



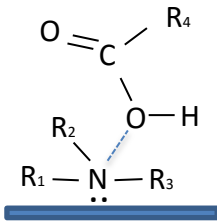
**MIGRATING CORROSION INHIBITORS**  
FROM GREY TO GREEN

4119 White Bear Parkway • St. Paul, MN 55110 USA  
Phone: (651) 429-1100 • (800) 4-CORTEC • Fax: (651) 429-1122  
www.CortecMCI.com • info@CortecVCI.com

## CORTEC MCI® ADMIXTURES

Cortec is a corrosion inhibitor manufacturer that has been in business since 1977. Our MCI (migrating corrosion inhibitors) line was first introduced in the early 1980's after a request from 3M to Cortec to see what could be done to protect epoxy coated steel that was nicked or scratched. In our testing, we showed that MCI not only worked well with epoxy coated steel, but also without it. Most of the information below was written as a description for ACI 212.

The latest generation of MCI admixtures is based on amine carboxylate technology. Amine Carboxylates are classified as mixed inhibitors, meaning they affect both anodic and cathodic portions of the corrosion cell. These inhibitors adsorb onto metal, forming a protective molecular layer on steel surfaces. This film prevents corrosive elements from further reacting with embedded reinforcement, and also reduces existing corrosion rates. Adsorption of the inhibitor takes place via its polar functional group anchored to the metal while the non-polar or hydrophobic chain is oriented perpendicularly to the metal surface. The hydrophobic chains not only repel aqueous corrosive fluids, but interact with each other to form aggregates thereby forming a tight film on the metal surface (Sastri, p. 699).



### Illustration of Molecular Interactions – Amine Carboxylate Inhibitor

Where  $R_{1,2,3}$  is H or alkyl group, and  $R_4$  is hydrophobic tail

Amine carboxylates reach embedded reinforcement in several ways. First, the inhibitor is dispersed through the concrete with adequate mixing. Secondly, the amine carboxylate inhibitors have a vapor pressure which allows them to migrate through the pore structure of the concrete in a gaseous state. The molecules move randomly from areas of high concentration to areas of low concentration until equilibrium is reached (Fick's 2<sup>nd</sup> Law). Finally, when the molecules come into contact with embedded metals, they have a specific ionic attraction to it, forming a protective, monomolecular layer, which also reduces the corrosion rate (Dr. Bavarian, Radioactive Isotope Tagging).

The bond strength of the MCI molecule is what delays the onset of corrosion and reduces corrosion rates compared to a control once initiated. Lab and field studies have shown that generally, amine carboxylate based admixtures will double the time to onset of corrosion

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compared to a control, and once corrosion initiates, corrosion rates are expected to be significantly lower (about five times less) than the control’s rate (AET ASTM G109 Testing).

Another small effect amine carboxylates have is that as they migrate through the concrete, some of them will react with calcium hydroxide to form  $\text{Ca}(\text{COO})_2$ , an insoluble salt, which effectively blocks some of the pores, making future ingress of chlorides and other contaminants more tortuous (Tourney Consulting Group, ASTM E96 Testing, 2010; Sastri, p. 700).

Amine carboxylates can be added with the mix water to concrete at a ready mix plant, or added on the jobsite to the ready mix truck prior to pouring. The dosage rate of amine carboxylates is independent of the expected chloride levels. The recommended dosage rate is a sufficient concentration of inhibitor to form a monomolecular film on embedded metals and that dosage rate is not dependent on chloride concentrations. Unlike anodic inhibitors, amine carboxylates do not have a “dangerous” concentration level—situations where a lower than required dosage rate relative to chloride content concentration would promote pitting corrosion (Nathan, p.259).

The standard dosage rate for amine carboxylates is 1.0-1.5 pints per cubic yard (0.6-1 liter per cubic meter) for liquids and 1 pound per cubic yard (0.6 kg per cubic meter) for powder versions. Amine carboxylates can retard setting times 3-4 hours at 70 degrees Fahrenheit (20 degrees Celsius); however, “normal set (NS)” versions containing an accelerator so that they set similarly to a “control” (mix with no amine carboxylate) are available.

MCI admixtures conform to ASTM C1582 testing. This is the most widely used method for evaluating concrete corrosion inhibitors. The standard consists of two components. The first is an evaluation of how the inhibitor affects concrete properties - ASTM C494 type testing. The second component involves corrosion testing - ASTM G109 or ASTM G180 (Tourney Consulting Group ASTM C1582 Report).

