	1773 \pm 91	1915	1615	25	1759 \pm 88	1875	1545	43	1811 \pm 43	1935	1755
8	1957 \pm 79	2055	1825	26	1871 \pm 65	1995	1795	44	1888 \pm 112	2045	1675
9	1813 \pm 69	1895	1695	27	1797 \pm 93	2015	1695	45	1803 \pm 58	1915	1695
10	1783 \pm 93	1965	1635	28	1912 \pm 93	2075	1775	46	1788 \pm 82	1925	1635
11	1815 \pm 120	1995	1615	29	1838 \pm 115	2105	1695	47	1796 \pm 65	1885	1655
12	1913 \pm 64	2065	1835	30	1822 \pm 98	1965	1695	48	1876 \pm 87	1995	1735
13	1752 \pm 90	1935	1625	31	1768 \pm 69	1875	1625	49	1801 \pm 141	2055	1655
14	1848 \pm 69	1955	1775	32	1787 \pm 80	1915	1665	50	1820 \pm 74	1935	1705
15	1847 \pm 73	1945	1675	33	1798 \pm 89	1925	1655	51	1853 \pm 125	2065	1715
16	1845 \pm 93	1965	1715	34	1682 \pm 94	1805	1565	52	1846 \pm 92	2085	1745
17	1857 \pm 92	2005	1705	35	1793 \pm 113	1965	1665				
18	1852 \pm 61	1965	1755	36	1738 \pm 59	1865	1655				

3.2 Hardness Shore "D"

Table 6: Shore D hardness (COT sample number 02-05-13/0176)

Test date: 22-05-2013

Panel no.	Shore "D" (n=10)										Sample mean	Test average
1	79	77	80	80	79	80	79	80	79	78	79.2 \pm 1.1	78.5 \pm 1.7
2	75	81	80	79	78	78	76	77	77	80	78.1 \pm 1.9	
3	78	79	80	75	79	80	75	79	79	78	78.2 \pm 1.8	

The panels have been conditioned at least one week at $23 \pm 2 \text{ }^\circ\text{C}$ and $50 \pm 5 \text{ \% RH}$. The test has been performed under the same conditions.

3.3 Appearance and continuity

The panels' surfaces of all panels with COT sample number 01-05-13/0176 have been examined visually on May 5th 2013. All panels are of uniform colour and smoothness and show no laminations, holidays or other detrimental defects.

3.4 Holiday detection

All panels with COT sample number 02-05-13/0176 were tested for holidays at 8 V/ μm of the nominal dry film thickness of the system (12 kV for Class B, 1500 μm) on May 22nd 2013, no unintentional holidays have been found.

3.5 Impact resistance

Table 7: Impact resistance at 23 ± 2 °C (COT sample number 02-05-13/0176)
 Test date: 22-05-2013

Panel no.	DFT (μm)	Requirement (J)	Drop height (cm)	Impact energy (J)	Impacts, number of failures (n=5)
46	1788 \pm 82	8.9	89	9	None
			100	10	None
			100	20 *	None
48	1876 \pm 87	9.4	94	9	None
			100	10	None
			100	20 *	None
22	1959 \pm 99	9.8	100	20 *	None
23	1798 \pm 66	9.0	100	20 *	None

* Drop weight increased from 1 kg to 2 kg.

Table 8: Impact resistance at -5 °C (COT sample number 02-05-13/0176). Test date: 22-05-2013

Panel no.	DFT (μm)	Requirement (J)	Drop height (cm)	Impact energy (J)	Impacts, number of failures (n=5)
51	1853 \pm 125	5.6	100	20 *	None
			100	20 *	None
			100	20 *	None
26	1871 \pm 65	5.6	100	20 *	None
27	1797 \pm 93	5.4	100	20 *	None
28	1912 \pm 93	5.7	100	20 *	None

* Drop weight increased from 1 kg to 2 kg.

