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Evaluation of Competitor Films

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Project #: 14-253-1125.bis

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Date: November 24, 2014

Purpose: To evaluate the corrosion protection and mechanical properties of the eight submitted films, and compare to VpCI-125 and VpCI-126 film.

Samples Received: The following samples were received on 11-6-14 in ok condition:

1. VCI Brasil, Aquatem Dana, 2mil orange film
2. VCI Brasil, Aquatem Dana, 2mil brown film
3. VCI Brasil, Aquatem Dana, 4mil blue film
4. Lord, 3.5mil blue film
5. Lord, 3mil blue film
6. Refiate (Cortec) VCI 126 blue film, 5.5mil
7. Lord, 2mil green film
8. Embraco, 4.5mil green film

Method: VIA Test, CC-027
Razor Blade Test, CC-004*
SO_2 Test, CC-003*
Mechanical Properties*
FTIR analysis, CC-006
*Cortec Laboratory is not accredited for the tests marked

Materials: VIA test kit
Razor blade test kit
SO_2 Test kit
Paragon 1000 FTIR
VpCI-125 Green film 4mil (Batch #36092)
VpCI-126 Blue film, 4mil (Batch #36225)
Control film (plain, non-vci PE film 3mils)

Procedure: The tests were conducted according to standard procedures for each test.

Results:

Razor Blade Test- Carbon Steel Panels

Sample #	Description of Film	Panel #1	Panel #2	Panel #3	Pass / Fail*
1	VCI Brasil, Aquatem Dana, orange film	Pass	Pass	Fail	Pass
2	VCI Brasil, Aquatem Dana, brown film	Pass	Pass	Fail	Pass
3	VCI Brasil, Aquatem Dana, blue film	Fail	Fail	Pass	Fail
4	Lord, blue film	Fail	Fail	Pass	Fail
5	Lord, blue film	Pass	Pass	Fail	Pass
6	Refiate (Cortec) VCI 126 blue film	Pass	Pass	Pass	Pass
7	Lord green film	Pass	Pass	Pass	Pass
8	Embraco green film	Pass	Pass	Fail	Pass
-	VpCI-125 film	Pass	Pass	Pass	Pass
-	VpCI-126 film	Pass	Pass	Pass	Pass
-	Control film	Fail	-	-	-

*Note- two out of three panels must pass for passing results

Results:

Razor Blade Test- Copper Panels

Sample #	Description of Film	Panel #1	Panel #2	Panel #3	Pass / Fail*
1	VCI Brasil, Aquatem Dana, orange film	Fail	Fail	Fail	Fail
2	VCI Brasil, Aquatem Dana, brown film	Fail	Fail	Fail	Fail
3	VCI Brasil, Aquatem Dana, blue film	Fail	Fail	Pass	Fail
4	Lord, blue film	Fail	Fail	Fail	Fail
5	Lord, blue film	Fail	Fail	Fail	Fail
6	Refiate (Cortec) VCI 126 blue film	Pass	Pass	Pass	Pass
7	Lord green film	Fail	Fail	Pass	Fail
8	Embraco green film	Fail	Fail	Fail	Fail
-	VpCI-125 film	Pass	Pass	Pass	Pass
-	VpCI-126 film	Pass	Pass	Pass	Pass
-	Control film	Fail	-	-	-

