DCOI - An Oil-borne Preservative System for Pressure - Treatment of Poles, Posts and Sawn Cross Arms

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Abstract

DCOI or 4,5-Dichloro-2-octylisothiazol-3(2H)-one is a broad-spectrum antimicrobial compound that was first standardized as a wood preservative by the American Wood Protection Association in 1989. In 2008 DCOI was successfully commercialized in the U.S. residential wood preservative marketplace as a waterborne formulation for above ground uses. In 2017 proposals for an oil-borne formulation of DCOI intended for the pressure treatment of southern pine poles, posts and cross arms as well as Douglas-fir cross arms were considered and adopted by the AWPA Technical Committees. Publication of the new/revised standards is expected in the 2018 BOS. This paper summarizes available data associated with the chemistry, the human and eco-toxicological properties, the treatability and the efficacy of the active ingredient in an oil borne formulation that supports its use as an effective wood preservative for industrial applications.

Introduction and Background Information

DCOI is a four-letter acronym for the active ingredient 4,5-Dichloro-2-octylisothiazol-3(2*H*)-one. DCOI was first proposed as a wood preservative in the late 1970's as an alternative to pentachlorophenol for industrial poles and cross arms (Nicholas *et al.*, 1984; Greenley, 1986; Hegarty *et al*., 1997). DCOI is well known to the American Wood Protection Association having been originally standardized as a wood preservative in an organic solvent carrier by AWPA Committee P3 in 1989. When it was initially standardized the active ingredient was known by the three-letter acronym ITA. ITA was later changed to DCOI in 1999.

The standard for DCOI was first published as P8 number 6 in the 1990 Book of Standards. In 2008 the Book of Standards was reorganized and the individual preservatives that comprised P8 were separated into standalone standards. As a result, P8 number 6 (DCOI) became AWPA Standard P39. Since its original listing in 1990 the preservative standard has been reaffirmed in accordance with AWPA procedures. The most recent reaffirmation was in 2015.

Minimum retention recommendations to the Treatments committees were established in 1995. The minimum retentions were set at 0.03 pcf for above ground exposure and at 0.08 pcf for ground contact use. Until June of 2017 no proposals had been made to the Treatments Committees to adopt DCOI in an oil borne solvent for any specific commodities. As a result, DCOI in an oil borne solvent was never listed in AWPA Standards U1 or T1.

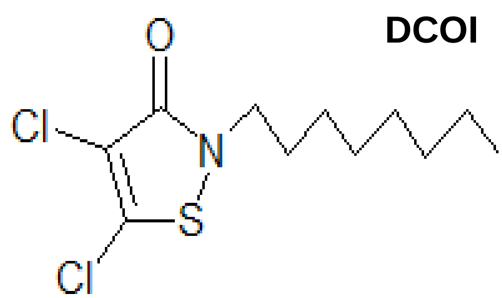
DCOI is a broad spectrum antimicrobial compound currently sold as a marine antifoulant, an algaecide for cooling towers, a moldicide for paints and finishes and most importantly, as a wood preservative fungicide component in the AWPA standardized EL2 formulation.

DCOI also exhibits substantial antibacterial activity which makes it very effective as an in-can biocide for paint formulations.

The active ingredient has an excellent environmental toxicity profile due in part to the fact that it is not persistent in the soil environment.

The CAS# for DCOI is 64359-81-5. Its chemical formula is $C_{11}H_{17}Cl_2NOS$. A structural diagram for DCOI is provided below in Figure 1.

Figure 1: Structural Diagram for DCOI



DCOI is sparingly soluble in water but relatively soluble in a wide range of organic solvents including #2 diesel fuel (AWPA HSA) as summarized in Table 1 below:

Table 1: Relative solubility of DCOI in selected solvents

Solvent	Solubility (by weight %)
Acetone	40
Ethanol	35
Cellosolve	40
Xylene	68
Benzyl Alcohol	64
Butyl Carbitol	32
HSA (#2 diesel)	47
Water	2 mg/L

The DCOI technical grade active ingredient is registered by the U.S. EPA for wood preservative use as Kathon™ 287T Industrial Microbicide. The EPA registration number for the TGAI is 707-224. A 23% a.i. end use product is available as UP-23, EPA registration number 83997-13. DCOI is not considered by the US EPA to be a Restricted Use Pesticide.

DCOI functions as an effective biocide by reacting with intracellular thiols which participate in the catalytic functions of enzymes (Diehl *et al.*, 1999; Chapman *et al.*, 1998). In addition, it is a potent inhibitor of spore germination in a wide range of fungi. It shows activity in a wide range of products and formulations, including in architectural paints, caulks as well as wood.

DCOI does not crystallize under standard conditions and remains as an amorphous semi-wax solid in pure form. This means that even if the loss of the carrier solvent is extreme DCOI will not crystallize out into a form that might not be able to provide biological control, a phenomenon that has been observed with penta in LPG gas and soft-rot.

Yu (1997) studied the burning characteristics of DCOI treated wood at different temperatures with and without supplied oxygen. The results of the study revealed that no harmful combustion products such as polychlorinated dibenzo-p-dioxins, polychlorinated dibenzo-p-furans and polychlorinated biphenyls were detected when DCOI treated wood was burned. This observation is significant because it means that DCOI treated wood is a potential candidate for end of life disposal through combustion at a co-gen facility.

The physical properties of DCOI are summarized in the table below.

Property	Result
Melt Point	41.1-41.7 °C
Boiling Point	>300°C (where degradation occurs)
Relative Density	1.27 g/cm^3 at 25°C
Vapor pressure	9.8 x 10^{-4} Pa at 25°C
Physical State	Solid at 20°C
Color	Off white
Odor	Moderately sweet/pungent
Solubility in water	2.85 mg/L @ 10°C
Thermal Stability	Under Accelerated storage - 2 weeks @54°C: Zero time 99.2% active: Two weeks 98.9% active. DSC: Decomposition @ 297.9 °C

Performance attributes of DCOI as a wood preservative

For a biocide to perform as a successful wood preservative it must be effective against wood decay fungi and termites, it must be stable in a solvent carrier and able to penetrate deeply into wood and at the same the active ingredient must be resistant to leaching and depletion. Data summarizing the treatability and effectiveness of DCOI as a wood preservative are presented below.

Treatability

Treatment studies to date have demonstrated that DCOI in #2 diesel will perform similar to penta in oil with respect to treatment cycle, solution uptakes, penetration gradients and uptake of the active ingredient into wood.

A full-scale commercial sized trial was conducted at the Cox Industries treatment facility in North SC in June of 2017 (Figure 2).

Timber Products (TP) and Southern Pine Inspection Bureau (SPIB) inspectors were on site to monitor the treatments, collect core samples and to provide confirmation of active ingredient retention by assay.

A total of twenty each Class 3, Class 4, and Class 5, 40 foot southern pine utility poles, sixty 9½ foot southern pine "posts" 8-9" in diameter, 50 southern pine cross arms, and 50 Douglas-fir cross arms were treated in four charges over the course of three days. Before treatment the moisture content of the southern pine poles was determined from cores removed from five of each pole class. Moisture contents averaged 20%, 23%, and 29% MC for the class 5, 4, and 3 poles respectively. The southern pine posts were much higher in MC, with average MCs calculated at 43% by core analysis, much higher than expected. These posts were then analyzed for moisture content at depth using a Delmhorst moisture meter. The average (range) moisture contents of these posts were 27% (14-46%) at ½", 33% (12-70%) at 1", and 34% (12-50%) at 2" depth.

Treatments were conducted using a treating solution containing 2.5% DCOI in #2 diesel at ambient temperature.

Individual treatment charge commodity composition, gross and net solution uptakes and overall charge gauge retentions are summarized in Tables 2A and 2B. Third party inspection of the materials treated in this trial was provided by SPIB and TP. A full summary of the inspection results from SPIB is provided in Table 3. Representative pictures illustrating the penetration into cores are provided as Figure 4. It is apparent that DCOI in #2 diesel can be successfully used to treat southern pine poles, southern pine posts, southern pine cross arms and Douglas fir cross arms to meet AWPA penetration requirements.

Figure 2. Commercial treatment of southern pine utility poles, southern pine and Douglas-fir cross-arms, and southern pine posts at Cox Industries North SC plant. June 2017.

Table 2A. Overall charge composition and uptake and retention parameters

				Charge parameters									648	Gal/Ft.	Gauge
Chg	Composition		Volume	Init	Pressure		Final	Tank Heights					Press	Final	kg/m3
No.	No.	Material	Cu.Ft.	Vac	Minutes	Max	Vac	Init	Flooded	End-Press	Empty	Post Vac	gal/ft3	gal/ft3	**pcf**
1	20	40' Class 5 Poles	534	15"	16	115	20"	23.60	9.60	7.70	21.50	22.00	2.31	1.94	5.54
	50	SYP X-arms													**0.35**
	50	D-fir X-arms													
	20	9.5' Posts													
2	12	40' Class 3 Poles	462	10"	8	95	23"	22.00	7.30	6.00	20.50	21.05	1.82	1.33	3.90
	50	SYP X-arms													**0.24**
	50	D-fir X-arms													
	20	9.5' Posts													
3	8	40' Class 3 Poles	410	10"	6	75	23"	21.1	5.75	4.38	19.78	20.21	2.17	1.41	4.21
	8	40' Class 4 Poles													**0.26**
	50	SYP X-arms													
4	12	40' Class 4 Poles	424	10"	7	105	22"	20.21	4.95	3.56	18.90	19.33	2.12	1.34	3.97
	50	SYP X-arms													**0.25**
	50	D-fir X-arms													
	20	9.5' Posts													

Table 2B. Retention analysis for the 4 charges of poles, analyzing three separate zones to provide information on preservative gradient.

Chg	Poles	Assay Depth	Est. Core Density	HPLC Assay (DCOI) % m/m	kg/m^3	pcf
1	20 Class 5 40’	0-0.5”		0.93	6.39	0.40
		0.5-2”	691	0.90	6.23	0.39
		2-3”	598	0.79	4.74	0.30
2	12 Class 3 40’	0-0.5”		0.82	5.35	0.33
		0.5-2”	650	0.65	4.24	0.26
		2-3”	538	0.35	1.86	0.12
3	8 Class 3 40’	0-0.5”		0.70	4.38	0.27
	8 Class 4 40’	0.5-2”	630	0.56	3.51	0.22
		2-3”	523	0.37	1.94	0.12
4	12 Class 4 40’	0-0.5”		0.73	4.75	0.30
		0.5-2”	650	0.67	4.36	0.27
		2-3”	553	0.49	2.68	0.17

Table 3. Report from SPIB for the Cox Industries Commercial Sized Treatment Trial

SOUTHERN PINE INSPECTION BUREAU
TREATED WOOD DIVISION
4555 SPANISH TRAIL
PENSACOLA, FL 32504

ANALYSIS SUMMARY REPORT

ACCREDITED
Testing Laboratory
TL-365

Date: 6/26/2017
Attn: Kevin Archer, PhD.
Director Research and Development
Viance, LLC
Charlotte, NC
karcher@viance.net

ANALYSIS FOR INFORMATION ONLY - NOT A CERTIFICATION

PROJECT REFERENCE: VIANCE OIL-BORNE DCOI TREATMENT TRIAL

SPIB REPORT NO: 21277

LAB ID	MATERIAL	CHARGE	ASSAY DEPTH	PENETRATION FAILURES	DCOI PCF
21277	20 CLASS 5 40' SYP POLES	1	0.0-0.5"	0/20	0.56
21278			0.5-2.0"		0.45
21282	12 CLASS 3 40' SYP POLES	2	0.0-0.5"	1/12	0.48
21283			0.5-2.0"		0.34
21284	8 CLASS 3 40' SYP POLES 8 CLASS 4 40' SYP POLES	3	0.0-0.5"	1/16	0.36
21285			0.5-2.0"		0.34
21286			2.0-2.5"		0.15
21290	12 CLASS 4 40' SYP POLES	4	0.0-0.5"	0/12	0.42
21291			0.5-2.0"		0.38
21292			2.0-2.5"		0.33
21274	CROSSARMS (SYP)	1	0.0-1.0"	0/20	0.35
21280		2	0.0-1.0"	0/20	0.21
21287		4	0.0-1.0"	0/20	0.23
21275	CROSSARMS (DF)	1	0.0-0.4"	3/20	0.26
21279		2	0.0-0.4"	1/20	0.16
21288		4	0.0-0.5"	1/20	0.17
21276	POSTS (SYP)	1	0.0-1.0"	2/20	0.27
21281		2	0.0-1.0"	4/20	0.27
21289		4	0.0-1.0"	0/20	0.25