3.6 Adhesion test – Resistance to removal

Table 9: Resistance to removal (COT sample number 02-05-13/0176). Test date: 22-05-2013

Panel no.	Temp. (°C)	Adhesion (rating)*							
		Readings						Mean	Test mean
4	23 ± 2	1	1	1	1	2	2	1	1
5		1	2	1	1	1	2	1	
6		1	2	1	1	3	1	1	

* Rating 1: < 1 mm loss of adhesion,
Rating 2: ≤ 2 mm loss of adhesion,
Rating 3: ≤ 3 mm loss of adhesion,
Rating 4: ≤ 5 mm loss of adhesion,
Rating 5: > 5 mm loss of adhesion.

Table 10: Resistance to removal at maximum service temperature (COT sample number 02-05-13/0176).

Test date: 22-05-2013

Panel No.	Temp. (°C)	Adhesion (rating)*							
		Readings						Mean	Test mean
7	23 ± 2	1	1	1	1	1	1	1	1
8		1	1	1	1	1	1	1	
9		1	1	1	1	1	1	1	

* See Table 9.

3.7 Adhesion test – Pull-off method

The panels have been conditioned at least one week at 23 ± 2 °C and 50 ± 5 % RH. The test has been performed under the same conditions.

The diameter of the dolly used was 20 mm. Dollies have been glued with a suitable epoxy glue, drying time 24 hours.

Table 11: Pull-off method (COT sample number 02-05-13/0176)

Test date: 22-05-2013

Panel no.	Temp. (°C)	Adhesion (MPa)				
		Readings			Mean	Test mean
10	23 ± 2	> 20	> 20	> 20	> 20	19
11		> 20	> 20	> 20	> 20	
12		20.0	16.3	13.6	16.6	
13	60 ± 2	8.0	6.0	12.6	8.9	10
14		9.3 *	10.2	10.8	10.5	
15		6.3	10.2 *	12.6	9.5	
13	23 ± 2	17.0	13.9	18.0	16.3	18
14		20.0	20.0	17.1	19.0	
15		17.6	20.0	18.6	18.7	

* Readings invalid due to break at substrate/coating interface.

3.8 Cathodic disbondment

Table 12: Cathodic disbondment

(COT sample number 02-05-13/0176)

Test date: 22-05-2013 to 19-06-2013

Panel no.	Disbondment (mm)							
	Diameter Readings						Radius	
							Mean	Max
40	21.5	20.9	21.10	21.15	21.55	21.85	7.7	7.9
41	25.30	25.70	25.40	25.45	26.10	24.75	9.7	10.1
42	15.20	14.90	15.75	15.90	16.00	16.15	4.8	5.1

3.9 Specific Electrical Insulation Resistance

 Table 13: Specific Electrical Insulation Resistance at 23 ± 2 °C

(COT sample number 02-05-13/0176)

Test date: 22-5-2013 to 30-08-2013

Panel no.	Area (m ²)	E (V)	Rs (Ωm ²)		Rs70/Rs100
			70 days	100 days	
44	0.027	200	$2.7 * 10^9$	$2.7 * 10^9$	1.0
45	0.027	200	$2.7 * 10^9$	$2.7 * 10^9$	1.0
46	0.027	200	$2.7 * 10^9$	$2.7 * 10^9$	1.0

 Table 14: Specific Electrical Insulation Resistance at 60 ± 2 °C

(COT sample number 02-05-13/0176)

Test date: 11-07-2013 to 13-08-2013

Panel no.	Area (m ²)	E (V)	Rs (Ωm ²) 30 days
49	0.027	200	$2.8 * 10^7$
50	0.027	200	$2.8 * 10^7$
51	0.027	200	$2.7 * 10^7$

3.10 Indentation resistance

 Table 15: Indentation resistance at 23 ± 2 °C

(COT sample number 02-05-13/0176)