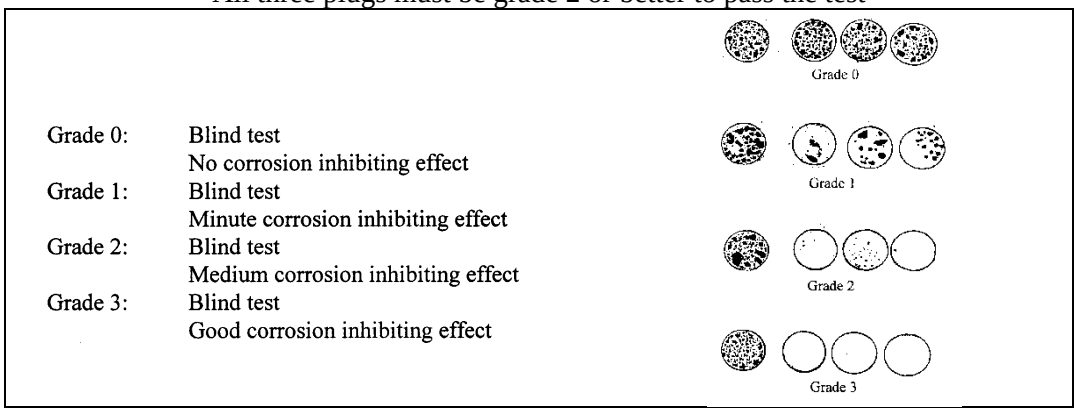
*Note- two out of three panels must pass for passing results

VIA Test

Sample #	Description of Film	Plug #1	Plug #2	Plug #3	Pass / Fail*
1	VCI Brasil, Aquatem Dana, orange film	Grade 1	Grade 0	Grade 0	Fail
2	VCI Brasil, Aquatem Dana, brown film	Grade 2	Grade 1	Grade 1	Fail
3	VCI Brasil, Aquatem Dana, blue film	Grade 1	Grade 1	Grade 0	Fail
4	Lord, blue film	Grade 2	Grade 2	Grade 0	Fail
5	Lord, blue film	Grade 0	Grade 0	Grade 0	Fail
6	Refiate (Cortec) VCI 126 blue film	Grade 2	Grade 2	Grade 2	Pass
7	Lord green film	Grade 1	Grade 0	Grade 0	Fail
8	Embraco green film	Grade 1	Grade 0	Grade 0	Fail
-	VpCI-125 film	Grade 2	Grade 2	Grade 2	Pass
-	VpCI-126 film	Grade 3	Grade 3	Grade 2	Pass
-	Control film	Grade 0	Grade 0	Grade 0	Fail

*Note- all samples were tested using two 1in. x 6in. strips of film

VIA Test Grades (Grade 2 or 3 are passing)
All three plugs must be grade 2 or better to pass the test



Results:

SO_2 Test

Sample #	Description of Film	Panel #1	Panel #2	Panel #3	Pass / Fail
1	VCI Brasil, Aquatem Dana, orange film	Grade 1	Grade 1	Grade 1	Fail
2	VCI Brasil, Aquatem Dana, brown film	Grade 0	Grade 0	Grade 0	Fail
3	VCI Brasil, Aquatem Dana, blue film	Grade 1	Grade 1	Grade 1	Fail
4	Lord, blue film	Grade 2	Grade 1	Grade 1	Fail
5	Lord, blue film	Grade 4	Grade 4	Grade 4	Pass
6	Refiate (Cortec) VCI 126 blue film	Grade 4	Grade 4	Grade 4	Pass
7	Lord green film	Grade 0	Grade 0	Grade 0	Fail
8	Embraco green film	Not enough sample was provided for this test			n.a.
-	VpCI-125 film	Grade 4	Grade 4	Grade 4	Pass
-	VpCI-126 film	Grade 4	Grade 4	Grade 4	Pass
-	Control film	Grade 0	Grade 0	Grade 0	Fail

SO_2 Test Grades- Grade 3 and 4 are passing

Grade 0 - Extensive corrosion covering 25% or more of panel surface
Grade 1 - Moderate corrosion covering 10-25% of panel surface
Grade 2 - Slight corrosion 5-10% of panel surface
Grade 3 - Very slight corrosion 0-5% of panel surface
Grade 4 - No visible corrosion on panel surface