Analyzed in accordance with Viance Analytical Method: Analysis of 4,5-Dichloro-2-N-Octyl-4-Isothiazolin-3-One (DCOIT) in Oil-Borne Systems

Kim Merritt — 6/30/2017

SPIB LABORATORY SIGNATURE — DATE

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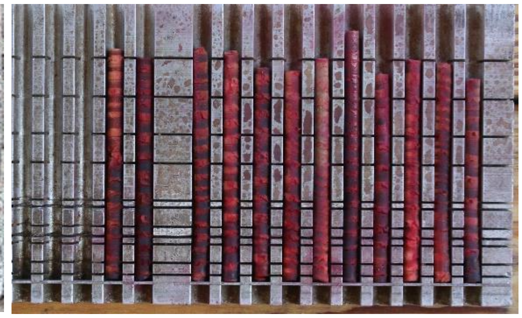
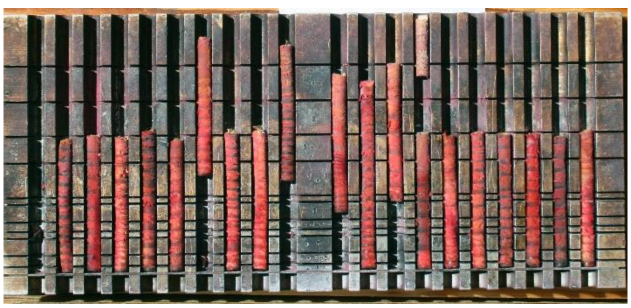
Figure 4. Penetration of oil in representative charges and commodities from the Cox Industries treatment trial, highlighted using a red oil-soluble dye (AWPA A71).

Charge 1: 20 Class 5 40' SYP Poles (0/20 failures)

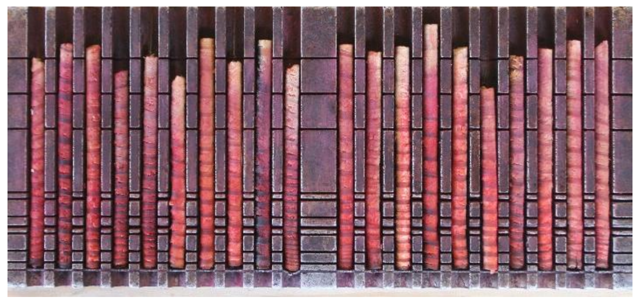
Chg 2: 12 Class 3 40' SYP Poles (1/12 failures)



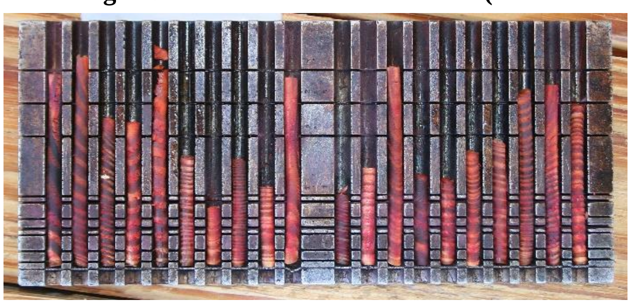
Charge 2 Southern Pine Posts (4/20 failures)



Charge 4 Southern Pine Posts (0/20 failures)



Charge 1: Southern Pine Crossarms (0/20 failures)



Charge 4: Southern Pine Crossarms (0/20 failures)

Charge 1: Douglas-fir Crossarms (3/20 failures)

Charge 4: Douglas-fir Crossarms (1/20 failures)

Biological Efficacy

AWPA E10 Soil block tests

The performance of DCOI solubilized in an organic solvent been thoroughly evaluated independently by several research laboratories using the AWPA E10/ASTM D1413 soil block procedure. The testing has shown that DCOI has a very low toxic threshold against brown and white rot fungi. Representative summaries of the data available from several sources have been reproduced to establish the efficacy of the DCOI active ingredient against a variety of basidiomycete fungi. It is apparent from the data that the minimum retentions being proposed for the different Use Classes in AWPA U1 exceed the calculated toxic threshold values by a significant margin.

Effect of Biodiesel on Performance of Isothiazolone (reproduced from Cheng et al. 2013)

Southern pine sapwood cubes (19mm) were oven dried at 50 °C then weighed prior to treatment. Treating solutions were prepared from concentrates of DCOI in water or DCOI in diesel and diesel amended with 15 or 30% soy-based biodiesel. Treatment solutions of different concentrations of active ingredient were prepared by dilution into toluene. Target active ingredient concentration in the blocks were 0.15, 0.30 and 0.45 kg/m^3. Leached and unleached blocks were exposed to *Gloeophyllum trabeum*, *Irpex lacteus* or *Trametes versicolor* for either 12 weeks (BR) or 16 weeks (WR). Weight loss data were recorded and are summarized in Table 4. From the results in Table 4 it is apparent that weight losses for the toluene only control averages 61% for *G. trabeum*, 21% for *I. lacteus* and 21% for *T. versicolor*. DCOI in #2 diesel was highly effective against the Brown rot *G. trabeum* with an apparent toxic threshold below 0.15kg/m^3 (<0.01pcf) in weathered blocks. Weight losses for the two white rot fungi tested also illustrate the fungicidal effectiveness of DCOI at levels below 0.15 kg/m^3 for weathered blocks.

Table 4. Effects of different solvent mixtures on ability of DCOI to protect southern pine sapwood against fungal attack in an AWPA E10 soil block test (results reproduced from Cheng *et al.*, 2013)

Solvent	Target retention (kg/m^3)	*Gloeophyllum trabeum*				*Irpex lacteus*				*Trametes versicolor*			
		not weathered		weathered		not weathered		weathered		not weathered		weathered	
		avg	std	avg	std	avg	std	avg	std	avg	std	avg	std
15% biodiesel/diesel	0	34.25	(3.13)	48.21	(7.47)	13.87	(1.25)	23.55	(7.02)	8.66	(1.06)	10.79	(3.98)
	0.15	5.13	(0.23)	2.02	(0.47)	7.26	(0.26)	1.95	(0.21)	6.95	(0.58)	5.73	(2.90)
	0.3	4.80	(0.33)	1.41	(0.42)	6.92	(0.39)	1.89	(0.23)	6.33	(0.46)	3.83	(0.93)
	0.45	4.89	(0.46)	1.31	(0.10)	6.64	(0.50)	1.52	(0.23)	6.64	(0.61)	2.26	(0.65)
30% biodiesel/diesel	0	42.49	(2.99)	33.84	(15.21)	13.55	(1.83)	11.59	(4.84)	10.49	(2.69)	7.06	(3.96)
	0.15	5.99	(0.28)	6.26	(1.16)	5.14	(0.82)	2.32	(0.32)	6.10	(0.51)	4.66	(1.37)
	0.3	5.65	(0.35)	2.91	(0.56)	5.41	(0.45)	1.93	(0.71)	5.73	(0.73)	5.24	(0.47)
	0.45	5.24	(0.41)	2.24	(0.20)	5.85	(0.35)	1.79	(0.18)	6.28	(0.50)	3.83	(1.52)
100% diesel	0	28.60	(5.33)	37.83	(8.62)	16.70	(5.21)	11.15	(1.87)	14.33	(1.52)	8.83	(1.32)
	0.15	8.67	(1.82)	2.85	(0.32)	11.47	(1.09)	3.24	(0.54)	11.39	(1.37)	3.48	(0.78)
	0.3	8.79	(1.00)	2.87	(0.18)	12.59	(1.26)	2.98	(0.26)	14.09	(1.35)	3.30	(0.40)
	0.45	7.30	(0.69)	3.10	(0.17)	13.35	(1.63)	2.84	(0.40)	11.80	(1.24)	3.06	(0.41)
Waterborne EL2 (DCOI)	0			36.38	(14.91)	25.00	(6.88)	38.13	(3.87)	26.21	(10.00)	26.34	(1.19)
	0.15	0.57	(0.35)	0.67	(0.23)	1.03	(0.30)	0.45	(0.40)	5.37	(3.89)	2.21	(2.18)
	0.3	0.91	(0.30)	0.44	(0.40)	1.29	(0.11)	0.12	(0.45)	1.37	(0.55)	0.78	(0.28)
	0.45	0.92	(0.31)	0.39	(0.29)	1.52	(0.68)	0.37	(0.27)	0.95	(0.28)	0.69	(0.24)
Toluene	0	60.49	(3.73)	61.04	(10.11)	25.44	(4.01)	33.92	(3.65)	18.64	(5.60)	24.17	(2.40)

Values represent means of 6 blocks per treatment. Figures in parentheses represent one standard deviation

AWPA M10-77 (ASTM D1413) Soil block testing – Data reproduced from Nicholas *et al*. 1984.

Six sets of five replicate 19mm cubes of southern pine sapwood were treated with DCOI diluted in toluene to achieve nominal a.i. retentions of 0.01, 0.05, 0.075, 0.1, 0.2 and 0.3% were exposed to three brown rot fungi (*G. trabeum*, *P. Placenta* and *P. incrassata.* Toxic Thresholds were determined by the linear regression technique. Results are summarized in Table 5. It is apparent from Table 5 that DCOI is highly effective against brown rot and white rot fungi. The minimum retentions being proposed for the current DCOI system exceed the calculated toxic threshold values by a wide margin.

Table 5. **Standard method of testing wood preservative efficacy by laboratory soil block Culture AWPA M10-77 (ASTM D-1413.) Data originally published by Nicholas *et al.*, 1984)**

Fungus	Average Retention (pcf)	Average weight loss (%)	Calculated toxic Threshold (pcf)
Gloeophyllum trabeum	0.000	65.5	
	0.003	51.6	
	0.008	24.1	0.02 (r^2 =0.9)
	0.017	3.6	
	0.032	0.2	
	0.063	0	
Poria placenta	0.000	38.5	
	0.003	42.5	
	0.008	31.1	0.03 (r^2-0.81)
	0.017	13.6	
	0.033	0.8	
	0.063	0	
Poria incrassata	0.000	48.3	
	0.003	14.7	
	0.008	9.1	
	0.017	5.0	0.02 (r^2= 0.57)
	0.030	0	
	0.063	0.5	
	0.103	0.1	
Coriolus versicolor	0.00	15.0	
	0.03	1.6	
	0.07	0.2	
	0.11	0.1	< 0.03 (estimated)
	0.18	0.1	
	0.25	0.1	
	0.27	0.0	

Modified ASTM D1413 soil block test of DCOI and PCP – Data Reproduced from Greaves *et al*. 1982.

In the early 1980's a series of soil block tests evaluating the relative performance of DCOI and Penta were carried out using the Australian modified ASTM D1413 soil block test by Greaves *et al*. 1982. Weight loss results reproduced from the paper are summarized in Table 6. The test results confirm a high degree of activity of DCOI against a wide range of brown and white rot basidiomycete fungi. It can be seen that calculated toxic threshold values from this test are well below the minimum retention values being proposed for the current DCOI system.