Test date: 10-06-2013 to 9-07-2013

Panel no.	DFT (μm)	Readings (μm)		Indentation (μm)	Mean (μm)
		Start	24 h		
4	1850	3990	3923	67	54 ± 26
	1820	3922	3851	71	
	1870	3932	3908	24	
5	1640	3828	3760	68	58 ± 24
	1890	4190	4115	75	
	1640	3752	3722	30	
6	1890	4016	3911	105	78 ± 15
	1760	3909	3842	67	
	1710	3815	3720	95	
	1700	3894	3821	73	

Table 16: Indentation resistance at 60 ± 2 °C
 (COT sample number 02-05-13/0176)

Test date: 9-7-2013 to 26-07-2013

Panel no.	DFT (μm)	Readings (μm)		Indentation (μm)		Mean (%)
		Start	24 h	(μm)	(%)	
16	1790	3808	3648	160	9	10 ± 1
	1770	3920	3745	175	10	
	1960	4115	3912	203	10	
17	2050	4311	3920	391	19	18 ± 1
	1940	4130	3805	325	17	
	1790	3980	3672	308	17	
18	1830	4220	3850	370	20	19 ± 3
	1930	4221	3930	291	15	
	1780	4227	3840	387	22	

3.11 Thermal ageing

Table 17: Thermal ageing, 100 days at 80 ± 2 °C
 (COT sample number 02-05-13/0176)

Test date: 22-05-2013 to 02-09-2013

Panel no.	Adhesion (MPa)				Test mean
	Readings			Mean	
19	19.6	17.6	17.7	18.3 ± 1.1	17.0 ± 3.4
20	19.2	11.1	11.5	13.9 ± 4.6	
21	18.8	20	17.8	18.9 ± 1.1	
Readings after 24 hours acclimation				Mean	Test mean
19	> 20	> 20	> 20	> 20	19.7 ± 0.7
20	> 20	> 20	19.5	19.8 ± 0.3	
21	> 20	> 20	17.8	19.3 ± 1.3	

Changes in appearance: After exposure, no differences as compared to reference sample.
 Pinholes (Annex B): no pinholes at start of test, no pinholes after exposure.

3.12 Flexibility

Table 18: Flexibility. (COT sample 02-05-13/0176)

Test date: week 24 and week 31 2013

Panel no.	Temp. (°C)	Mandrel \varnothing (mm)	support gap (mm)	Cracking / delamination/ pinholes	
				Immediately	After 24 h
34	0 ± 2	1194	22.5	None	None
35				None	None
36				None	None
37	23 ± 2	594	22.5	None	None
38				None	None
39				None	None



3.13 Elongation

Table 19: Elongation (COT sample number 28-05-13/0192) Test date: week 22 2013

Free film Specimen (Type 2)	Dimensions		Elongation, $L_0 = 50$ mm		Remarks
	Width (mm)	Thickness (mm)	$L_0 = 50$ mm		
			ΔL (mm)	ϵ_t (%)	
53	19.3	1.7	5.5	11	Invalid reading
54	20.3	1.4	6.5	13	
55	19.8	1.6	3.5	7	
56	20.6	1.5	10.5	21	
57	20.5	1.7	2.0	4	
58	20.8	1.7	11.5	23	
59	20.7	1.7	19.0	38	
60	20.7	1.7	23.0	46	
61	20.8	1.6	21.3	43	
Mean ϵ_t			27 ± 16 %		(Valid only)