Mechanical Properties- 2 Mil Comparison Chart

Property		Test Method	Units	Sample #1	Sample #2	Sample #7	VpCI-126
Caliper		ASTM D6988	mil	1.99	2.11	1.85	2.21
Breaking Factor	MD	ASTM D882-02	lbs/in	8.00	8.64	6.72	10.03
	TD			7.18	8.10	7.67	8.52
Tensile Strength at Break	MD	ASTM D882-02	psi	4173.00	4155.00	3728.00	4288.80
	TD			3735.00	3934.00	4013.00	3850.31
Elongation at Break	MD	ASTM D882-02	%	736.72	728.59	740.63	694.17
	TD			832.81	852.03	829.53	817.03
Yield Strength	MD	ASTM D882-02	psi	2459.94	2441.14	1918.03	1354.13
	TD			1763.82	1820.50	1888.13	1560.12
Puncture Resistance	Outside	MIL-STD-3010, TM 2065	lbf	3.74	3.65	3.45	3.73
Puncture Resistance	Inside	MIL-STD-3010, TM 2065	lbf	3.63	3.74	3.24	N/A
Tear Strength	MD	ASTM D1922-06A	gram force	112.40	53.20	8.20	59.80
	TD			603.20	259.20	833.60	24.60
Coefficient of Friction		ASTM D1894	static	0.06	0.15	N/A	0.51
			kinetic	0.31	0.25	N/A	0.59
Seal Strength	left	ASTM F88-99	lbs/in	N/A	N/A	N/A	5.61
	center			N/A	N/A	6.06	4.28
	right			N/A	N/A	N/A	5.47

Mechanical Properties- 3 Mil Comparison Chart