Table 6. **Average Weight losses for DCOI and PCP treated Southern pine using an Australian Modified ASTM D1413 soil block procedure. (Data originally published by Greaves *et. al.* 1982)**

Fungus	Retention (pcf)	Percent Weight Loss			
		DCOI	Pentachlorophenol	Untreated	Solvent Control
Coniophora olivacea	0.000	-	-	61.9	57.3
	0.009	56.3			
	0.019	58.5			
	0.037	37.8			
	0.075	25.2	53.6		
	0.150	-	39.5		
	0.300	-	23.8		
Fomes lividus	0.000	-	-	12.7	14.1
	0.009	13.7			
	0.019	14.6			
	0.037	14.2			
	0.075	2.4	23.0		
	0.150		17.6		
	0.300		17.6		
Gloeophyllum abietinum	0.000	-	-	41.1	45.2
	0.009	20.6	-		
	0.019	18.8	-		
	0.037	11.3	-		
	0.075	1.6	27.3		
	0.150	-	19.8		
	0.300	-	9.1		
Poria xantha	0.000	-	-	31.9	16.4
	0.009	0.6			
	0.019	0.0			
	0.037	0.0			
	0.075	0.0	0.0		
	0.150	-	0.0		
	0.300	-	0.0		

Table 6 (Continued) Average Weight losses for DCOI and PCP treated Southern pine using an Australian Modified ASTM D1413 soil block procedure. (Data originally published by Greaves *et. al.* 1982)

Fungus	Retention (pcf)	Percent Weight Loss			
		DCOI	Pentachlorophenol	Untreated	Solvent Control
***Pycnoporus* coccineus**	0.000	-	-	8.8	11.6
	0.009	12.4			
	0.019	3.2			
	0.037	0.5			
	0.075	0	6.4		
	0.150	-	4.8		
	0.300	-	2.3		
***Trametes* lilacino-gilva**	0.000	-	-	57.9	63.1
	0.009	65.1			
	0.019	39.2			
	0.037	16.2			
	0.075	2.6	68.2		
	0.150		44.7		
	0.300		9.9		
***Serpula* lacrymans**	0.000	-	-	41.1	45.1
	0.009	34.0	-		
	0.019	32,5	-		
	0.037	18.1	-		
	0.075	4.5	29.3		
	0.150	-	23.1		
	0.300	-	8.8		

AWPA E10 soil block testing – Viance

Southern pine sapwood cubes (19mm) were vacuum pressure treated with DCOI in #2 diesel to achieve nominal retentions in the wood ranging from 1.08 kg/m^3 (0.07 pcf) to 3 kg/m^3 (0.18 pcf). Treated blocks were dried for several weeks in a conditioning chamber to remove excess solvent before exposure to three brown rot fungi (*C. olivacea*, *P. placenta*, *G. trabeum*) and two white rot fungi (*T. versicolor I. lacteus*) for 12 weeks. Weight losses for the treated material, untreated controls and solvent only controls are summarized in Table 7. The high weight loss results with all fungi for the untreated controls indicates that the decay fungi were active. The data demonstrate that the brown rot fungi are effectively controlled at a retention below 1.08 kg/m^3 (0.07 pcf). Effective control of *C. versicolor* is achieved between 1.8 and 3 kg/m^3 (0.11-0.19 pcf) and with I. lacteus the toxic threshold is < 1.08 kg/m^3 (0.11 pcf).

Table 7. AWPA E10-Soil block test results – Viance

Fungus	Retention (kg/m^3)	Weight loss (%)		
		DCOI	Untreated	Solvent Control
Coniophora olivacea	0.00	-	47	46
	1.08	3.2		
	1.80	0.0		
	3.00	0.9		
Postia Placenta	0.00	-	53	31
	1.08	-0.2		
	1.80	-0.4		
	3.00	0.0		
Gloeophyllum trabeum	0.00	-	41	13
	1.08	1.8		
	1.80	0.0		
	3.00	-0.3		
Trametes Versicolor	0.00	-	75	60
	1.08	10.6		
	1.80	6.6		
	3.00	2.0		
Irpex lacteus	0.0	-	47	13
	1.08	0.2		
	1.80	0.1		
	3.00	0.1		

AWPA E1 Termite Tests

Laboratory choice and no-choice termite tests of DCOI in an organic solvent carrier were conducted by Mississippi State University in accordance with the AWPA E1 test protocol. In preparation of for the study *Coptotermes formosanus* termites were obtained from the McNeil, MS test site and *Reticulitermes flavipes* termites were obtained from Dorman Lake MS.

Southern pine sapwood blocks 25mm x 25 mm x 6mm were treated with a range of DCOI retentions from 0.05pcf – 0.30 pcf a.i. A DCOI concentrate was diluted in toluene to achieve the desired retentions in the blocks.

Results for *Reticulitermes flavipes* are summarized in Tables 8A, 8B and 8C

The high weight losses for the untreated samples in the no choice test with *Reticulitermes* (Table 8A) indicate that the termites were sufficiently active and the test results are valid. The low weight losses and high termite mortality for the DCOI treated samples exposed in the same no choice test indicates that the toxic threshold value is below the lowest retention tested (0.05pcf DCOI).

Table 8B and 8C summarize the weight loss results for *Reticultermes flavipes* in the E1 choice test.
The low weight losses in the DCOI treated blocks and the high weight loss observed in the untreated blocks in this test suggests that the termites were repelled by the DCOI treatment and chose the untreated controls.

Results for *Coptotermes formosanus* are summarized in Tables 8D, 8E and 8F.

The high weight losses for the untreated samples in the no choice test with *Coptotermes* (Table 8D) indicate that the termites were sufficiently active and the test results are valid. The low weight losses and high termite mortality for the DCOI treated samples exposed in the same no choice test indicates that the toxic threshold value is below the lowest retention tested (0.05pcf DCOI).

The low weight loss for the choice test indicates the termites were repelled by the treated blocks and chose the untreated controls. (Tables 8E and 8F).

Table 8E and 8F summarize the weight loss results for *Coptotermes* in the E1 choice test.
The low weight losses in the DCOI treated blocks and the high weight loss observed in the untreated blocks in this test suggests that the termites were repelled by the DCOI treatment and chose the untreated controls.

In summary, the E1 test results with both *Reticulitermes* and *Coptotermes* termites demonstrate that DCOI is highly effective as a termiticide at retentions below 0.05 pcf.

Table 8A. AWPA E1 Termite Test Results - Average percent weight loss, visual rating and termite mortality count for samples exposed to *Reticulitermes* termites in a no choice test for four weeks.

DCOI (pcf)	Sample #	Tunnels		Mortality %	Rating	Int Wt (g)	Final Wt (g)	% Wt. Loss
0.059	1-5	Top/Bttm	Average	100	9.20	1.61	1.60	1.16
			std	0.00	0.45	0.06	0.05	0.35
0.117	6-10	Top/Bttm	Average	100	10.00	1.67	1.67	0.36
			std	0.00	0.00	0.12	0.12	0.31
0.229	11-15	Top/Bttm	Average	100	10.00	1.75	1.74	0.64
			std	0.00	0.00	0.02	0.02	0.57
0.367	16-20	Top/Bttm	Average	100	10.00	1.69	1.68	0.75
			std	0.00	0.00	0.05	0.05	0.55
SYP Cont	26-30	Top/Bttm	Average	0	0.00	1.55	0.75	51.35
			std	0.00	0.00	0.05	0.04	2.92

Table 8B. AWPA E1 Termite Test Results - Average percent weight loss, visual rating and termite mortality count for DCOI samples exposed to *Reticulitermes* termites in a choice test for four weeks.

DCOI (pcf)	Sample #	Tunnels		Mortality %	Rating	Int Wt (g)	Final Wt (g)	% Wt. Loss
0.100	101-105	Top/Bttm	Average	<14%	10.00	1.64	1.63	0.53
			std	<2.24	0.00	0.06	0.06	0.25
0.128	106-110	Top/Bttm	Average	<15%	10.00	1.69	1.68	0.50
			std	0.00	0.00	0.12	0.11	0.30
0.152	111-115	Top/Bttm	Average	<10	10.00	1.72	1.71	0.56
			std	<5.00%	0.00	0.02	0.02	0.21
0.192	116-120	Top/Bttm	Average	<10%	10.00	1.69	1.69	0.48
			std	0.00	0.00	0.08	0.08	0.22

Table 8C. AWPA E1 Termite Test Results - Average percent weight loss, visual rating and termite mortality count for untreated control samples exposed to *Reticulitermes* termites in a **choice test** for four weeks alongside DCOI treated samples.

Controls for DCOI block #'s	Sample#	Tunnels		Mortality%	Rating	Int Wt (g)	Final Wt (g)	% Wt. Loss
101-105	201-205	Top/Bttm	Average	<14%	4.80	1.77	1.20	32.37
			std	2.24	1.10	0.07	0.21	10.45
106-110	206-210	Top/Bttm	Average	<15%	4.00	1.72	1.04	39.32
			std	0.00	0.00	0.08	0.09	3.42
111-115	211-215	Top/Bttm	Average	<10	0.00	1.99	1.14	42.78
			std	<5.00%	0.00	0.11	0.11	3.33
116-120	216-220	Top/Bttm	Average	<10%	0.80	1.69	0.87	48.35
			std	0.00	1.79	0.12	0.06	6.18

Table 8D. AWPA E1 Termite Test Results - Average percent weight loss, visual rating and termite mortality count for samples exposed to *Coptotermes* termites in a **no choice** test for four weeks.

DCOI (pcf)	Sample #	Tunnels		Mortality%	Rating	Int Wt(g)	Final Wt (g)	% Wt. Loss
0.059	31-35	Top/Bttm	Average	100%	8.90	1.70	1.66	2.51
			std					
0.117	36-40	Top/Bttm	Average	100%	9.90	1.64	1.62	0.97
			std					
0.229	41-45	Top/Bttm	Average	100%	10.00	1.71	1.70	0.57
			std					
0.367	46-50	Top/Bttm	Average	100%	10.00	1.70	1.69	0.55
			std					
SYP Cont	56-60	Top/Bttm	Average	0.00%	0.00	1.56	0.20	87.23
			std					

Table 8E. AWPA E1 Termite Test Results - Average percent weight loss, visual rating and termite mortality count for DCOI samples exposed to Coptotermes termites in a choice test for four weeks.

DCOI (pcf)	Sample #	Tunnels		Mortality %	Rating	Int Wt (g)	Final Wt (g)	% Wt. Loss
0.100	131-135	Top/Bttm	Average	88%	10	1.69	1.69	0.01
			std					
0.128	136-140	Top/Bttm	Average	80%	10	1.61	1.60	0.18
			std					
0.152	141-145	Top/Bttm	Average	77%	10	1.61	1.61	0.09
			std					
0.192	146-160	Top/Bttm	Average	63%	10	1.80	1.79	0.66
			std					

Table 8F. **AWPA E1 Termite Test Results -** Average percent weight loss, visual rating and termite mortality count for untreated control samples exposed to Coptotermes termites in a choice test for four weeks alongside DCOI treated samples.

Controls for DCOI Block #'s	Sample #	Tunnels		Mortality %	Rating	Int Wt (g)	Final Wt (g)	% Wt. Loss
131-135	231-235	Top/Bttm	Average	88%	6.60	1.79	1.43	20.36
			std					
136-140	236-240	Top/Bttm	Average	80%	6.20	1.75	1.35	22.89
			std					
141-145	241-245	Top/Bttm	Average	77%	5.80	1.80	1.31	27.16
			std					
146-150	246-250	Top/Bttm	Average	63%	5.60	1.73	1.16	33.17
			std					

Simulated Field Testing

Unsterile Fungus Cellar (soil bed) Testing (data originally reported by Greenley, 1986).

Greenley, 1986 reported on the relative performance of hardwood birch (*Betula papyrifera*) stakes treated with DCOI in an organic solvent (Toluene), penta in a P9A oil and CCA over a 12-month exposure period in a fungus cellar test. Conditions in the fungus cellar were optimized for soft rot attack in accordance with guidelines established by Preston *et al*. 1983. It is apparent from untreated stake data provided in Table 5.2.2.1 that the test conditions are very severe. Greenlee went on to conclude that DCOI at a 4kg/m^3 retention provided similar efficacy to penta in P9 type oil at the same retention. The test results also suggest that DCOI is approximately twice as effective as CCA (Table 9).

Table 9. Fungus Cellar (Soil Bed) Test Results (Data originally reported by Greenley, 1986)

Formulation	Retention (kg/m^3)	Average rating			
		3 mon.	6 mon.	9 mon.	12 mon.
DCOI in toluene	0.49	9.2	5.0	0.0	0.0
	1.03	9.8	2.8	1.4	0.0
	1.94	10.0	5.6	0.0	0.0
	4.02	10.0	10.0	9.0	8.6
Penta/P9 oil	2.09	7.4	7.0	5.0	4.2
	3.98	9.2	7.0	7.0	7.0
	8.03	9.8	7.0	7.0	7.0
CCA-C	2.12	8.2	5.6	0.0	0.0
	4.32	9.0	7.4	4.2	0.0
	8.36	9.6	9.2	7.8	7.0
Untreated	0.0	2.8	0.0	0.0	0.0

Field Testing

E7 Stake Tests

In 1988 the Electric Power Research Institute (EPRI) sponsored a large test program involving several preservatives which included DCOI. As part of that program ground contact stake tests were installed at the MSU Saucier and Dorman Lake test plots. While the core EPRI study is proprietary, data relevant to the performance of DCOI and Penta were made available by MSU. All treatment and testing was performed by MSU personnel following established procedures and appropriate AWPA Standards.