4 SUMMARY RESULTS

Table 20: Summary of results

COT sample numbers: 02-05-13/0175, 02-05-13/0176, 28-05-13/192

EN 10290 - Test		Results	Test Method
Minimum Dry Film Thickness of the coating		All panels > 1500 µm	ISO 2178
Hardness Shore "D"		79 ± 2	ISO 868
Appearance and continuity		Uniform colour, smooth appearance, free from defects	EN 10290, section 7.4
Holiday detection		No holidays	EN 10290, Annex B
Impact resistance	23 ± 2 °C	> 20 J	EN 10290, Annex C
	-5 ± 2 °C	> 20 J	EN 10290, Annex B
Adhesion – Resistance to removal	23 ± 2 °C	Rating 1	EN 10290, Annex D
	24 h 23 ± 2 °C	Rating 1	
Adhesion – Pull-off method	23 ± 2 °C	19 MPa	EN 24624
	60 ± 2 °C,	10 MPa,	
	+ 24 h 23 ± 2 °C	18 MPa	
Cathodic disbondment	Average	7 mm	EN 10290, Annex E
	Maximum	8 mm	
Specific electrical insulation resistance	23 ± 2 °C	Rs70 = 2.7·10 ⁹ Ωm ² ; Rs70/Rs100 = 1.0 Rs100 = 2.7·10 ⁹ Ωm ²	EN 10290, Annex F
	60 ± 2 °C	Rs100 = 1.4·10 ⁸	
Indentation resistance	23 ± 2 °C	0.068 ± 0.025 mm	EN 10290, Annex H
	60 ± 2 °C	25 ± 5 %	
Thermal ageing	80 ± 2 °C, + 24 h 23 ± 2 °C	17 MPa, 20 MPa	EN 10290, Annex J. EN 24624
Flexibility	23 ± 2 °C, + 24 h 23 ± 2 °C	No cracking	EN 10290, Annex K
	0 ± 2 °C, + 24 h 23 ± 2 °C	No cracking	
Elongation		27 ± 16 %	ISO 527-1 ISO 527-3
Infra-red scan		Appendix	FTIR Protocol

CENTRUM VOOR ONDERZOEK
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APPENDIX

