

Twenty-Five-Year Corrosion Tests of 55% Al-Zn Alloy Coated Steel Sheet

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Long-term atmospheric corrosion tests of steel sheet hot-dip coated with a series of aluminum-zinc alloy compositions were conducted in a wide range of environments. In a severe marine environment, coatings containing 44.6 percent or more aluminum lasted about three times as long as conventional galvanized with the same coating thickness. In moderate marine, rural, and industrial environments, coatings containing 44.6 percent or more aluminum remained intact after 25 years and have already lasted twice as long as conventional galvanized.

During the early stages of Bethlehem Steel Corporation's development of Galvalume[†] sheet, a series of aluminum-zinc (Al-Zn) alloy coatings were hot-dip applied to steel sheet on a continuous pilot coating line. In 1964, samples of these materials were exposed at severe marine, moderate marine, rural, and industrial corrosion test sites. During the ensuing years, these tests formed the basis for the selection of the 55% Al-Zn alloy for the Galvalume coating.

In a previous series of these tests, the 55% Al-Zn alloy coating was shown to have an optimum combination of durability, resistance to cut-edge corrosion, and resistance to crevice corrosion.¹⁻⁴ An update on the durability of the alloy coatings after 25 years of outdoor testing is reported here.

Experimental Procedures

Test Materials

Al-Zn alloy coatings were applied to low carbon (0.06% C) steel strip (0.41 by 152 mm) on a pilot-scale, continuous hot-dip coating line. Coating baths were prepared from pure zinc and Al-3% silicon alloy. Coating compositions are given in Table 1.

Of particular interest among the alloy coating compositions in Table 1 are:

- 0.2% Al—representative of conventional galvanized;
- 4.0 and 7.4% Al—similar to 5% Al alloy coatings such as Galfan^{†5} and Superzinc^{†,6};
- 35.1% Al—similar to Lavegal^{†,7};
- 53.9% Al—similar to the 55% Al Galvalume coating composition.

Also included in the tests were commercially produced G90 galvanized and aluminum-coated sheet. Coating thickness for all materials

was generally in the range 20 to 25 μm , except for the aluminum-coated which had a 40- μm coating.

Atmospheric Corrosion Testing

Test specimens, 102 by 152 mm, were sheared, degreased, and exposed at four atmospheric corrosion test sites.

- Severe marine—located 25 m from the Atlantic Ocean at Kure Beach, North Carolina, at the site oper-

TABLE 1
Compositions of Hot-Dip Coatings

Composition, wt%			Sheet Thickness (mm)
Al	Si	Pb	
Pilot-line Product			
0.2	0	0.2	0.41
1.0	0.03	0	0.41
4.0	0.12	0	0.41
7.4	0.22	0	0.41
12.2	0.37	0	0.41
16.6	0.50	0	0.41
21.0	0.63	0	0.41
24.9	0.75	0	0.41
35.1	1.05	0	0.41
44.6	1.34	0	0.41
53.9	1.62	0	0.41
69.6	2.01	0	0.41
Commercial Products			
0.2	0	0.1	0.69
100	0	0	0.55

[†]Trade names.

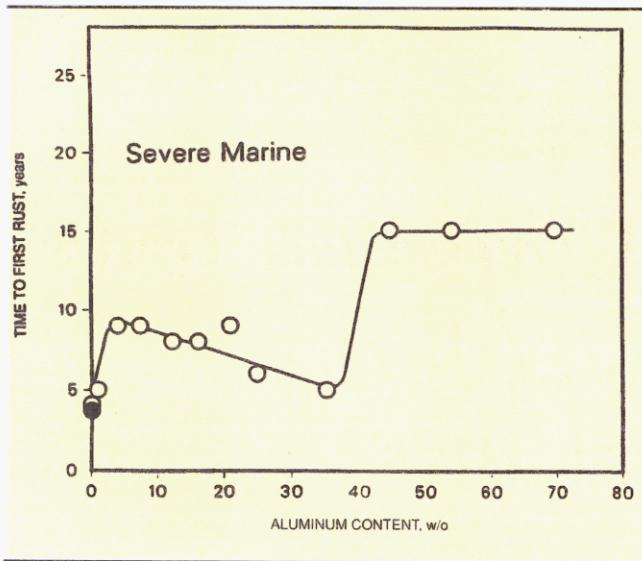


FIGURE 1

Effect of aluminum content on coating life in severe marine environment. Open circles: pilot-line material; solid circle: commercial product.