Originally these systems included three oils which met AWPA P9A requirements. Those oils were identified as Ashland Oil, California Shell, and Lilyblad base oil. Toluene was used as the diluent in a 20/80 ratio so as to allow different retentions of active ingredient in the treated wood. Three additional solvent systems included in the test were based on #2 diesel fuel containing adjuvants to allow the formulations to meet P9A criteria. A seventh solvent blend based on Vinsol and the Lilyblad oil completed the list of solvent systems evaluated.

MSU Dorman Lake, MS and Saucier, MS AWPA E7 Stake Test Installations - 1988

Ten replicate IUFRO stakes (1" x 2” x 18") for each oil solvent/DCOI concentration combination were installed at both the MSU Dorman Lake and Saucier test sites in April of 1988. Dorman Lake is considered an AWPA Hazard Zone 4 location and the Saucier site is considered to be in AWPA Hazard Zone 5.

The nominal retentions of DCOI tested were 0.05, 0.1, 0.2 and 0.4 pcf. Positive control treatments included 0.1, 0.2, 0.4 and 0.8 pcf PCP in the same oils, with untreated stakes and stakes treated with the different solvents (without biocides) included as negative controls.

A full report of this test after 15 years exposure was provided to the AWPA P3 committee in 2005. The data are summarized for the Dorman Lake site in Tables 10A-D and in Tables 11A-D for the Saucier test site. The tables provide mean decay and termite ratings for the tests from inspections for over 27 Years at the Dorman Lake site, and for 25 years at the Saucier site. Decay ratings for DCOI treated stakes at 0.1 and 0.2 pcf along with penta at 0.2 and 0.4 pcf are graphed below each table. The graphs presented below each data table illustrate the fact that DCOI outperforms penta at an equivalent retention. This is shown where the dashed blue lines (0.1 pcf DCOI) typically lie about half-way between the two red lines (penta at 0.2 and 0.4 pcf) strongly supporting that DCOI is as effective as penta at about 1/3rd its concentration. This relative performance relationship holds against the wide range of oil carrier systems tested. Photos are included for a few of the stakes treated with 0.2 pcf and 0.4 pcf DCOI and 0.4 pcf penta in plane as well as cross sectional-sectional view at above and below ground line zones of these stakes.

The data strongly support that DCOI is an effective wood preservative in so far as it demonstrates significantly superior performance to penta at equivalent retention levels. If we use 0.40 penta as the baseline, the data across all of the solvent types indicate that a DCOI retention between 0.1 and 0.2 pcf provides equivalent performance to penta at a nominal retention of 0.4pcf.

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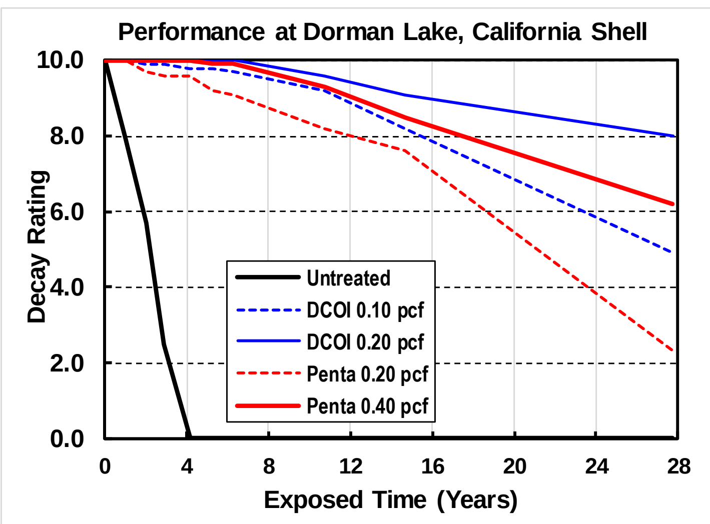
Table 10A. AWPA E7 Stake Test Installed by MSU in April 1988 at Dorman Lake, MS (California Shell Oil Carrier)

Treatment	RETN (pcf)	Performance Rating in California Shell, diluted (20:80) with Toluene, Dorman Lake, MS																	
		APR 89		APR 90		MAR 91		MAY 92		JUL 93		JUL 94		JAN 99		DEC 02		JAN 16	
		1 Year		2 Year		2.9 Year		4.2 Year		5.3 Year		6.3 Year		10.8 Year		14.7 Year		27.8 Year	
		Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter
DCOI	0.05	10.0	10.0	9.7	9.9	9.3	9.8	9.1	9.6	9.0	9.3	8.9	9.3	8.2	8.8	7.3	8.0	3.2	5.1
	0.10	10.0	10.0	9.9	9.9	9.9	9.9	9.8	9.9	9.8	9.9	9.7	9.8	9.2	9.6	8.2	8.8	4.9	6.1
	0.20	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	9.6	9.6	9.1	9.6	8.0	8.6
	0.39	10.0	10.0	10.0	10.0	10.0	10.0	9.8	10.0	9.8	10.0	10.0	10.0	9.6	10.0	9.4	9.9	8.9	9.1
Oil only 20/80	6.29	10.0	10.0	9.6	9.9	9.4	9.9	9.4	9.7	8.9	9.5	8.0	9.4	7.8	8.7	6.1	8.5	2.5	2.6
Oil only 40/60	12.7	10.0	10.0	10.0	10.0	10.0	10.0	9.9	10.0	9.8	10.0	9.8	10.0	9.8	10.0	9.9	10.0	5.8	6.4
PENTA	0.10	10.0	10.0	9.9	10.0	9.7	10.0	9.7	10.0	9.7	10.0	9.8	10.0	9.7	9.9	9.5	9.9	6.2	7.0
	0.20	10.0	10.0	9.7	10.0	9.6	9.9	9.6	9.7	9.2	9.5	9.1	9.5	8.2	8.3	7.6	8.0	2.3	3.7
	0.40	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	9.9	10.0	9.9	9.9	9.3	9.7	8.5	9.4	6.2	6.7
	0.82	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	9.9	10.0	9.9	10.0	8.9	9.3	8.5	9.2	7.2	8.0
Controls	0	7.9	8.3	5.7	6.0	2.5	3.1	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



DCOI (0.2 pcf)

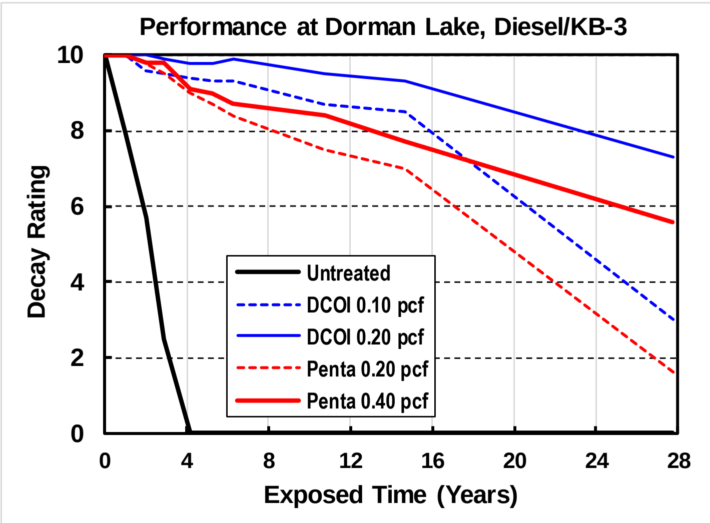
Penta (0.40 pcf)

Table 10B. AWPA E7 Stake Test installed by MSU in April of 1988 at Dorman Lake, MS (Diesel/KB-3 Carrier)

Treatment	RETN (pcf)	Performance Rating in Diesel/KB-3/B-11, diluted (17/2/1:80) with Toluene, Dorman Lake, MS																	
		APR 89		APR 90		MAR 91		MAY 92		JUL 93		JUL 94		JAN 99		DEC 02		JAN 16	
		1 Year		2 Year		2.9 Year		4.2 Year		5.3 Year		6.3 Year		10.8 Year		14.7 Year		27.8 Year	
		Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter
DCOI	0.05	10.0	10.0	9.2	9.4	9.1	9.2	8.8	9.1	8.6	8.8	8.6	8.8	7.5	7.9	5.4	7.4	0.4	0.4
	0.10	10.0	10.0	9.6	10.0	9.5	10.0	9.4	10.0	9.3	9.9	9.3	9.7	8.7	9.0	8.5	8.8	3.0	4.0
	0.20	10.0	10.0	10.0	10.0	9.9	10.0	9.8	10.0	9.8	10.0	9.9	10.0	9.5	9.4	9.3	9.3	7.3	7.9
	0.40	10.0	10.0	10.0	10.0	9.9	10.0	9.9	10.0	9.9	10.0	9.9	10.0	9.8	9.9	9.6	9.9	8.0	8.4
Oil only 20/80	6.5	10.0	10.0	9.6	9.8	9.3	9.6	9.0	9.4	8.8	9.4	8.6	9.0	4.1	7.6	2.8	3.8	0.0	0.0
PENTA	0.10	10.0	10.0	9.8	10.0	9.6	9.9	9.4	9.6	8.8	9.3	8.3	9.0	7.5	7.7	6.2	6.8	0.0	0.4
	0.20	10.0	10.0	9.8	10.0	9.5	9.8	9.0	9.8	8.7	9.3	8.4	8.6	7.5	8.0	7.0	7.8	1.6	2.2
	0.40	10.0	10.0	9.8	9.9	9.8	9.9	9.1	9.4	9.0	9.1	8.7	9.0	8.4	8.3	7.7	8.1	5.6	6.0
	0.80	10.0	10.0	9.9	10.0	9.8	10.0	9.5	9.8	9.3	9.8	9.1	9.5	9.0	9.2	8.3	8.9	7.2	7.9
Controls	0	7.9	8.3	5.7	6.0	2.5	3.1	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DCOI (0.2 pcf)

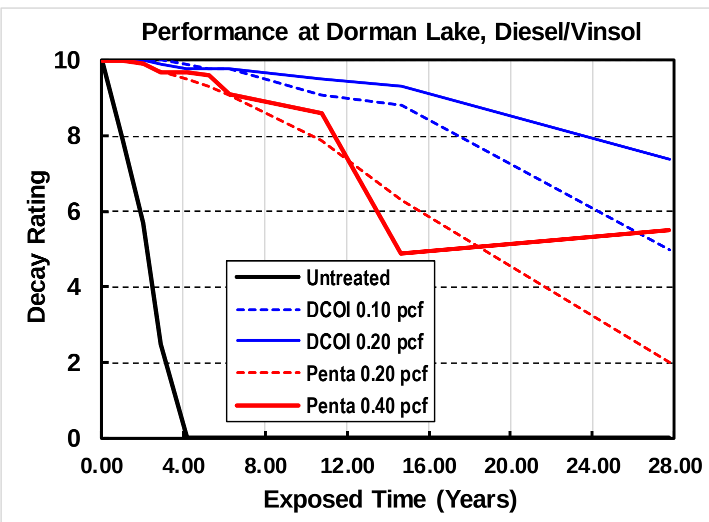
Penta (0.39 pcf)



Performance at Dorman Lake, Diesel/KB-3
Decay Rating
Exposed Time (Years)
0
2
4
6
8
10
0
4
8
12
16
20
24
28
Untreated
DCOI 0.10 pcf
DCOI 0.20 pcf
Penta 0.20 pcf
Penta 0.40 pcf

Table 10C. AWPA E7 Stake Test installed by MSU in April of 1988 at Dorman Lake, MS (DieselVinsol Carrier)

