CLIFFS

ALUMINIZED STEEL TYPE 1

STAINLESS 409 AND 439

- **Muffler**
- **Converter**
- **Resonator**
- **Tail Pipe**

Cleveland-Cliffs **ALUMINIZED 409 AND 439 STAINLESS STEEL** products have been developed to provide the automotive industry with life-of-the-car exhaust system materials. Type 1 hot-dip aluminum coating provides excellent resistance to pitting from muffler condensate and road salt, allowing the exhaust system to resist internal chlorides and retain good external appearance, even at uncoated welds. The aluminum coating significantly extends the life of the exhaust system over that of bare stainless.

- Red rust protection to 800 °F (427 °C)
- Oxidation resistance to 1550 °F (843 °C) (Aluminized 409) and 1700 °F (927 °C) (Aluminized 439).
- Excellent formability for exhaust system components.
- Easier to post-paint or coil-coat than uncoated stainless.

Product Description

COATING

The Type 1 Aluminized coating, containing approximately 91% aluminum and 9% silicon, is metallurgically bonded to the stainless steel substrate. The hot-dip coating process assures a tightly adherent, uniform coating on both sides of the product. A thin alloy layer readily permits normal forming practices without incurring significant damage to the coating.

Aluminized Steel Type 1 Stainless 409 and 439 are currently available in a coating weight of 0.25 oz./ft^2 minimum. A schematic of a cross section is shown in Figure 1.

HIGH TEMPERATURE PROPERTIES

- Oxidation resistance of the stainless substrate is enhanced by diffusion of the aluminum coating (Figure 2). AL409 is resistant to 1550 °F (843 °C). AL439 is resistant to 1700 °F (927 °C).
- At temperatures above 800 °F (427 °C), the diffused aluminum coating provides long-term resistance to hot salt attack and wet salt pitting in front pipes, converter shells and intermediate pipes. The diffused aluminum coating will take on a dark gray appearance and is subject to cosmetic red rusting.
- Creep and fatigue strength equal to the stainless steel substrate.

FIGURE 1 – COATING CROSS SECTION

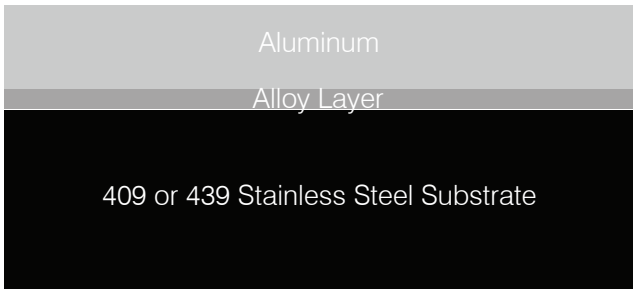
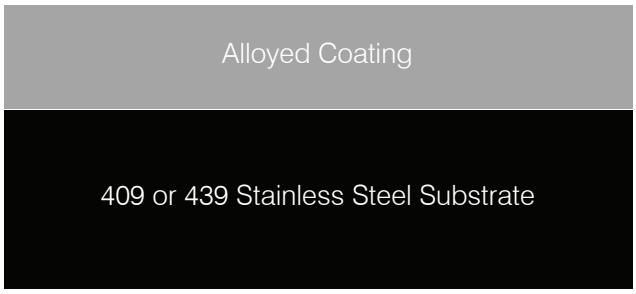
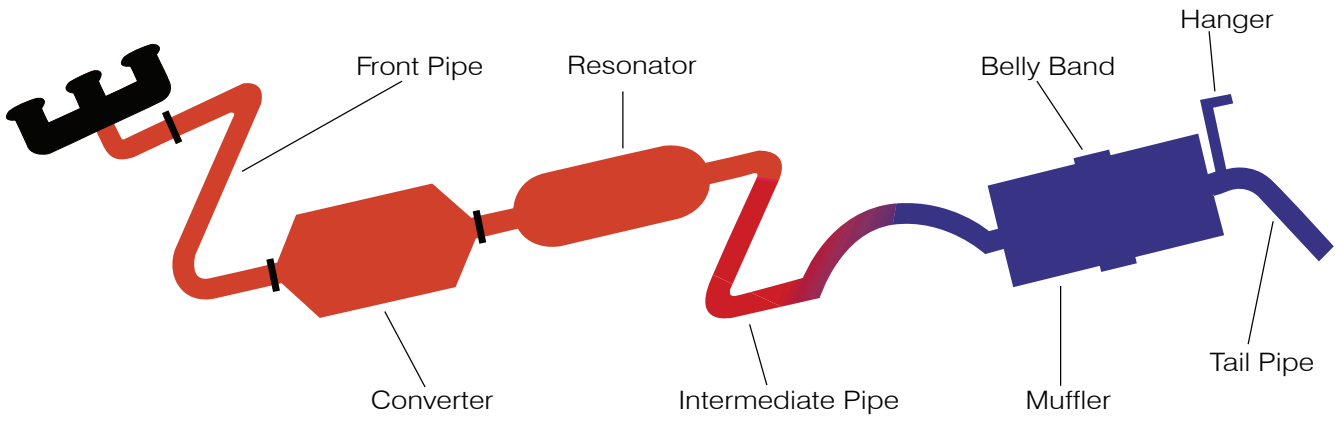