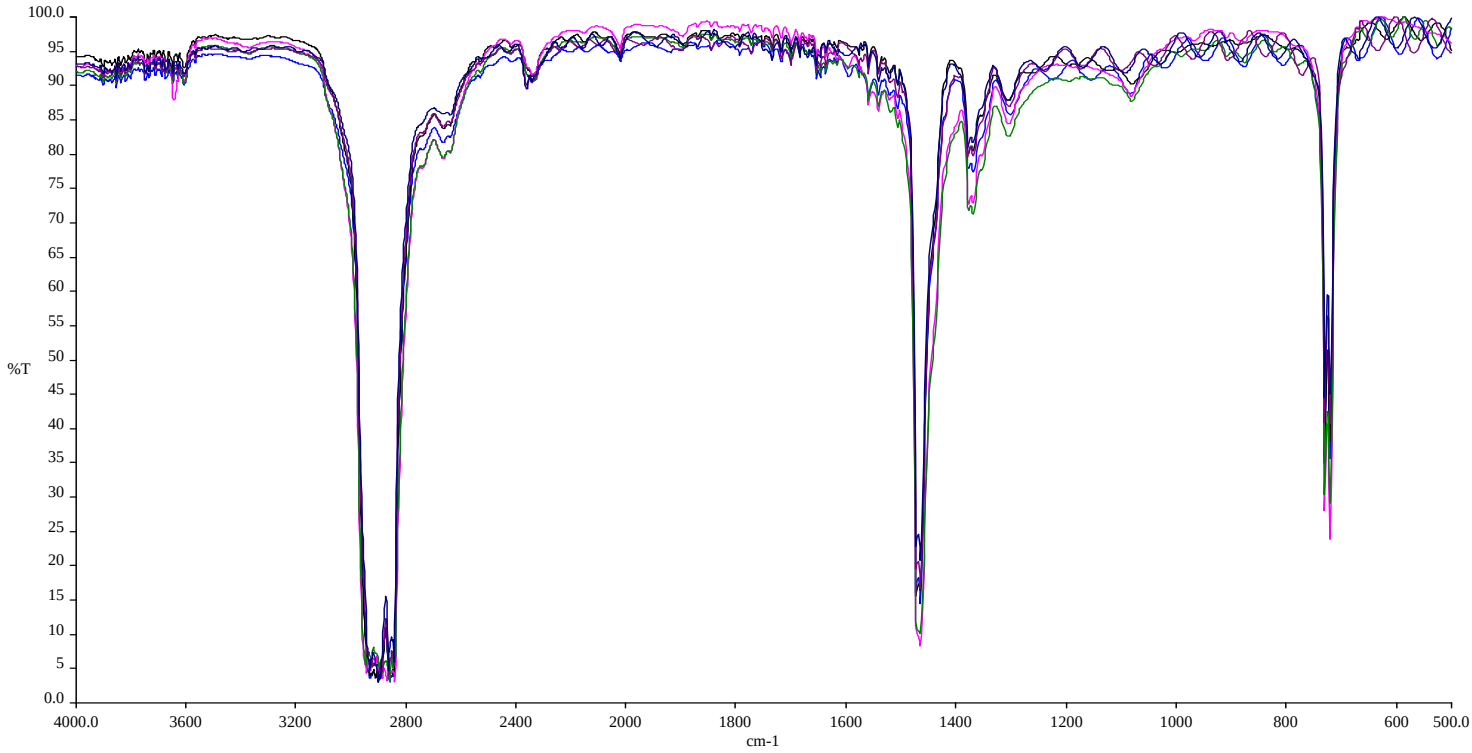
Property		Test Method	Units	Sample #4	Sample #5	VpCI-126	VpCI-125
Caliper		ASTM D6988	mil	2.99	3.00	3.30	3.11
Breaking Factor	MD	ASTM D882-02	lbs/in	12.08	11.24	12.30	12.32
	TD			12.06	11.43	11.50	13.13
Tensile Strength at Break	MD	ASTM D882-02	psi	4141.00	4262.00	3803.98	4032.00
	TD			3993.00	4160.00	3917.06	4181.00
Elongation at Break	MD	ASTM D882-02	%	647.66	804.53	682.71	662.50
	TD			927.24	878.75	803.65	564.06
Yield Strength	MD	ASTM D882-02	psi	2388.09	1933.35	1297.02	1505.99
	TD			1613.88	1738.96	1577.24	1847.91
Puncture Resistance	Outside	MIL-STD-3010, TM 2065	lbf	4.54	4.94	5.55	4.94
Puncture Resistance	Inside	MIL-STD-3010, TM 2065	lbf	5.68	5.12	N/A	5.01
Tear Strength	MD	ASTM D1922-06A	gram force	169.60	396.80	368.00	544.00
	TD			544.00	676.80	1184.00	1235.20
Coefficient of Friction		ASTM D1894	static	0.09	0.11	0.39	0.04
			kinetic	0.15	0.18	0.41	0.23
Seal Strength	left	ASTM F88-99	lbs/in	N/A	N/A	8.55	7.76
	center			N/A	5.37	6.67	6.09
	right			N/A	N/A	8.97	7.52