Treatment	RETN	Performance Rating in Diesel/Vinsol, diluted (20/2.5:37.5/40) with Acetone/Toluene, Dorman Lake, MS																	
		APR 89		APR 90		MAR 91		MAY 92		JUL 93		JUL 94		JAN 99		DEC 02		JAN 16	
		1 Year		2 Year		2.9 Year		4.2 Year		5.3 Year		6.3 Year		10.8 Year		14.7 Year		27.8 Year	
	(pcf)	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter
DCOI	0.05	10.0	10.0	9.9	9.8	9.8	9.8	9.6	9.7	9.1	9.6	9.0	9.4	8.1	8.4	6.9	8.2	0.0	0.0
	0.10	10.0	10.0	10.0	10.0	10.0	10.0	9.9	10.0	9.8	10.0	9.8	10.0	9.1	9.2	8.8	9.0	5.0	5.7
	0.20	10.0	10.0	10.0	9.9	9.9	9.9	9.8	9.8	9.8	9.8	9.8	9.8	9.5	9.6	9.3	9.5	7.4	7.9
	0.40	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	9.9	9.9	9.9	9.9	8.6	8.9
Oil only 20/80	6.2	10.0	10.0	10.0	10.0	10.0	10.0	9.9	10.0	9.6	9.8	9.2	9.4	2.2	4.2	0.0	0.4	0.0	0.0
PENTA	0.10	10.0	10.0	10.0	10.0	9.7	9.9	9.6	9.5	9.1	9.3	9.2	9.0	7.0	7.2	5.4	6.9	0.0	0.7
	0.20	10.0	10.0	9.9	10.0	9.7	10.0	9.5	9.6	9.3	9.5	9.1	9.0	7.9	8.0	6.3	7.7	2.0	4.3
	0.40	10.0	10.0	9.9	10.0	9.7	9.9	9.7	9.8	9.6	9.7	9.1	9.5	8.6	8.7	4.9	6.4	5.5	6.6
	0.81	10.0	10.0	10.0	10.0	9.8	10.0	9.7	9.9	9.7	9.9	9.7	9.9	9.0	9.2	7.7	9.1	7.4	8.3
Controls	0	7.9	8.3	5.7	6.0	2.5	3.1	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



DCOI (0.2 pcf)

Penta (0.4 pcf)

Table 10D. AWPA E7 Stake Test installed by MSU in April of 1988 at Dorman Lake, MS (Diesel/Vinsol/DMF Carrier)

Treatment	RETN (pcf)	Performance Rating in Diesel/Vinsol/DMF, diluted (20/2.5/4:20/33.5/20) with Acetone/MIBK/Toluene, Dorman Lake, MS																	
		APR 89		APR 90		MAR 91		MAY 92		JUL 93		JUL 94		JAN 99		DEC 02		JAN 16	
		1 Year		2 Year		2.9 Year		4.2 Year		5.3 Year		6.3 Year		10.8 Year		14.7 Year		27.8 Year	
		Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter
DCOI	0.05	10.0	10.0	10.0	9.9	9.7	9.6	9.5	9.5	9.1	9.3	8.7	9.2	8.0	8.0	5.2	6.7	0.0	0.0
	0.10	10.0	10.0	10.0	10.0	9.8	10.0	9.4	9.4	9.3	9.4	9.2	9.3	8.8	8.9	7.9	8.2	4.3	6.1
	0.20	10.0	10.0	10.0	10.0	9.9	10.0	9.9	9.9	9.9	9.9	10.0	9.9	9.8	9.7	9.6	9.5	8.4	8.2
	0.40	10.0	10.0	10.0	10.0	10.0	9.9	10.0	9.9	10.0	9.9	10.0	9.9	10.0	9.9	10.0	9.7	9.0	9.1
Oil only 20/80	6.5	10.0	10.0	9.6	9.9	9.3	9.6	9.0	9.5	8.6	9.3	7.7	9.2	3.8	5.8	1.5	3.7	0.0	0.0
PENTA	0.10	10.0	10.0	9.9	9.9	9.6	9.9	9.4	9.7	9.4	9.6	9.6	9.7	8.5	8.8	4.5	6.2	1.4	2.3
	0.20	10.0	10.0	9.9	10.0	9.8	9.9	9.5	9.8	9.4	9.5	9.1	9.4	8.5	8.7	6.9	8.3	4.1	5.0
	0.40	10.0	10.0	10.0	10.0	9.9	10.0	9.8	9.9	9.8	9.7	9.6	9.6	9.0	9.0	7.5	8.8	6.9	7.0
	0.81	10.0	10.0	10.0	9.9	10.0	9.9	9.9	9.9	9.8	9.9	9.7	9.9	9.2	9.4	5.6	7.1	6.9	7.6
Controls	0	7.9	8.3	5.7	6.0	2.5	3.1	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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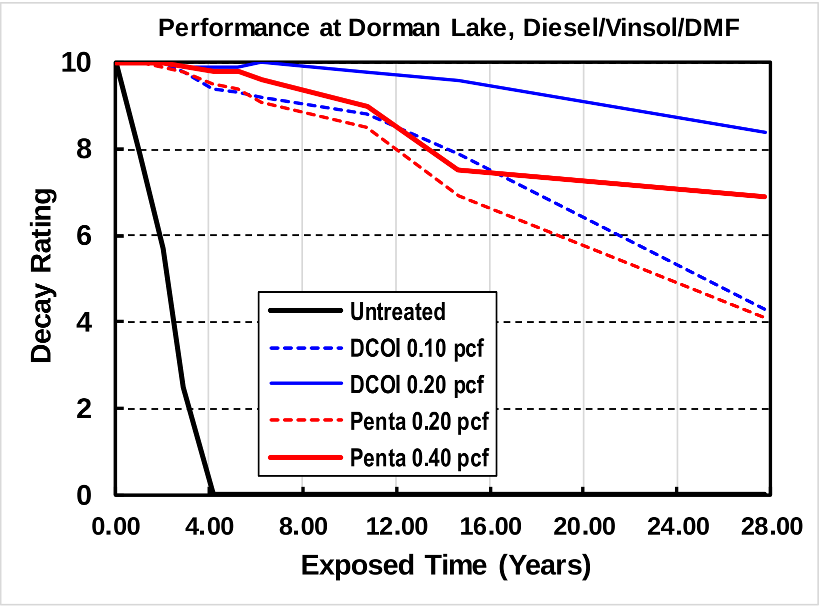

DCOI (0.2 pcf)

Penta (0.4 pcf)

Table 11A. AWPA E7 Stake Test installed by MSU in April of 1988 at Saucier, MS (California Shell Carrier)

Treatment	RETN (pcf)	Performance Rating in California Shell, diluted (20:80) with Toluene, Saucier, MS																					
		MAY 89		MAY 90		MAY 91		MAY 92		APR 93		APR 94		APR 95		APR 98		DEC 02		AUG 09		APR 13	
		1.1 Year		2.1 Year		3.1 Year		4.1 Year		5.0 Year		6.0 Year		7.0 Year		10.0 Year		14.7 Year		21.3 Year		25.0 Year	
		Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter
DCOI	0.05	9.7	10.0	8.8	9.5	8.5	8.9	8.3	8.6	7.9	8.1	7.7	8.0	6.8	8.1	6.5	6.2	4.9	4.9	2.5	2.2	0.4	0.4
	0.10	9.9	10.0	9.8	10.0	9.5	9.9	9.1	9.3	8.9	9.0	8.8	8.9	8.7	8.9	8.2	8.4	7.6	7.6	5.2	5.8	4.4	3.2
	0.20	10.0	10.0	9.8	10.0	9.7	9.8	9.4	9.6	9.1	9.6	9.2	9.5	9.1	9.5	9.0	8.5	8.3	7.7	8.0	7.9	8.0	7.1
	0.40	10.0	10.0	9.8	10.0	9.4	10.0	9.3	9.7	9.3	9.6	9.5	9.6	9.5	9.6	9.3	8.9	8.7	8.5	8.3	8.5	8.2	8.1
Oil only 20/80	6.38	9.5	9.8	8.4	9.2	8.1	8.6	5.4	8.1	3.7	5.7	4.0	4.0	3.8	3.8	3.4	3.6	1.0	2.7	0.6	1.3		
Oil only 40/60	12.8	9.6	9.9	9.5	9.7	9.3	9.1	9.3	9.1	8.3	9.0	8.4	8.4	8.4	8.4	7.8	8.2	7.3	6.8	4.6	6.0		
PENTA	0.10	9.9	9.9	9.5	9.5	9.4	9.5	8.7	9.0	8.7	9.1	8.7	9.0	8.8	9.0	8.5	9.0	8.0	8.5	3.9	7.1	1.9	3.4
	0.20	9.7	9.9	9.1	9.5	8.5	9.2	8.1	8.2	7.6	8.0	7.6	7.9	7.0	7.7	6.6	6.9	5.8	6.0	1.7	2.6	0.6	1.4
	0.41	9.9	10.0	9.0	9.6	8.7	9.2	8.6	8.6	8.3	8.3	8.4	8.4	8.2	8.4	7.8	7.7	7.3	7.4	5.9	6.2	3.0	3.6
	0.83	10.0	10.0	9.5	9.9	9.4	9.5	9.1	9.2	8.9	9.1	8.7	8.9	8.8	8.6	8.5	8.6	8.1	8.1	6.8	7.3	5.3	6.1
Controls	0	6.4	6.5	1.4	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

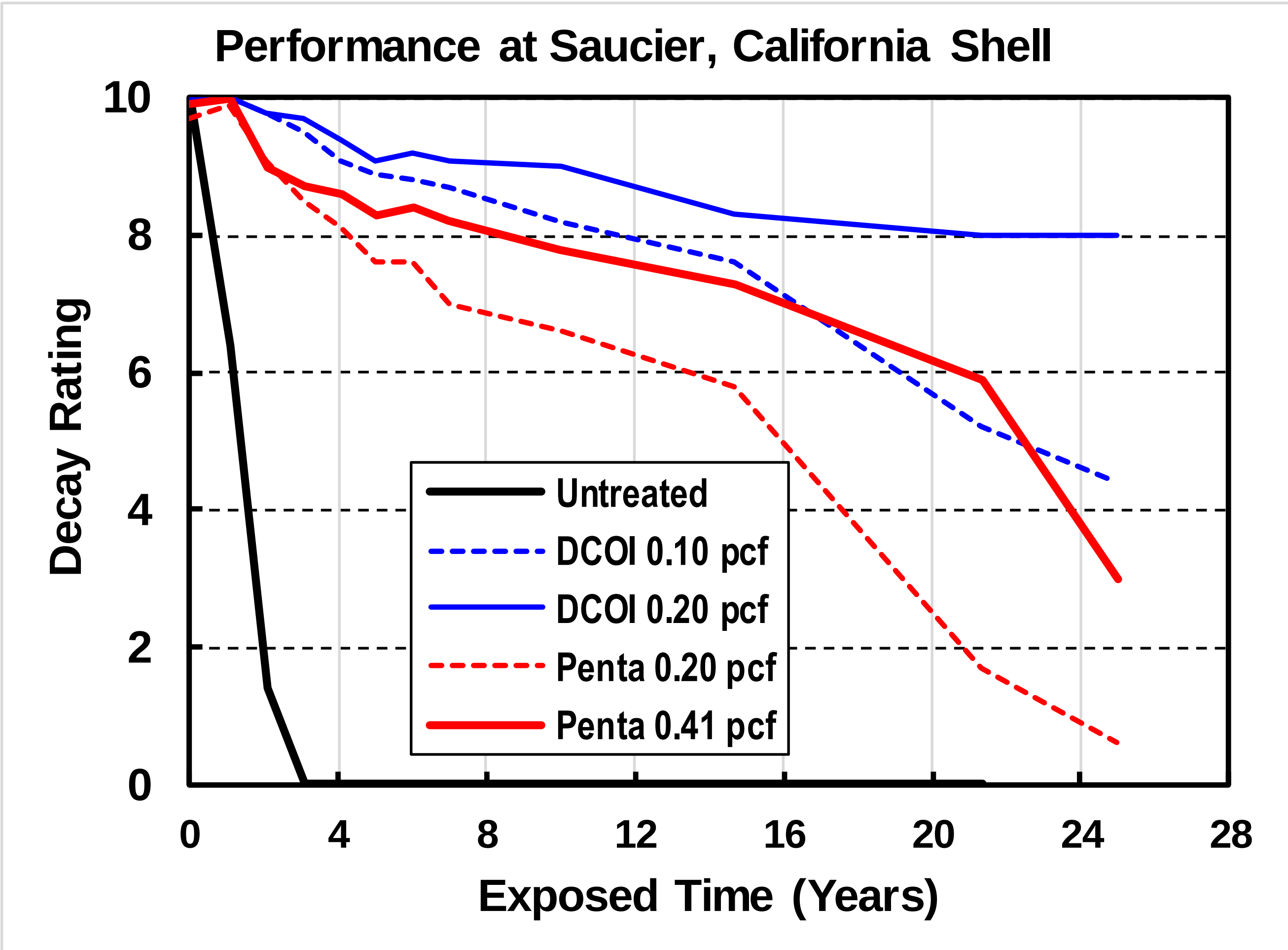
Performance at Saucier, California Shell
Decay Rating
10
8
6
4
2
0
0
4
8
12
16
20
24
28
Exposed Time (Years)
Untreated
DCOI 0.10 pcf
DCOI 0.20 pcf
Penta 0.20 pcf
Penta 0.41 pcf

