J&L
Arcelor Group

Internal Memo

From	B A Christman Development Engineer – Manager, PRL	To	A C Coleman Market Development Engineer - Automotive
Date	May 22, 2003	Ref.	
Copy			
Re	J&L Modified Kawasaki Condensate Corrosion Test		

Abstract:

A common problem in the automobile industry is pitting corrosion in mufflers. Seventy percent of the time, corrosion of this type leads to muffler failure in North America [1]. Another concern is that stainless steel is sometimes too "bright" and is very noticeable underneath the car. Automakers are looking for something that is black, in order to better hide the muffler, and have resistance to pitting corrosion. Neukote™ is a product that can come in a variety of colors and has high corrosion resistance. An automaker requested that the Kawasaki Condensate Corrosion test be run on 409 and 439 stainless steel with no coating, coated with Neukote™, and on 409 with competitive coatings. Neukote™ performed the best out of all the samples that were tested in both appearance and in corrosion resistance. Both 409 and 439 coated with Neukote™ had a maximum pit depth of 80 micrometers while uncoated 409 had pitting up to 209 micrometers. Competitive coatings performed much worse than Neukote™ with Aluminized 409 pitting greater than 630 micrometers. Upon visual inspection after the test, Neukote™ showed little corrosion, which was not noticeable from a distance. Corrosion on the other samples was noticeable from a distance.

Introduction:

Neukote™ is a coating with good corrosion resistance available in a variety of colors. J&L Specialty Steel, LLC has exclusive rights for this coating for stainless steel applications in automotive and other industries. Several automakers are interested in this coating for muffler applications. A large problem with mufflers is that they are very susceptible to pitting corrosion. Another concern is that stainless steel is sometimes too "bright" making it very noticeable underneath the car. Automakers are looking into Neukote™ to solve the problems of pitting corrosion, and to conceal the brightness of stainless steel exhaust systems. An automaker requested that the Kawasaki Condensate Corrosion Test, or a modified version of it, to be performed on bare stainless steel, Aluminized stainless steel, and stainless steel with Neukote™. This test was developed by the Kawasaki Steel Corp. to simulate condensate corrosion found in mufflers [2]. This is an accelerated test developed to simulate 40 – 46 months of actual service [3]. The goal of this experiment is to determine the relative corrosion resistance of various stainless steel coatings as compared to bare stainless steel.

Experimental Procedure:

Six samples were cut to approximately 50 mm by 90 mm. Samples were then oxidized in air at 400^{o}C for 5 hours. The edges were coated so that edge corrosion did not affect the results. A constant temperature water bath was prepared with a stabilized temperature of approximately 73^{o}C (see Figure 1).

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Figure 1: Water Bath Configuration for Performing the J&L Modified Kawasaki Condensate Corrosion test.

Once the bath was configured, the samples were suspended without touching the bottom or the sides of the beakers. The beakers were filled with the corrosive solution that was used in the Kawasaki Condensate Corrosion Test [3]. The chemical composition is shown in Table 1.

Table 1 Chemical Composition of the Kawasaki Condensate Corrosion Test Solution (ppm)

Cl^-	SO_3^{2-}	SO_4^{2-}	CO_3^{2-}	NO_2^-	NO_3^-	CH_3COO^-	HCHO	$COOH^-$	NH_4^+	Activated carbon
50	250	1250	2000	100	20	400	250	100	2500	50g/l

Beakers remained in the water bath until the corrosive solution evaporated (approximately 26 hours). Samples were then rinsed and cleaned by scrubbing gently with a paintbrush. This cycle was repeated 10 times. After the final cycle, the samples were once again cleaned. The samples were photographed to show the corrosion products that had built up from the test. These samples were cleaned using an 8% HNO_3 solution. Three sets of samples were tested for repeatability.

Results:

Table 2: J&L Modified Kawasaki Condensate Corrosion Test Results: Maximum Pit Depth in Substrate (µm).