Mechanical Properties- 4 Mil Comparison Chart

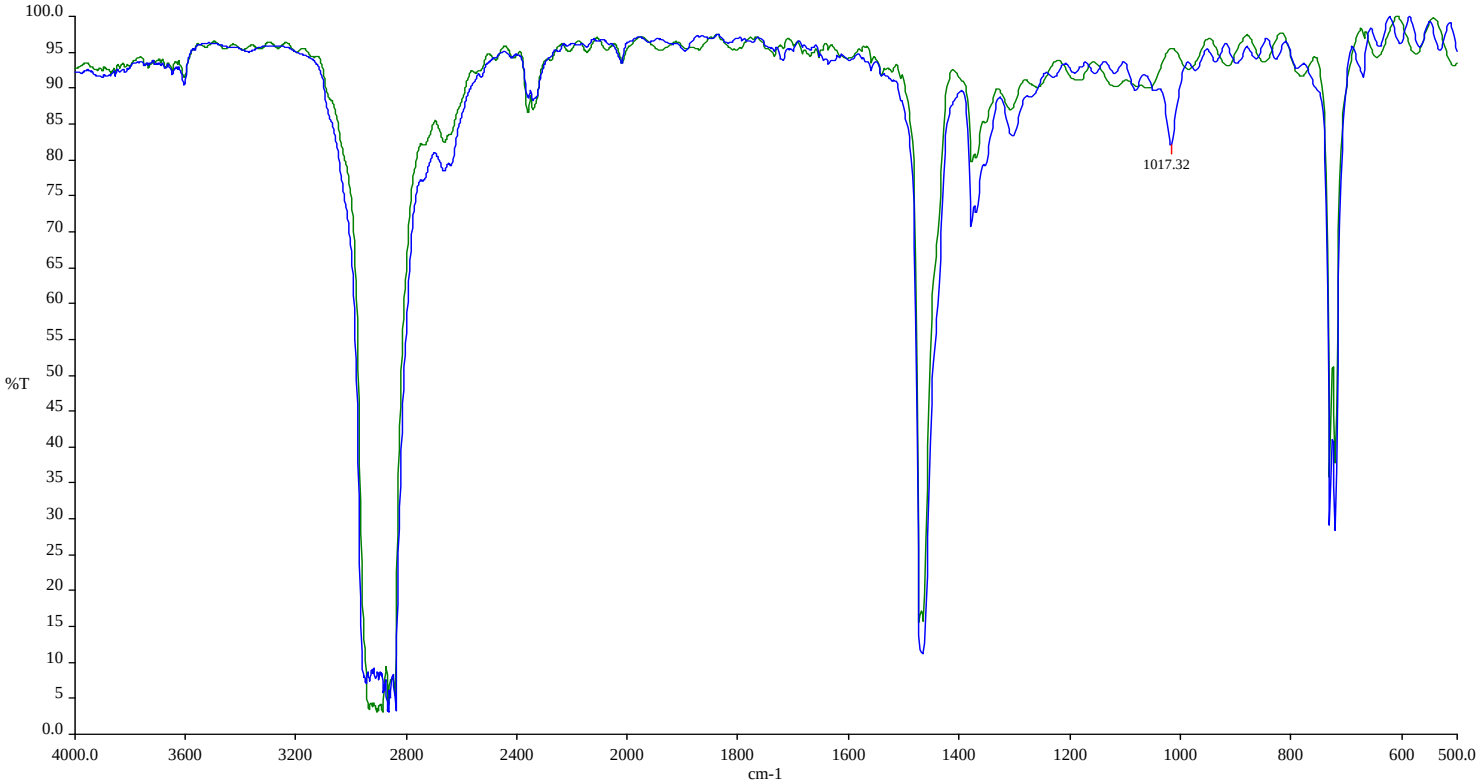
Property		Test Method	Units	Sample #3	VpCI-126	VpCI-125
Caliper		ASTM D6988	mil	3.80	4.00	4.25
Breaking Factor	MD	ASTM D882-02	lbs/in	11.89	17.92	14.15
	TD			10.18	17.77	15.79
Tensile Strength at Break	MD	ASTM D882-02	psi	3196.00	4412.83	3538.00
	TD			2802.00	4055.48	3947.00
Elongation at Break	MD	ASTM D882-02	%	490.31	709.63	639.38
	TD			841.51	866.82	789.85
Yield Strength	MD	ASTM D882-02	psi	2482.17	1269.43	1772.53
	TD			1833.26	1482.04	1647.79
Puncture Resistance	Outside	MIL-STD-3010, TM 2065	lbf	5.53	8.39	5.18
Puncture Resistance	Inside	MIL-STD-3010, TM 2065	lbf	5.97	N/A	5.01
Tear Strength	MD	ASTM D1922-06A	gram force	761.60	374.00	848.00
	TD			988.80	1696.00	1497.60
Coefficient of Friction		ASTM D1894	static	N/A	0.57	0.18
			kinetic	N/A	0.60	0.22
Seal Strength	left	ASTM F88-99	lbs/in	N/A	N/A	5.53
	center			11.05	10.81	N/A
	right			N/A	N/A	6.56

FTIR Analysis

Film samples #1, 2, 4, 5, and 7 compared to plain PE film
(Note- all films show the same peaks)