Table 11B. AWPA E7 Stake Test installed by MSU in April of 1988 at Saucier, MS (Diesel/KB-3 Carrier)

Treatment	RETN	Performance Rating in Diesel/KB-3/B-11, diluted (17/2/1:80) with Toluene, Saucier, MS																					
		MAY 89		MAY 90		MAY 91		MAY 92		APR 93		APR 94		APR 95		APR 98		DEC 02		AUG 09		APR 13	
		1.1 Year		2.1 Year		3.1 Year		4.1 Year		5.0 Year		6.0 Year		7.0 Year		10.0 Year		14.7 Year		21.3 Year		25.0 Year	
	(pcf)	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter
DCOI	0.05	9.2	9.8	8.4	9.0	8.1	8.5	7.5	7.8	7.1	7.3	6.2	6.4	6.0	6.2	3.5	2.8	0.0	0.0	0.4	0.0	0.0	0.0
	0.10	9.7	9.9	8.8	9.5	8.6	8.8	8.3	8.5	8.3	8.4	8.1	8.2	8.2	8.0	7.8	7.4	5.6	5.5	2.7	2.0	1.1	0.4
	0.20	9.9	10.0	9.6	9.9	8.9	9.9	8.5	8.6	8.5	8.5	8.1	8.6	8.3	8.1	8.4	7.8	7.4	6.8	6.5	5.5	3.0	1.2
	0.40	10.0	10.0	9.7	10.0	9.5	10.0	9.1	9.3	8.9	9.2	9.1	9.1	9.2	9.3	9.3	8.8	9.1	8.1	8.2	7.5	8.0	7.2
Oil only 20/80	6.6	9.4	9.7	8.1	8.8	7.8	7.8	7.1	7.1	5.3	6.9	4.6	4.7	3.0	3.1	1.6	2.3	0.4	0.0	0.0	0.0		
PENTA	0.10	9.5	9.9	8.6	9.1	8.1	8.1	7.5	7.3	7.5	7.3	7.3	7.2	6.9	6.9	5.7	5.5	2.8	2.5	0.8	0.4	0.0	0.0
	0.20	9.8	10.0	9.1	8.8	8.7	8.5	8.2	8.1	7.6	7.7	7.5	7.6	7.5	7.5	6.9	6.6	5.7	5.7	2.2	0.4	0.0	0.0
	0.40	10.0	10.0	9.2	9.4	8.7	9.1	8.1	8.4	8.0	8.1	8.1	8.0	7.9	8.1	7.6	7.5	7.0	6.6	4.0	2.8	1.2	1.2
	0.81	10.0	9.9	9.3	9.6	9.2	9.3	8.9	8.9	8.7	8.8	8.8	8.8	8.6	8.6	8.5	7.9	8.3	7.7	7.1	7.1	5.8	5.4
Controls	0	6.4	6.5	1.4	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

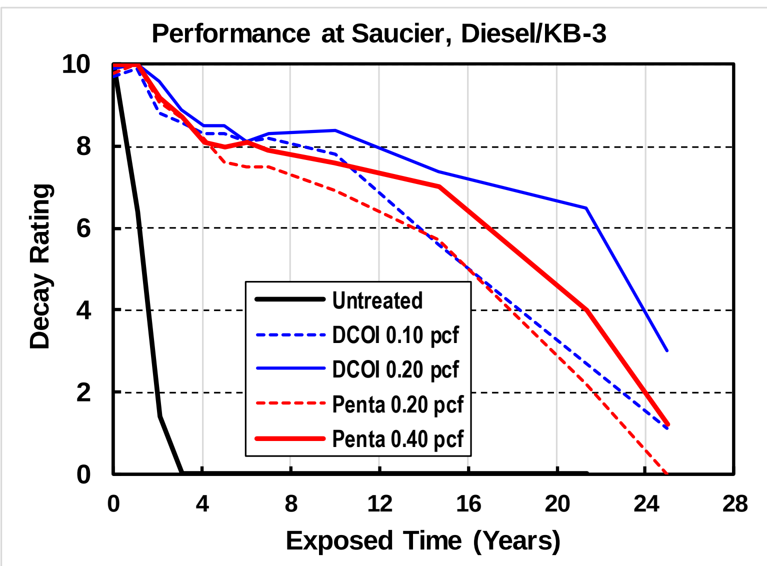

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Table 11C. AWPA E7 Stake Test installed by MSU in April of 1988 at Saucier, MS (Diesel/Vinsol Carrier)

Treatment	RETN (pcf)	Performance Rating in Diesel/Vinsol, diluted (20/2.5:37.5/40) with Acetone/Toluene, Saucier, MS																					
		MAY 89		MAY 90		MAY 91		MAY 92		APR 93		APR 94		APR 95		APR 98		DEC 02		AUG 09		APR 13	
		1.1 Year		2.1 Year		3.1 Year		4.1 Year		5.0 Year		6.0 Year		7.0 Year		10.0 Year		14.7 Year		21.3 Year		25.0 Year	
		Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter
DCOI	0.05	9.7	10.0	9.4	9.8	9.1	9.5	8.3	8.9	8.1	8.5	7.9	8.3	7.7	7.9	6.8	6.0	2.3	2.3	1.6	0.0	0.0	0.0
	0.10	10.0	9.9	9.5	9.5	9.2	9.3	8.8	8.8	8.9	8.8	8.7	8.6	8.9	8.8	8.3	8.0	7.7	7.3	4.1	2.5	1.0	0.6
	0.20	9.9	10.0	9.7	9.8	9.6	9.7	9.3	9.2	9.1	9.1	9.3	9.3	9.2	9.3	9.0	8.8	8.5	8.1	7.1	6.7	6.8	5.8
	0.41	10.0	10.0	9.8	10.0	9.7	9.9	9.6	9.7	9.5	9.7	9.6	9.6	9.4	9.5	9.4	9.4	9.2	8.6	8.8	8.2	8.6	7.6
Oil only 20/80	6.2	9.2	10.0	8.8	9.9	8.1	8.8	6.4	7.6	4.3	5.4	3.3	2.9	1.2	0.8	0.0	0.6	0.0	0.0	0.0	0.0		
PENTA	0.10	9.8	9.9	9.0	9.5	8.3	8.8	8.1	8.1	8.0	7.9	8.0	7.8	7.5	7.7	6.4	6.1	4.7	3.0	3.3	1.6	0.0	0.0
	0.20	9.8	9.9	9.1	9.4	8.9	8.9	8.1	8.2	7.8	8.0	8.0	8.0	7.0	7.5	6.7	6.5	6.1	5.7	3.3	1.6	0.4	0.4
	0.40	10.0	10.0	9.5	9.8	9.2	9.5	8.9	8.8	8.6	8.5	8.8	8.8	8.7	8.7	8.5	8.3	8.1	7.5	6.2	5.1	3.9	2.4
	0.82	10.0	10.0	10.0	10.0	9.9	9.9	9.6	9.2	9.2	9.1	9.5	9.4	9.3	9.3	8.8	8.4	8.7	8.1	7.3	7.0	5.9	5.6
Controls	0	6.4	6.5	1.4	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

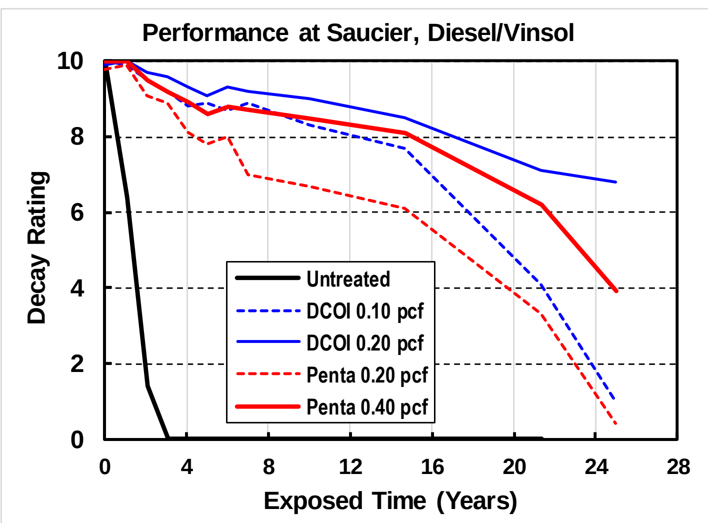
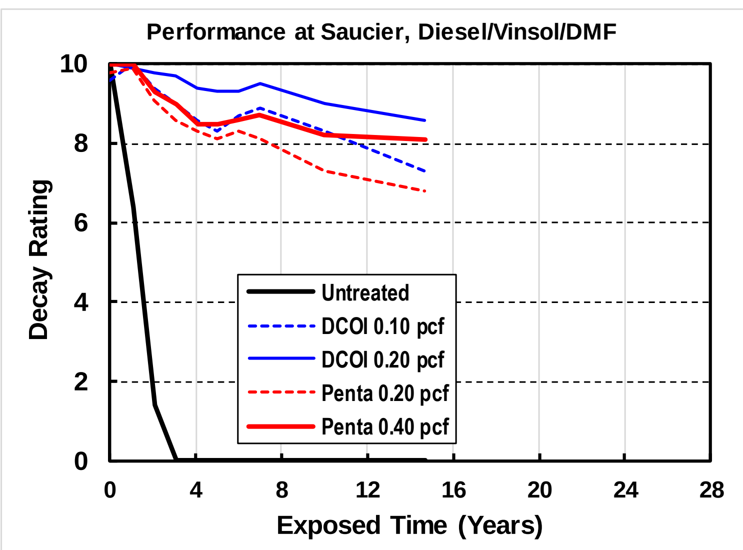


Table 11D. AWPA E7 Stake Test installed by MSU in April of 1988 at Saucier, MS (Diesel/Vinsol/DMF Carrier)

Treatment	RETN (pcf)	Performance Rating in Diesel/Vinsol/DMF, diluted (20/2.5/4:20/33.5/20) with Acetone/MIBK/Toluene, Saucier, MS																					
		MAY 89		MAY 90		MAY 91		MAY 92		APR 93		APR 94		APR 95		APR 98		DEC 02		AUG 09		APR 13	
		1.1 Year		2.1 Year		3.1 Year		4.1 Year		5.0 Year		6.0 Year		7.0 Year		10.0 Year		14.7 Year		21.3 Year		25.0 Year	
		Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter	Dec	Ter
DCOI	0.05	9.9	10.0	9.3	9.5	8.7	9.1	8.1	8.5	8.1	8.4	7.9	8.1	7.4	7.7	6.8	6.6	2.8	2.5				
	0.10	9.6	10.0	9.4	9.4	9.0	9.0	8.6	8.4	8.3	8.3	8.7	8.7	8.9	8.6	8.3	8.0	7.3	7.1				
	0.20	10.0	9.9	9.8	9.8	9.7	9.7	9.4	9.3	9.3	9.3	9.3	9.3	9.5	9.4	9.0	8.4	8.6	7.9				
	0.41	10.0	10.0	10.0	9.9	9.7	9.8	9.7	9.8	9.8	9.9	9.8	9.8	10.0	9.9	9.8	9.5	9.8	9.1				
Oil only 20/80	6.5	9.6	9.9	9.0	9.5	8.7	8.5	6.3	7.8	5.2	5.6	3.8	4.2	3.2	3.1	1.5	0.6	0.0	0.0	0.0	0.0		
PENTA	0.10	9.9	10.0	9.5	9.7	9.3	9.3	8.6	8.7	8.5	8.4	8.3	8.4	8.1	8.3	7.1	6.9	5.7	5.4				
	0.20	9.8	9.9	9.1	9.3	8.6	9.0	8.3	8.5	8.1	8.2	8.3	8.3	8.1	8.2	7.3	7.3	6.8	6.2				
	0.40	10.0	10.0	9.3	9.4	9.0	9.1	8.5	8.5	8.5	8.5	8.6	8.7	8.7	8.6	8.2	8.2	8.1	7.5				
	0.82	10.0	10.0	9.7	9.9	9.7	9.9	9.6	9.3	9.6	9.6	9.6	9.4	9.2	9.4	8.9	9.0	8.8	8.2				
Controls	0	6.4	6.5	1.4	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		



E8 Posts (Pole Stub) Testing

In 2012 Viance worked with the Forest Products Laboratory in Madison to treat southern pine and red pine pole stubs with DCOI in #2 diesel fuel. Treatment data for the posts was previously summarized in Section 4.9.3. After treatment, the pole stubs were installed at three different test sites, Corvallis, OR, Harrisburg, NC and Gainesville, FL. A photo illustrating the Florida test installation is provided below. After 5 years exposure, all DCOI treated posts (0.10 to 0.19 pcf) at all three test sites are completely sound. Similarly, 0.4 pcf treated penta posts are 100% sound but untreated posts are showing signs of significant decay.