FIGURE 2 – CROSS SECTION OF DIFFUSED COATING



APPLICATIONS FOR ALUMINIZED 409 / 439



Corrosion

EXTERNAL EXHAUST SALT-HUMIDITY PITTING CORROSION

At relatively low temperatures, e.g. 600 °F (316 °C), 409 forms a heat-tinted (oxidized) surface and pits readily after exposure to moist salt. The hot-dip aluminum coating provides long-term galvanic protection against pitting corrosion.

Uncoated 439 is only slightly affected by pitting after 600 °F (316 °C) exposure, but will form surface red rust due to heat tinting. Aluminized 439 provides long-term protection against cosmetic red rusting.

After a 800 °F (427 °C) heat treatment, the four materials tested all show at least double the pitting rates compared to 600 °F (316 °C). However, the effects of increased heat tint are much greater for uncoated 439.

Test Cycle:

- Sample – 4 x 6 in. (102 x 152 mm) formed
- Heat 1 hr. in air once per week
- Daily dip 15 min. –5% NaCl
- Air dry (75 min.)
- Humidity cabinet – 85% RH,
- 140 °F (60 °C) (remainder of day)

FIGURE 3 – MUFFLER SIMULATION 600 °F (316 °C) HEAT TREATMENT – BOLD EXPOSURE

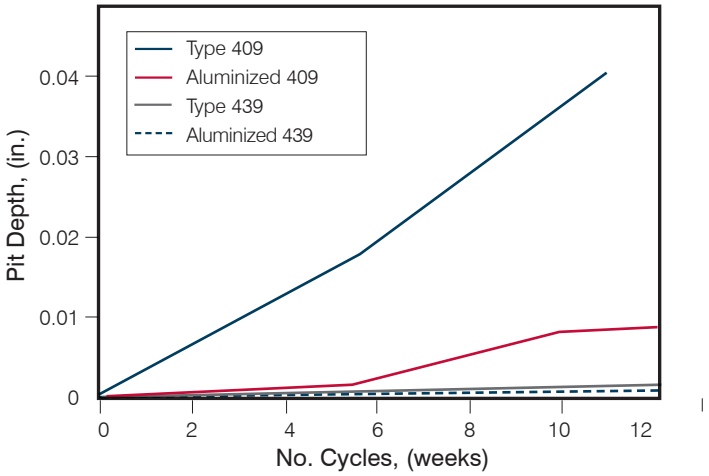
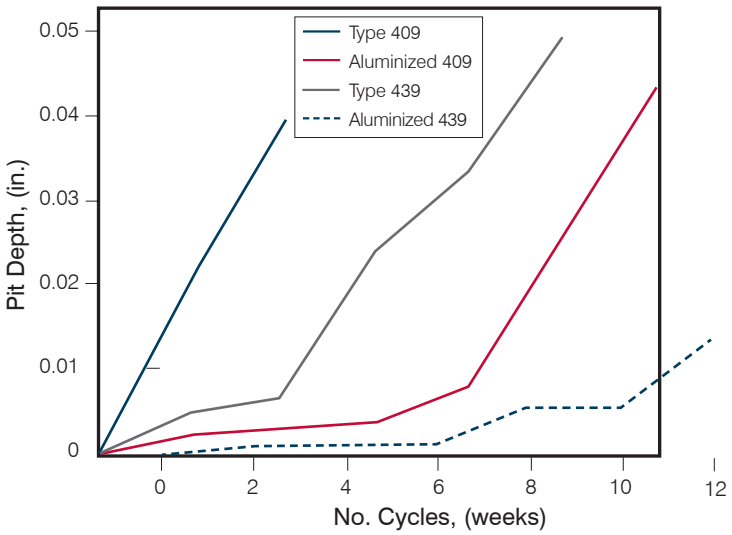


FIGURE 4 – I PIPE SIMULATION 800 °F (427 °C) HEAT TREATMENT – BOLD EXPOSURE



Corrosion (Continued)

EXTERNAL EXHAUST SALT-HUMIDITY PITTING CORROSION

A 1000 °F (538 °C) heat treatment in the corrosion cycle test fully alloys the aluminum coating with the stainless steel substrate. The lower galvanic potential of the thick alloy coating provides longer-term protection against pit initiation. The effects of oxidation, plus salt on the higher chromium uncoated grades, cause earlier perforation compared to lower temperature testing. In Figure 5, bare 409 shows a shelf in pitting rate, and eventually exhibits large weight loss due to development of a loose scale jacket.