<b>ASTMC1582 Physical Properties – MCI 2005 NS</b>					
	Control	MCI-2005 NS	Relative to Control	ASTMC1582 Requirements	Result
Initial Set (Minutes)	308	318	+10	+/- 210 minutes of Control	Meets Requirement
Final Set (Minutes)	406	419	+13	+/- 210 minutes of Control	Meets Requirement
Length Change (%)	-0.0245	0.021	0.003	Max 0.010 over Control	Meets Requirement
Freeze Thaw Durability	99.21	98.9	99.8%	RDF 80%	Meets Requirement



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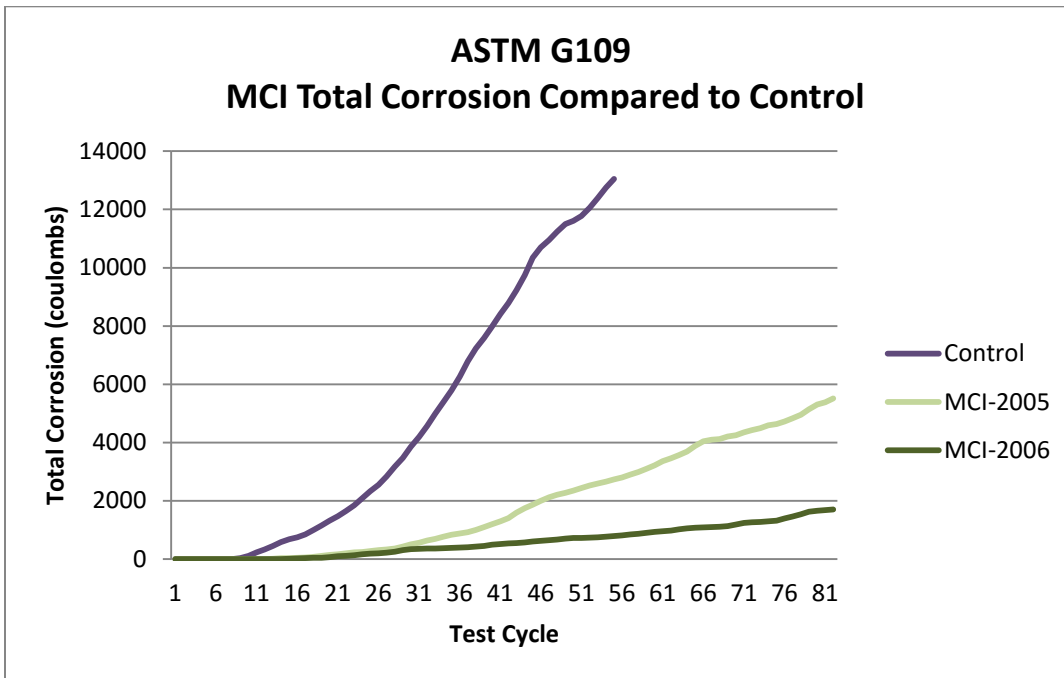


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ASTM C1582 Corrosion Properties - MCI 2005 NS					
	Control	MCI-2005 NS	Relative to Control	ASTMC1582 Requirement	Result
Average Integrated Current, C	155	29	n/a	≤50C when Control is 150C	Meets Requirement
Average Area Corroded, in <sup>2</sup>	8.93	2.36	0.29%	≤ 1/3 of Control	Meets Requirement
Critical Chloride Content*, ppm	2861	2898	1.01%	≥1 Standard Deviation of Control Critical	Meets Requirement

\* Critical Chloride Content based on control average at 50 Coulombs



ASTM G109 results for Liquid Amine Carboxylate based inhibitor versus control\*  
(1 Cycle = 4 weeks, 3.5% NaCl solution used for Ponding)

\*This test was done by American Engineering and Testing to an older version of ASTM G109 which was carried out longer than the current standard requirements.

Cracked beam studies of the amine carboxylate based admixture have shown that it reduces corrosion rates in cracked areas better than other corrosion inhibiting admixtures due to its