Figure 4. Pole stub testing of DCOI in southern pine, Gainesville FL

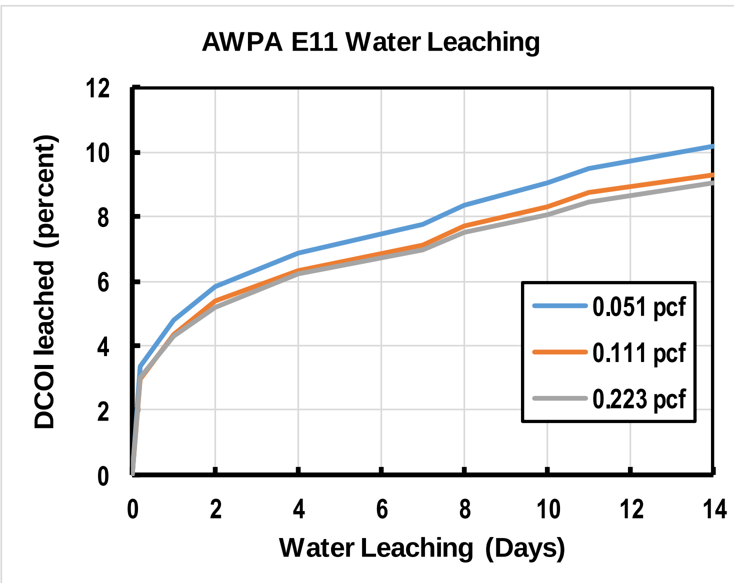
Preservative Depletion

Based on relative solubility in water DCOI should exhibit significantly lower leaching that Pentachlorophenol. Compare 2 mg/L for DCOI vs 20 mg/L for pentachlorophenol.

AWPA E11 Standard Method for Accelerated Evaluation of Preservative Leaching

Southern pine blocks were treated with DCOI in #2 diesel at three different solution concentrations (2.8%, 1.38%, and 0.68%), using a 5-minute initial vacuum at 5” Hg, a 2 minute press at 150 psi, and a 1 hour final vacuum at 26” Hg. Block uptakes averaged 25-26% by weight for the three treatments. The final percent DCOI leached after the 14 day E11 leaching test was 9.0%, 9.3%, and 10.2% for the sets of blocks treated to 0.223, 0.111, and 0.051, pcf, respectively. Rates of leaching are shown in Figure 5.

Figure 5. AWPA E11 Water Leaching



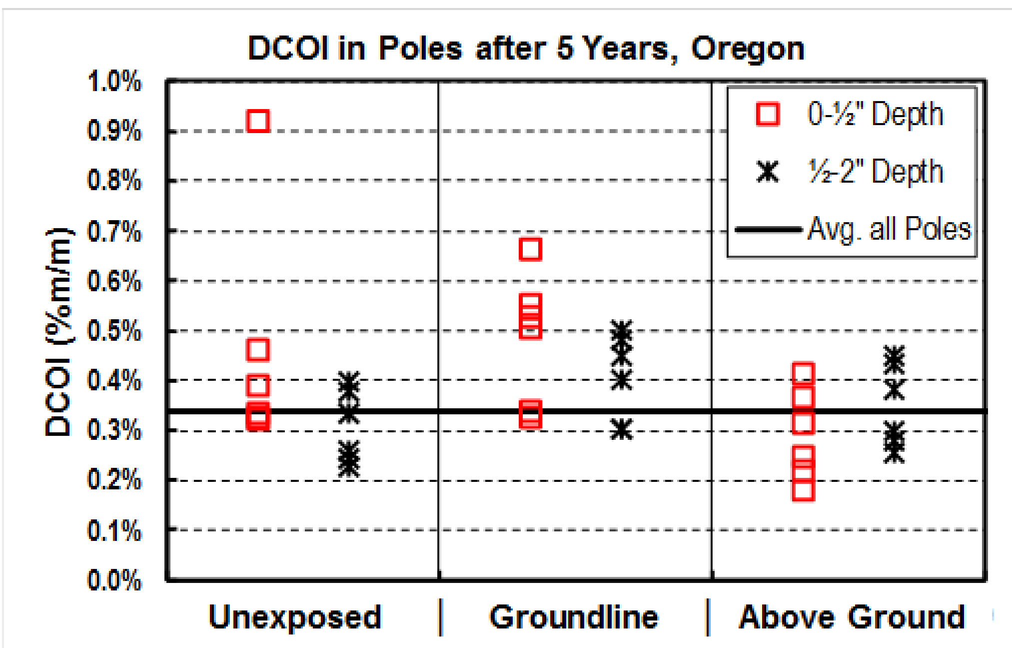
AWPA E8 Posts (Pole Stub) Depletion Test

In 2012 Viance worked with the Forest Products Laboratory in Madison to treat southern pine and red pine pole stubs with DCOI at 1.5% and 2.5% (southern pine only) in #2 diesel fuel (AWPA HSA solvent). After treatment, the pole stubs were installed at three different test sites, Corvallis, OR, Harrisburg, NC and Gainesville, FL. A photo illustrating the Florida test installation is provided below. After 5 years exposure, all DCOI posts at all three test sites are completely sound, with no indication of any decay or termite attack on any of the posts.

After 5 years exposure, six of the pole stubs treated with 1.5% DCOI solutions and exposed at the Corvallis, OR site were sampled for retention at the ground-line and at two-foot above ground in both the outer ½ and ½-2” depth zones to provide data on migration and depletion of the active DCOI. Unfortunately, these poles were not individually sampled for retention gradients prior to exposure, although composite core samples from all poles in each charge were analyzed in the assay zone.

In addition, six individual poles from these charges were sampled for retention gradient, although these poles were not exposed in the field (destructively sampled for penetration). They do provide an additional information on relative preservative variability and gradients to go along with the overall average retentions for the combined charges. Retention results from the six unexposed southern pine pole stubs after treatment, as well as six unmatched pole stubs from these same charges after 5 years exposure in Corvallis, OR are shown in Figure 6 below. This figure also includes the average retention in the assay zone for all poles in the three charges treated with the 1.5% DCOI in diesel solution (0.34% wt/wt). The retentions in the assay zone (½-2") for the six individual poles sampled after treatment as well a separate set of 6 poles as after 5 years exposure in Corvallis, OR were reasonably consistent with the average of the composite charge assay retentions. The retentions in the ground line zone did tend to show an increase in retention after 5 years exposure, while retentions above ground tended to show a relative decrease in the outer 0-½" assay zone compared to the inner zone, possibly due to some migration of the preservative/oil down the pole stubs. Overall, there is very little evidence of any significant depletion of the preservative from these poles after 5 years exposure.

Figure 6. Assay retentions at two depth zones in 6 unexposed southern pine pole stubs and in a separate set of 6 pole stubs from the same treatment charges after 5 years exposure in Corvallis, OR. Pole stubs were sampled at 2' above ground and at the ground line. The average initial charge assay retentions in the ½-2" assay zone is also included for reference.



Ancillary properties of DCOI treated wood

Strength of Solid Wood and Other Dimensional Wood Products

The Composite Materials and Engineering Center (CMEC) at Washington State University in Pullman WA performed static bending tests on wood specimens supplied by Viance LLC. Three sets of twenty-five end/side matched 1x1 by 15” southern pine beams were machined to provide samples for three treatments for the comparative strength testing. Sets of 25 samples were either left untreated, treated with diesel only, or treated with a solution of 2.5% DCOI in diesel. Treatments were witnessed by Mr. Bob Mooney (SPIB), and involved a 5 minute initial vacuum at 5” Hg, a 3 minute pressure period to 150 psi, and a 75 minute final vacuum at 27” Hg. Charge uptakes averaged 137 liter/m3 (115 kg/m3) of the treatment solutions, for an average retention of 0.18 pcf for the DCOI treatment. Test specimens were conditioned at 68F and 65 R.H. for 32 days until constant weight was achieved prior testing. Flexure tests were conducted according to ASTM D143-14 Standard Test methods for Small Clear Specimens of Timber Section 8, secondary method. Results from this testing are summarized in Table 12, along with statistical analysis using a randomized block design for these end-side matched samples. Results show that there is no statistical impact of the DCOI-oil treatment on MOE, MOR, or WML.

Table 12. Average Strength and Stiffness of small clear southern pine specimens (14-in. Span), along with statistical analysis of the data. Means with the same double underline are not significantly different at α=0.05.

	Mean for End/Side-Matched Samples			Randomized Block Design			
	Untreated	Diesel-only	DCOI-Diesel	ANOVA	Blocking	Critical Difference α=0.05	
Property		138 l/m3	2.88 kg/m3	"F"	Efficiency	1 mean	2 means
MOE (psi x 1000000)	1.934	1.974	1.907	0.37	327%	0.159	0.168
MOR (psi x 1000)	13.20	12.95	13.09	0.39	353%	0.577	0.607
WML (lbf)	673.5	659.9	667.0	0.41	234%	30.4	32.0

Electrical Resistance

While electrical resistance data is listed as a mandatory requirement for preservative submissions associated with components of utility line structures and railway ties (AWPA GDA Table 1) a standard test method has not actually been defined with any degree of certainty. AWPA GDA refers users to a 1963 AWPA Proceedings paper by Katz and Miller. The Katz and Miller paper was consulted along with another publication (Morrell *et al*. 2010) to help develop a method to generate conductivity data in southern pine posts treated with DCOI in # 2 diesel.

The basic test apparatus is illustrated in Figure 7 which illustrates a representative test post supported and insulated on a pair of wooden saw horses. A 1 ½" 4d common galvanized nail (Fas-n-tite) was driven to a depth of 1" into the test posts 3" from the end grain and thereafter at points every 6" along a straight line 45" long running parallel to the long axis of the post. A Megger MIT 430 ohmmeter set at 500V was used to measure resistance. The procedure entailed attaching an electrical lead from the Megger to the nail 3" from the end of the test pole and then taking a resistance measurement by attaching the other terminal of the Megger to the next nail in the line moving down the post.

Figure 7 Test Setup for Resistance Measurements

The following wood samples were tested in this arrangement:

1) DCOI in #2 diesel treated posts after 6 months in outdoor dry storage
2) Untreated poles in open outdoor storage for approximately 8 months

3) CA-C (0.15 pcf) 4 x 4 posts in dry storage for over 1 year

Resistance measurement results from the samples described above are summarized in Table 13A

Table 13A. Resistance Measurements

				Resistance (MΩ) at Intervals (in.)						
Treatment	**Sample Type**	**ID #**	**% MC**	**6**	**12**	**18**	**24**	**30**	**36**	**42**
DCOI in # 2	Post	1	14.6	93.7	96.0	83.2	88.0	82.0	94.2	95.4
diesel		2	14.1	120	115	114	120	120	110	131
		3	14.6	41.0	41.4	43.2	53.0	53.1	66.5	54.5
		4	15.8	73.0	61.4	64.1	63.7	68.6	76.5	121
		5	11.7	189	192	214	231	225	256	259
		6	13.5	210	207	191	213	239	272	294
		7	14.6	99.8	99.2	92.3	88.2	90.3	95.1	124
		8	12.9	202	213	180	172	214	238	249
		9	12.9	214	214	252	253	230	276	256
		10	12.3	222	250	246	281	283	259	313
Untreated	Post	11	18.8	14.9	13.7	12.9	13.6	13.1	11.5	10.9
		12	28.1	1.25	1.08	0.88	1.04	1.20	1.24	1.18
		13	11.7	275	311	301	296	341	357	353
		14	11.1	223	271	280	317	347	325	362
		15	11.1	503	618	564	571	643	668	662
CA-C	4x4	16	12.3	206	232	284	305	329	390	421
		17	12.9	148	177	220	267	288	339	394

It is well known that conductivity/resistance in treated wood is affected by moisture content. To investigate the impact of moisture content all of the test measurements reported in Table 13A were repeated after first exposing the test materials to a water spray for 1 hour (equivalent to 4.5" of simulated rainfall).