A thinner-walled AL439 product can result in improved catalytic converter life and reduced weight compared to bare 409.

Field corrosion data indicates that the 1000 °F (538 °C) test equivalence is approximately 1 week = 1 year in severe salt climate service. At lower test temperatures, the indicated equivalence is more than 1 year.

Due to rapid pitting rates after a 1400 °F (760 °C) heat treatment, the measurement is switched to weight loss. All bare stainless grades tested exhibit similar behavior, while the coated grades continue to benefit from extended galvanic protection by the fully alloyed coating. Salt corrosion of this type is generally associated with salt held on a pipe by insulation or shielding.

FIGURE 5 – CONVERTER SIMULATION 1000 °F (538 °C) HEAT TREATMENT – BOLD EXPOSURE

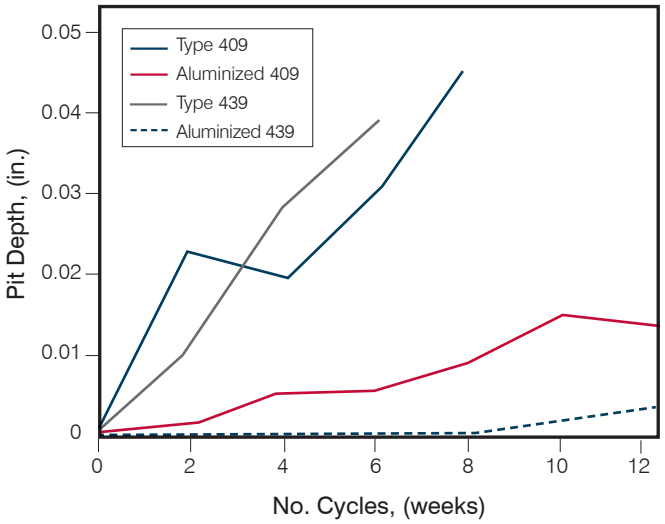
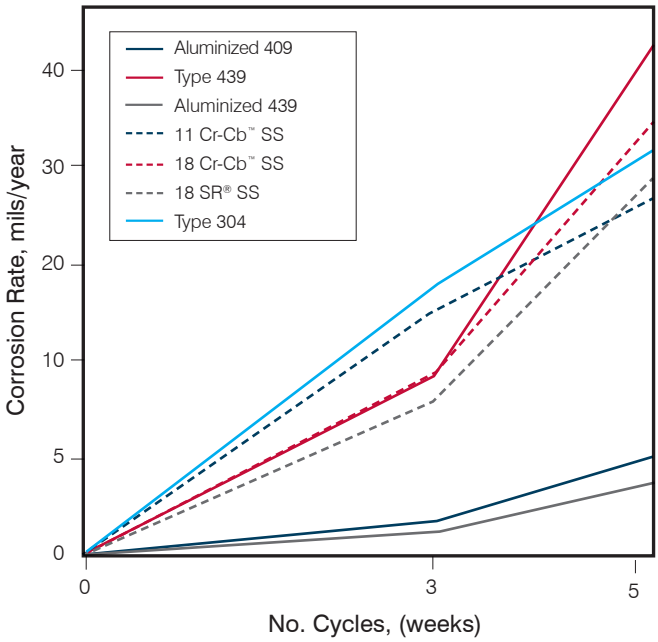