Set Number	Bare 409	Aluminized 409	Neukote™ 409	Bare 439	Neukote™ 439
Set 1	140	159	80[2]	145	20[3]
Set 2	209	>630[1]	57[2]	151	40[3]
Set 3	179	>630[1]	48[2]	157	79[3]
Maximum	209	>630[1]	80[2]	157	79[3]

[1] 409 Thickness using an average aluminized coating thickness of 15 µm.
[2] 409 Thickness using an average Neukote™ coating thickness of 18 µm.
[3] 439 Thickness using an average Neukote™ coating thickness of 20 µm.

Discussion:

The samples will be discussed in order of increasing pitting corrosion resistance. The Aluminized 409 (Al409) had poor pitting resistance. In all three sets, the Al409 did the worst of all the samples tested. In the first set it had pitting up to 159 micrometers. In the second and third sets the samples perforated (aluminized samples were 630 micrometers thick) (see Figure 2).

The uncoated 409 corroded the most in all three runs except the first one (aside from the aluminized 409) in which the uncoated 439 corroded 5 micrometers more. The corrosion shown in both the bare 409 and the bare 439 were very similar in looks with the biggest difference being that there was more corrosion on the 409 than the 439 (see Figure 3).

Figure 2: Al409 with corrosion removed.

Figure 3: Uncoated 409 and 439 after test

The last two samples were the Neukote™ samples. These samples had less pitting than the bare and Al409 samples in all three sets. Neukote™ 439 performed approximately the same as Neukote™ 409. Several things were noticed during the corrosion removal process for these coatings. The Neukote™ coating was extremely difficult to remove. The nitric solution and ultrasonic cleaning had a minimal effect on the removal of the coating and the corrosion. What was discovered, was that the Neukote™ formed small pimples all over the sample (see Figure 4).

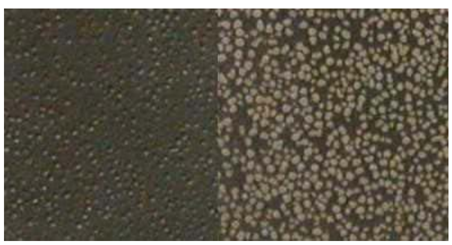

Figure 4: Neukote™ sample - pimples after test completion on the left and pimples removed on the right (approx. 7x).

This is thought to have happened due to the sulfur that was present in the test solution [4]. Pitting occurred underneath these pimples. It should be noted, corrosion was only found under a small percentage of these pimples. When looking at the samples from a distance, these pimples were not noticeable.

Conclusion:

Neukote™, provided better pitting resistances than any of the other samples that were tested. The maximum pit depth on the Neukote™ samples were 80 and 79 micrometers for 409 and 439 respectively. Compared to uncoated 409 and 439 that had pitting depths of 209 and 157 micrometers respectively. The other coatings that were tested also performed worse than the Neukote™. The Aluminized 409 became perforated in sets two and three. When it came to appearance the Neukote™ also out performed the other samples. When standing back 15 feet from the samples, the Neukote™ samples exhibited minimal corrosion. All of the other samples had noticeable corrosion even from this distance. The J&L Modified Kawasaki Condensate Corrosion test has shown that Neukote™ is the best solution for pitting resistance for exhaust systems.

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References:

1. R. R. Gaugh, “Corrosion of Materials for Automotive Exhaust Systems,” SAE Technical Paper, p.305, 912294 (1991)

2. T. Ujiro, M. Kitazawa and F. Togashi, “Corrosion of Muffler Materials in Automotive Exhaust Gas Condensates”, Materials Performance, Vol.33, No.12, p.49 (1994)

3. J. Hirasawa, T. Ujiro, S. Satoh and O. Furukimi, “Development of High Corrosion Resistant Stainless Steels for Automotive Mufflers Based on Condensate Corrosion Test and Field Investigation”, SAE Technical Paper, SP-1614 (2001).

4. Conversation with Dr. James E. Neely, inventor of Neukote™ on February 19, 2003.