A summary of the resistance measurements after the rain event is provided in Table 13B

Table 13B. Resistance Measurements at increased moisture content after a simulated rain event

			Weights (kg)			Resistance (MΩ) at Interval (in.)			
Treatment	**Board Type**	**Board #**	**Pre**	**Post**	**% MC**	**6**	**12**	**18**	**24**
DCOI in #2 Diesel	Pole	1	13.63	13.80	19.9	1.00	1.26	1.23	1.36
		2	13.26	13.57	20.5	0.72	0.87	1.00	1.08
		3	11.26	11.67	18.8	0.20	0.26	0.39	0.40
		4	17.86	18.19	23.4	1.30	1.65	2.03	1.73
		5	12.15	12.43	19.9	2.59	3.22	3.44	4.16
		6	12.11	12.41	18.8	2.86	3.45	3.86	4.53
		7	12.80	13.66	18.2	0.89	1.05	1.34	1.67
		8	14.31	14.65	21.1	0.81	0.70	0.80	0.75
		9	10.36	10.66	18.8	1.60	1.88	2.25	2.94
		10	12.17	12.45	19.9	2.17	2.81	3.16	3.18
Untreated	Pole	11	--	--	22.3	1.01	1.40	1.42	1.46
		12	--	--	34.0	0.22	0.22	0.17	0.23
		13	13.05	13.65	22.3	0.25	0.30	0.37	0.38
		14	9.82	10.40	22.9	0.31	0.33	0.41	0.40
		15	11.46	12.58	23.4	0.66	0.81	1.01	0.95
CA-C	4x4	16	3.22	3.47	25.8	0.19	0.25	0.29	0.29
		17	2.94	3.28	21.1	0.26	0.30	0.36	0.42

Resistance measurements were also made on southern pine post stubs exposed for approximately 5 years (DCOI in #2 diesel) and 3.5 years (penta) in ground at a field site in Harrisburg, NC.

Table 13C. Summary of Resistance Measurements on DCOI and Penta treated pole stubs and untreated controls exposed outdoors in Harrisburg NC for 5 years

					Resistance (MΩ) at Interval (in.)			
Treatment	**Board #**	**Location**	**retn (pcf)**	**% MC**	**6**	**12**	**18**	**24**
DCOI in #2 Diesel	99211	1-5	0.43	26.4	1.43	0.51	1.28	0.69
	99219	2-5	0.30	31.6	0.14	0.19	0.15	0.14
	99221	3-5	0.38	23.4	0.25	0.57	0.62	0.47
	99222	3-9	0.24	28.1	0.24	0.46	0.56	0.46
	99216	5-4	0.34	23.4	0.53	2.76	2.27	0.49
Penta	--	7-1	--	22.3	2.92	10.2	12.1	10.7
	--	7-3	--	22.3	1.05	1.61	1.65	2.05
	--	0-4	--	28.7	0.22	0.28	0.46	0.31
	--	0-5	--	22.3	0.62	1.59	2.21	2.10
	--	0-6	--	24.6	0.65	0.84	0.82	0.78
Untreated	99231	3-2	--	45.0	0.08	0.07	0.07	0.06

Hygroscopicity

While the relevance of hygroscopicity to wood preservative treatments in an oil-borne carrier is questionable the hygroscopicity of post sections treated with DCOI in #2 diesel were made in accordance with ASTM D3201.

Short sections ½” (12mm) thick x post diameter 5.8-7.5” (145mm-180mm) were removed from the ends of 10 DCOI treated posts either 5’ or 10’ long. With those dimensions the samples exceeded the ASTM D3201 requirement for a surface area to volume ratio greater than 3.7 in^2: 1 in^3 (0.15 mm^2: 1mm^3). Similar sized samples cut from nine untreated posts were used as control material.

Prior to testing the parent post samples were air dried under cover for at least 6 months. The individual samples were weighed then placed in an environmental chamber maintained at 92± 2% RH at a temperature of 27°C ± 2°C in accordance with the standard for a period of 7 days then reweighed. Following exposure to high humidity conditions to determine the equilibrium moisture content untreated samples were dried in a 103°C oven until constant weight was achieved (≈8h) and the oil treated samples were dried at 40°C until constant weight (≈ 45h).

Results for treated and untreated posts are summarized in Table 14.

Table 14. Summary of Hygroscopicity Results

Treatment	Sample ID	Moisture content (%)	
		Pre-exposure to high humidity conditions	Post-exposure to high humidity conditions
DCOI in #2 diesel	1	9.8	13.7
	2	10.8	14.3
	3	11.2	13.9
	4	9	12.1
	5	9.5	12.5
	6	9.9	13.7
	7	11.3	14.2
	8	10.9	14.0
	9	10.2	13.6
	10	9.4	12.7
	Average	10.2	13.5
Untreated	A	14.3	19.3
	B	14.7	20.4
	C	14.9	20.2
	D	14.5	19.9
	E	14.9	20.3
	F	15.0	19.7
	G	14.9	20.6
	H	14.5	19.2
	I	14.2	18.5
	Average	14.7	19.8

The data demonstrate that southern pine treated with DCOI in #2 diesel is no more hygroscopic than untreated wood.

Corrosion in Treated Wood

AWPA E12 Wood Sandwich Corrosion Test

A metal coupon corrosion test was set up in accordance with the AWPA E12 procedure. Southern pine sapwood 19 x 38 x 89 mm blocks were used as the substrate. After first predrilling to accommodate the nylon bolts that are used to clamp the wood firmly together the samples were vacuum pressure treated with DCOI and pentachlorophenol diluted in #2 diesel. Target retentions were 0.2pcf for the DCOI treatment and 0.40 pcf for the Penta treatment. Preservative retentions were calculated from pre and post treatment weights of the blocks and solution concentrations. Post treatment the test samples were dried until they reached an equilibrium weight. Electroplated zinc and hot-dipped galvanized (G185) metal coupons 1” x 2” were used for the test. After cleaning and weighing the metal coupons were “sandwiched” between two wood blocks. Ten replicate assemblies were set up for each wood type. Assemblies were exposed in a temperature humidity chamber maintained at 49 °C ± 3°C and 90% ±3% RH for 408 Hours as specified in the standard.

After exposure metal coupons were separated from the wood, cleaned then weighed to determine the amount of corrosion in mils per year. Results are presented in Table 15.

Table 15. Summary of AWPA E12 corrosion test results after 408 Hours exposure

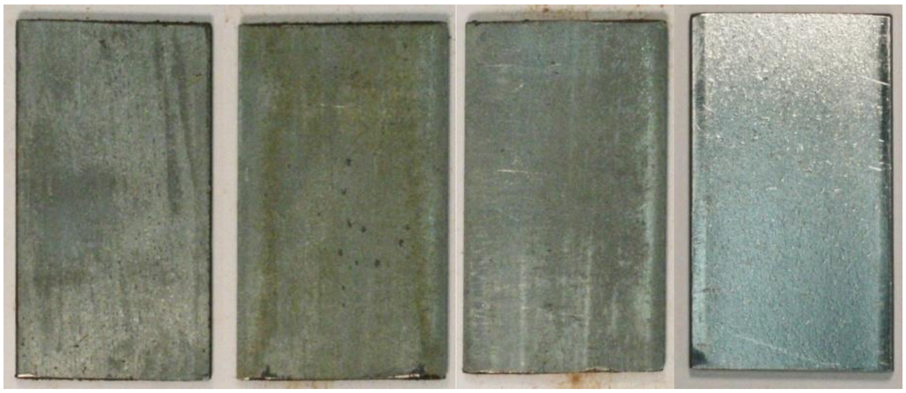
	Treatment		Corrosion rate (mils/yr)		
Metal	**Solution**	**pcf**	**Average**	**Minimum**	**Maximum**
G185 HD Galvanized	DCOI	0.17	0.42	0.23	0.65
	Penta	0.48	0.38	0.19	0.61
	Untreated	--	0.17	0.11	0.29
Electroplated Zinc	DCOI	0.17	0.63	0.41	1.19
	Penta	0.47	0.68	0.43	0.90
	Untreated	--	0.48	0.39	0.60

Photographs of representative coupons before and after the test are provided in Figures 8A and 8B.

Figure 8A. Appearance of the G185 metal coupons before and after exposure for 408 hours in the AWPA E12 corrosion procedure

from left to right
DCOI, Penta, Untreated and unexposed

Figure 8B. Appearance of the Electroplated zinc coupons before and after exposure for 408 hours in the AWPA E12 corrosion procedure



from left to right
DCOI, Penta, Untreated and unexposed

AWPA E17 Preservative Solution Corrosivity

A modified version of AWPA E17 was used to evaluate the corrosivity of DCOI in # 2 diesel. The modifications to E17 were as follows:
1. Solution volume for each coupon was approximately 100 ml.
2. The solutions were not changed over the course of the test.
3. There was no agitation of the solution during the test.
4. Only 1 time period was analyzed.

Solutions of 23% DCOI concentrate and 2.5% DCOI in #2 Diesel were evaluated against C1010 Mild steel and CDA230 red brass test coupons. 1.1% CCA solution was used as a reference control solution with the same metal coupon types. Results of the testing are summarized in Table 16 and Figures 9A and 9B. It is apparent that the concentrated DCOI and 2.5% W/W DCOI in #2 diesel is less corrosive to C1010 mild steel and CDA230 red brass than 1.1% CCA.

Table 16. AWPA E17 Solution Corrosion Test Results

		Corrosion (mils/yr)		
Metal	**Solution**	**Average**	**Minimum**	**Maximum**
C1010	2.5% DCOI	0.03	0.00	0.07
	23% DCOI	0.08	0.02	0.18
	1.1% CCA	0.21	0.16	0.30
CDA230	2.5% DCOI	0.04	0.02	0.07
	23% DCOI	0.36	0.23	0.55
	1.1% CCA	2.12	2.01	2.19

Figure 9A. Appearance of C1010 mild steel coupons before and after exposure to DCOI concentrate and work solution diluted in # 2 diesel

2.5 % DCOI in #2 Diesel	23% DCOI Concentrate	1.1 % CCA	Unexposed

Figure 9B. Appearance of red brass coupons before and after exposure to DCOI concentrate and work solution diluted in # 2 diesel

Before Cleaning

2.5% DCOI in #2 diesel	23% DCOI Concentrate	1.1% CCA	Unexposed

After Cleaning

2.5% DCOI in #2 diesel	23% DCOI Concentrate	1.1% CCA	Unexposed

Summary

DCOI is an EPA registered wood preservative for the control of decay fungi and subterranean termites. Due to its relatively low human and ecotoxicity characteristics DCOI is not classified by the EPA as a restricted use pesticide. DCOI in an oil-based carrier has been AWPA standardized since 1989. In 1994 minimum retention recommendations were set at 0.03 pcf for above ground use and for ground contact use at 0.08 pcf. Long term (up to 28 years) AWPA E7 stake tests in hazard zones 4 and 5 have demonstrated its effectiveness relative to pentachlorophenol at 1/3 of the standardized pentachlorophenol retentions. The active ingredient exhibits excellent solubility in AWPA HSA solvents without the need for co-solvents. Pilot scale combustion tests of DCOI treated wood suggest that it may be a candidate for end-of-life disposal at energy co-gen facilities. Based on laboratory and commercial treatment trials DCOI in an oil-based carrier has demonstrated excellent treatability characteristics in southern pine utility poles, southern pine posts and southern pine and Douglas-fir cross arms using conventional treating plant processes and treatment cycles. In conclusion, DCOI in an oil-borne carrier can be expected to perform as an effective wood preservative for use in the industrial treatment of wood poles and sawn cross arms with a service life expected to be equal to, or exceeding, other AWPA preservatives used at standardized retentions.

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