FIGURE 6 – FRONT PIPE SIMULATION 1400 °F (760 °C) HEAT TREATMENT – BOLD EXPOSURE



Muffler Condensate Corrosion

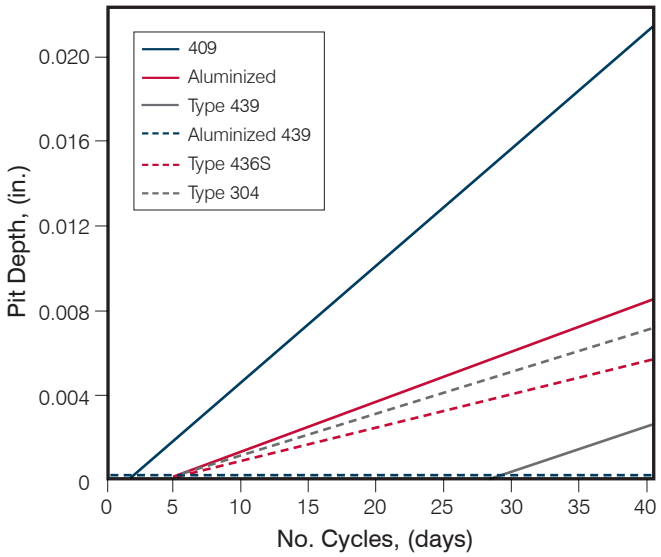
Aluminized Steel Type 1 Stainless 409 and 439 are highly resistant to acid condensate pitting. The aluminum coating provides protection against the start of pitting for much of the vehicle life. It galvanically protects against initial converter chloride corrosion at very low pH levels. This protection can be extended even further by avoiding dissimilar material contacts. Figure 7 shows pitting rates in a synthetic condensate boil-down test.

Daily Test Cycle:

- Partially immerse flat sample in synthetic condensate* and slowly evaporate to dryness at 194 °F (90 °C) – approx. 12 – 16 hrs.
- When dry, heat sample to 482 °F (250 °C) for 1 hr. – humidity cabinet at 122 °F (50 C) 85% RH – approx. 6 hrs.

*Synthetic Condensate:
Ammonium salts of Cl^- (100 ppm);
NO_3 (100 ppm); CO_3 (3000 ppm);
SO= (5000 ppm); initial pH = 8.5

FIGURE 7 – BOILING BEAKER CYCLE TEST FOR MUFFLER CONDENSATE CORROSION



MECHANICAL PROPERTIES

TABLE 1 – MECHANICAL PROPERTIES ALUMINIZED 409

Sheet Thickness, (Nom.)	0.2% YS, ksi. (MPa)	UTS, ksi. (MPa)	Average % Elongation in 2 in. (50.8 mm)
0.022 to under 0.030 in. (0.56 to under 0.76 mm)	43 (297)	65 (448)	26
>0.030 in. (0.76 mm)	38 (262)	60 (414)	32

TABLE 2 – MECHANICAL PROPERTIES ALUMINIZED 439

Sheet Thickness, (Nom.)	0.2% YS, ksi. (MPa)	UTS, ksi. (MPa)	Average % Elongation in 2 in. (50.8 mm)
0.022 to under 0.030 in. (0.56 to under 0.76 mm)	48 (331)	73 (504)	26
>0.030 in. (0.76 mm)	43 (297)	68 (469)	32

ALUMINIZED STEEL TYPE 1 STAINLESS 409 AND 439

WELDABILITY

- High Frequency – Aluminized Type 1 Stainless 409 and 439 are welded using established techniques for uncoated stainless and aluminized carbon steels.
- Laser – Successfully applied to exhaust tubing and seam welds.
- Spot and Resistance Seam – Techniques are similar to those for other aluminized steels, and the weld structure will be similar to that of uncoated 409 or 439 Stainless Steel.
- Gas Tungsten Arc Welding (GTAW) – Not recommended without sufficient filler wire to avoid excess aluminum in the weld.
- Carbon steel or lower chromium wire should be avoided because of lower oxidation resistance and sacrificial corrosion due to galvanic coupling with Type 409 and 439.

MORE INFORMATION/TECHNICAL ASSISTANCE

Cleveland-Cliffs Technical Representatives can provide you with more detailed information concerning these products. They are also available to assist you in solving any welding, forming, painting or other material selection issue.

OUTSIDE PROCESSING

Some services Cleveland-Cliffs can provide through arrangements with outside processors include: tailored blanks, tension leveling, resquaring, slitting, cutting-to-length and coil coating.

MILL LIMITS

Aluminized Steel Type 1 Stainless 409 and 439 are generally available in thicknesses from 0.018 – 0.080 in. (0.46 – 2.03 mm), and widths up to 48 in. (1219 mm) depending on thickness.

For sizes outside these limits, contact your Cleveland-Cliffs sales representative.

About Cleveland-Cliffs Inc.

Cleveland-Cliffs is the largest flat-rolled steel producer in North America. Founded in 1847 as a mine operator, Cliffs also is the largest manufacturer of iron ore pellets in North America. The Company is vertically integrated from mined raw materials and direct reduced iron to primary steelmaking and downstream finishing, stamping, tooling, and tubing. The Company serves a diverse range of markets due to its comprehensive offering of flat-rolled steel products and is the largest steel supplier to the automotive industry in North America. Headquartered in Cleveland, Ohio, Cleveland-Cliffs employs approximately 25,000 people across its mining, steel and downstream manufacturing operations in the United States and Canada.

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