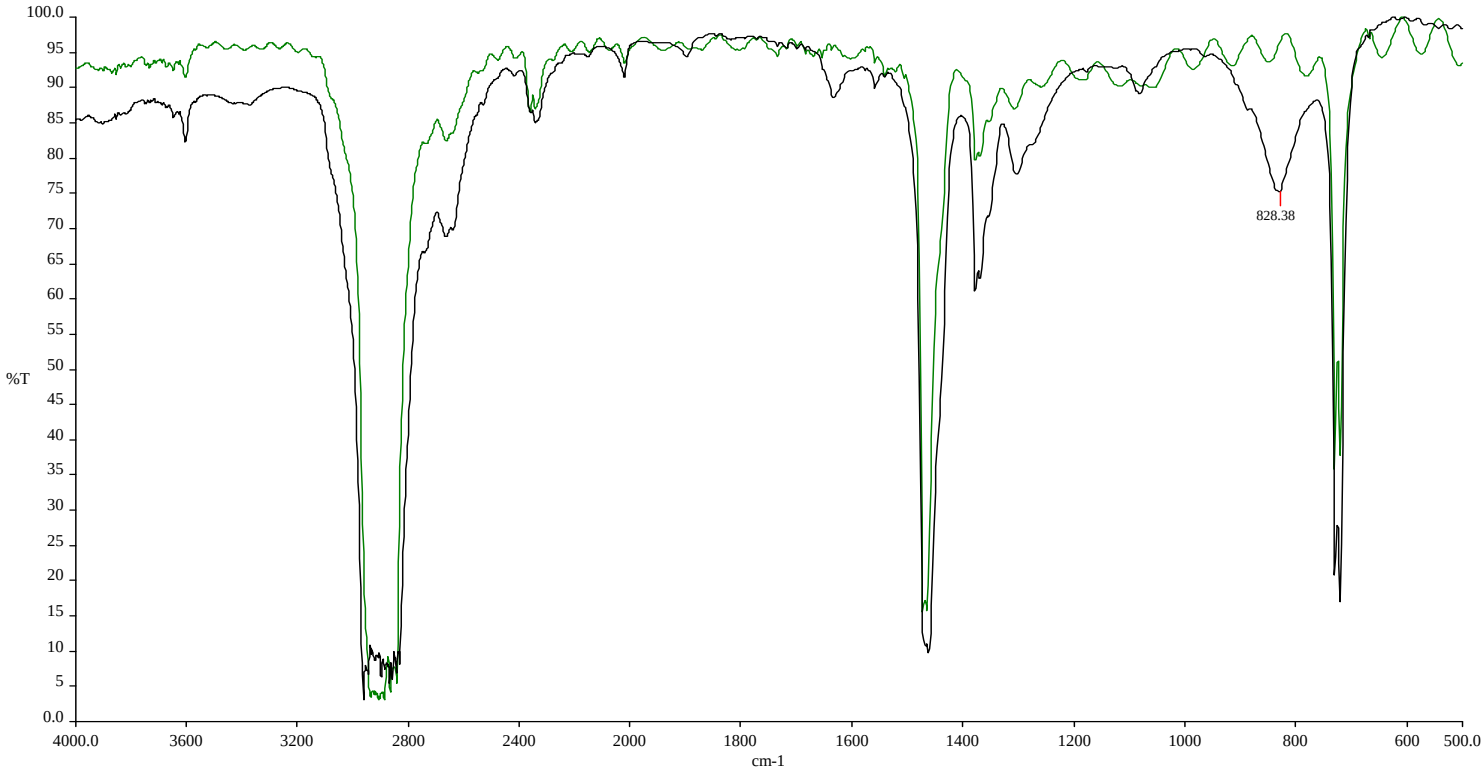


Film sample #3 compared to plain PE film

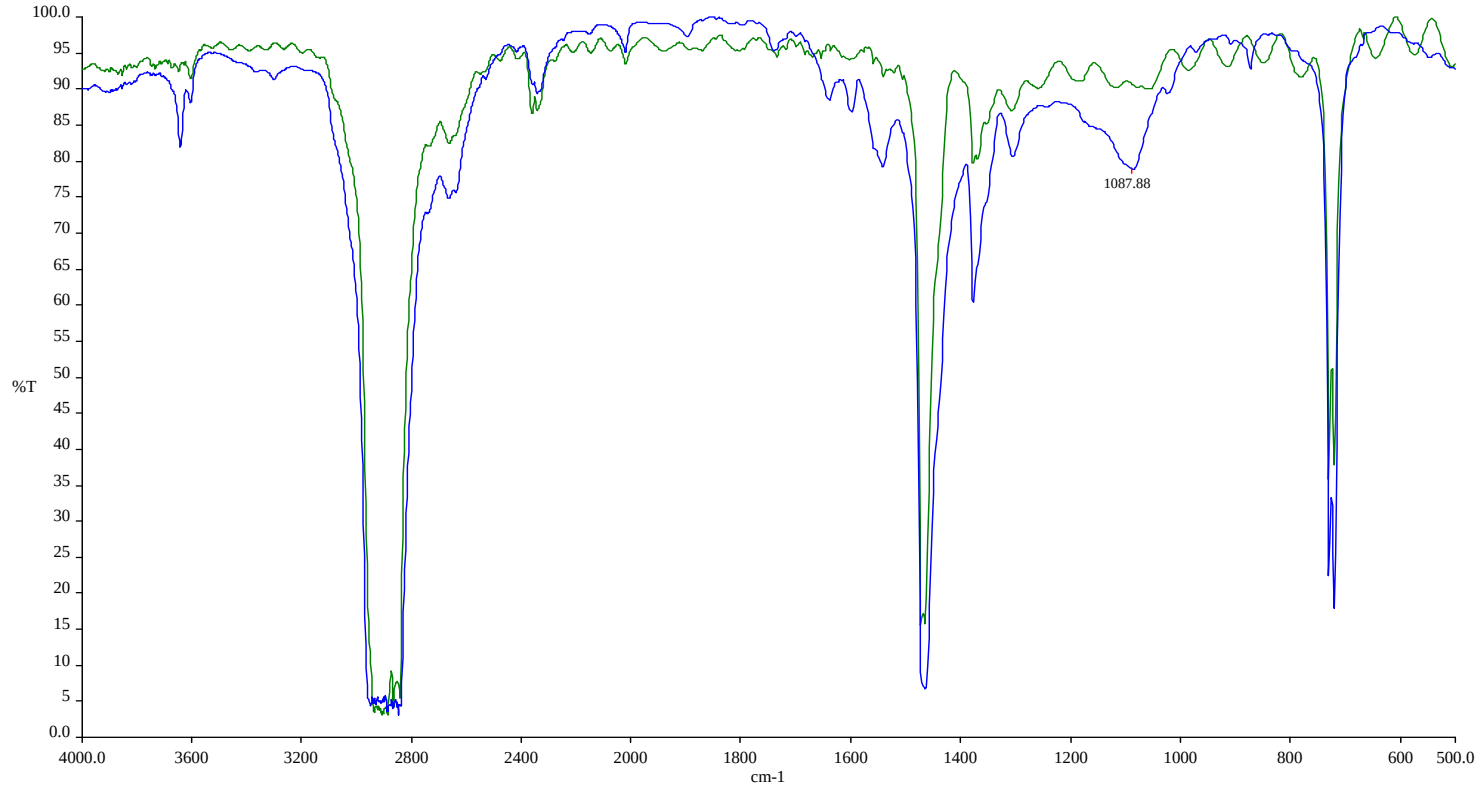


FTIR Analysis

Film sample #6 compared to plain PE film



Film sample #8 compared to plain PE film



Interpretations: 1) Film Sample #6 was the only submitted film with Cortec's logo on it, and was the only film tested out of eight that passed all of the corrosion testing. This film compares equally in corrosion protection when compared to VpCI-126 and VpCI-125 film. However, not enough film samples were provided for mechanical properties testing. All of the other seven submitted films do not provide sufficient corrosion protection to pass all of the tests. VpCI-126 and VpCI-125 film offer much better corrosion protection.

2) Based on the FT-IR spectra, the samples # 1-5 and #7 do not show the presence of corrosion inhibitors. The FT-IR graphs for #8 showed the presences of corrosion inhibitor, probably sodium benzoate, but not in a sufficient amount. This can explain the failure of mentioned films in corrosion tests.

3) Mechanical properties are attached.