FTIR spectra

Figure 1: WG Welepipe, Grey, Base

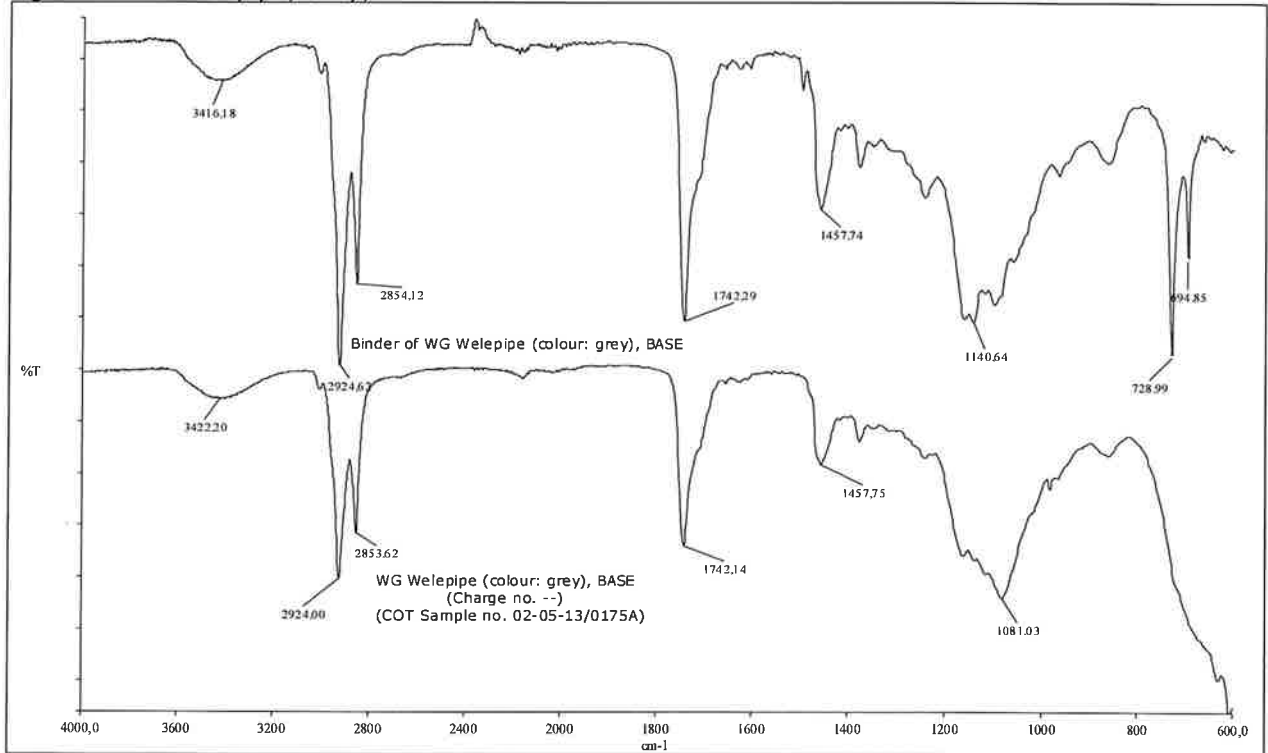


Figure 2: WG Welepipe (120127248), Hardener

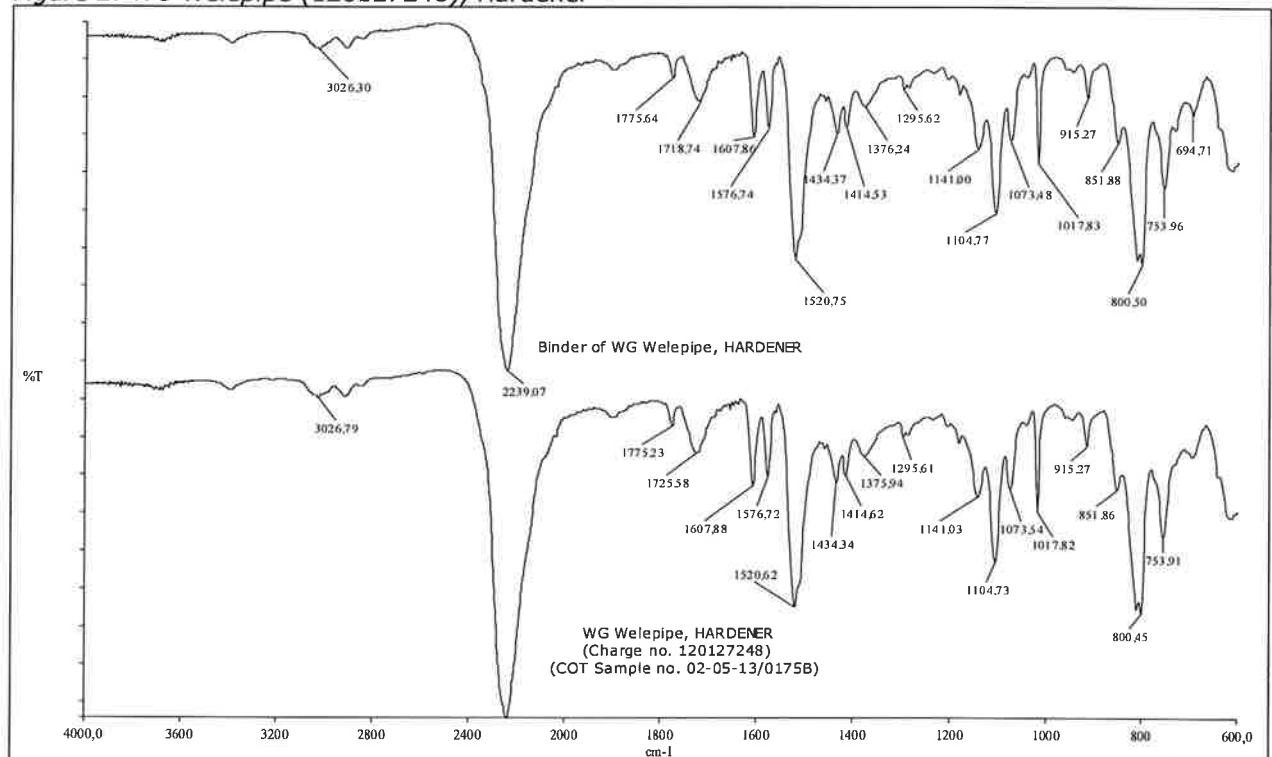


Figure 3: WG Welepipe, cured product