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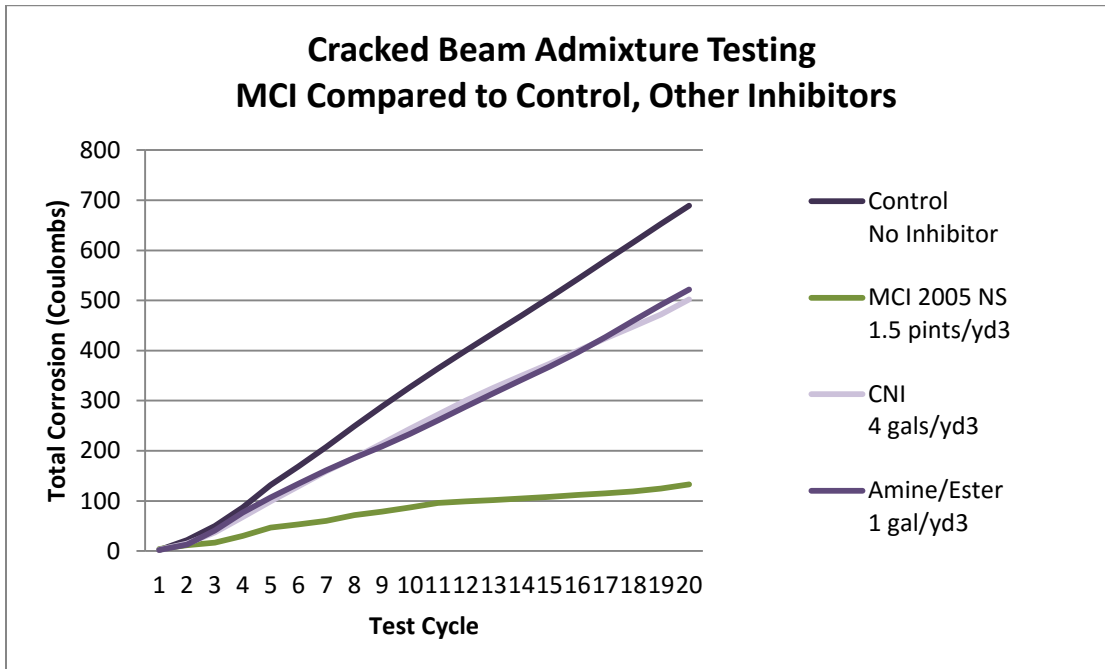




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ability to move through the concrete as a vapor and its attraction to anodic and cathodic portions of the metal (in essence, excess inhibitor present in the concrete replenishes itself on the bar to keep rates lower).



Normal Set, Liquid Amine Carboxylate vs. Control & Competitors, Cracked Beam Testing (1 cycle = 1 week, 6% NaCl solution used for ponding), done per IL DOT test instructions at American Engineering and Testing

#### Applications:

Amine carboxylate base admixtures are appropriate to use for reducing chloride-induced corrosion of any good quality concrete, both from seawater, salt-laden air, and de-icing salt exposure. They are also effective in reducing corrosion due to carbonation (or combinations of the two) (Dr. Xu).

#### Proportioning:

Amine carboxylates are generally compatible with the use of pozzolans or slag, and do not affect the finishing properties of the concrete when used in combination with them. Because the dosage rate is so low, there is no need for adjustments to the mix design. Care must be taken to ensure that when amine carboxylate based admixtures are used together with lignin or naphthalene sulphonate superplasticizers that the setting time is acceptable. To avoid this



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problem it is recommended to use melamine or polycarboxylate based superplasticizers when using amine carboxylate based corrosion inhibitors.

**Effect on Fresh and Hardening Concrete:**

Amine carboxylates generally has little effect on the early fresh properties of concrete, so long as proper mixture proportioning has been followed. Some versions may delay setting time up to 2 hours at 70 degrees Fahrenheit. This is solved by using an NS (normal set) version of the material.

**Effect on Hardened Concrete:**

The corrosion inhibiting effect has been discussed above. Amine carboxylates would have strengths similar to a control, and would experience similar amounts of shrinkage as a control (these materials do NOT increase the drying shrinkage). The also will not have any effect on rapid chloride permeability testing of concrete ("RCPT" - AASHTO T-277 or ASTM C1202).

**Advantages of MCI 2005 NS over calcium nitrite based inhibitors:**

Much lower dosage rate (MCI 2005 NS is dosed at 1.5 pints/yd<sup>3</sup> whereas CNI is dosed anywhere from 2-6 gallons/yd<sup>3</sup>).

No detrimental effect when used with pozzolans such as silica fume or fly ash (CNI can make the mix even stickier and harder to finish)

Does not affect shrinkage (CNI dramatically increases compared to Control)

Does not accelerate setting times

Can be used in conjunction with cathodic protection – does not significantly change concrete resistivity

- NSF Standard 61 certification
  - ~1/4th the solubility in water
  - CNI 84.5% at 20°C
  - MCI component 21.3% at 20°C

I hope that you find this information useful. Please feel free to contact Cortec should you have any further questions or comments.

Sincerely,

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V.P. Sales – Asia/MCI

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