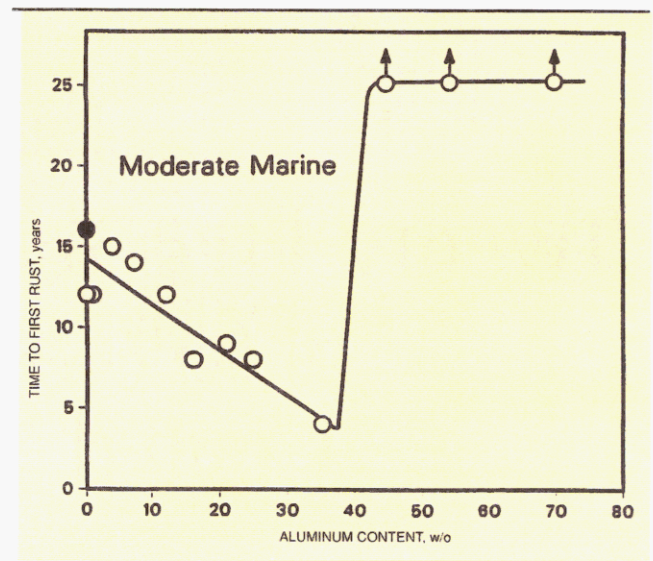


FIGURE 2

Effect of aluminum content on coating life in moderate marine environment. Open circles: pilot-line material; solid circle: commercial product.

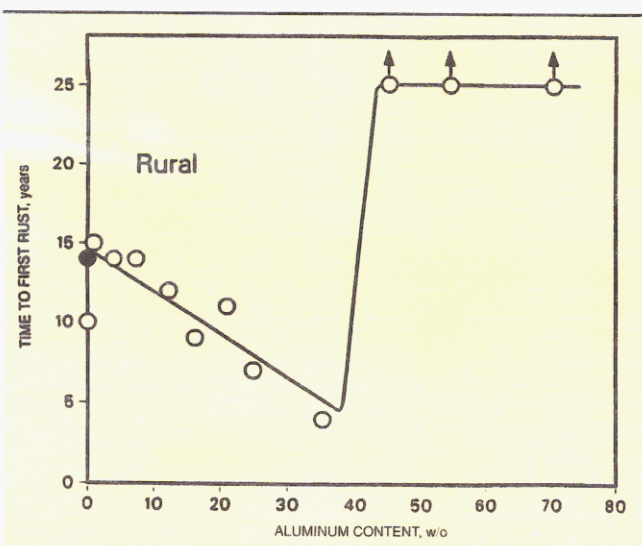


FIGURE 3

Effect of aluminum content on coating life in rural environment. Open circles: pilot-line material; solid circle: commercial product.

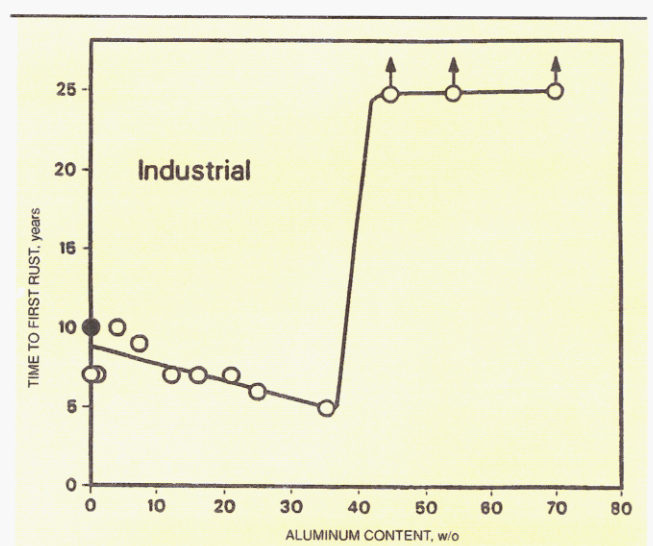


FIGURE 4

Effect of aluminum content on coating life in industrial environment. Open circles: pilot-line material; solid circle: commercial product.

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- Moderate marine—same as above, except 250 m from the ocean;
- Rural—in the Pocono Mountains at Saylorsburg, Pennsylvania, about 50 km north of Bethlehem;
- Industrial—on South Mountain in Bethlehem, Pennsylvania, about 3 km from an integrated steel plant.

Test panels were exposed at 30 degrees from the horizontal, facing south, except at the severe marine site where they faced east toward the ocean.

Results and Discussion

Time to First Rust

Time to the initial appearance of more than two percent red rust on the skyward surfaces of the coated specimens was recorded during the 25 years of corrosion testing (Figures 1 through 4).

In the severe marine environment (Figure 1), coating durability initially increased as the Al content is increased in the range of 0 to 7.4%. Further increases of 12.2 to 35.1% in Al content appear to be detrimental. Of particular importance is the sig-

nificant increase in corrosion resistance that occurred at 44.6% Al and above. In this environment, the Galvalume composition exhibited a better than threefold improvement in durability over conventional galvanized.

In the moderate marine, rural, and industrial environments (Figures 2 through 4), aluminum in amounts up to 35.1% appeared to have a generally detrimental effect on corrosion resistance. It is only at 44.6% Al and above that a significant improvement in corrosion resistance was evident. The 55% Al-Zn coating

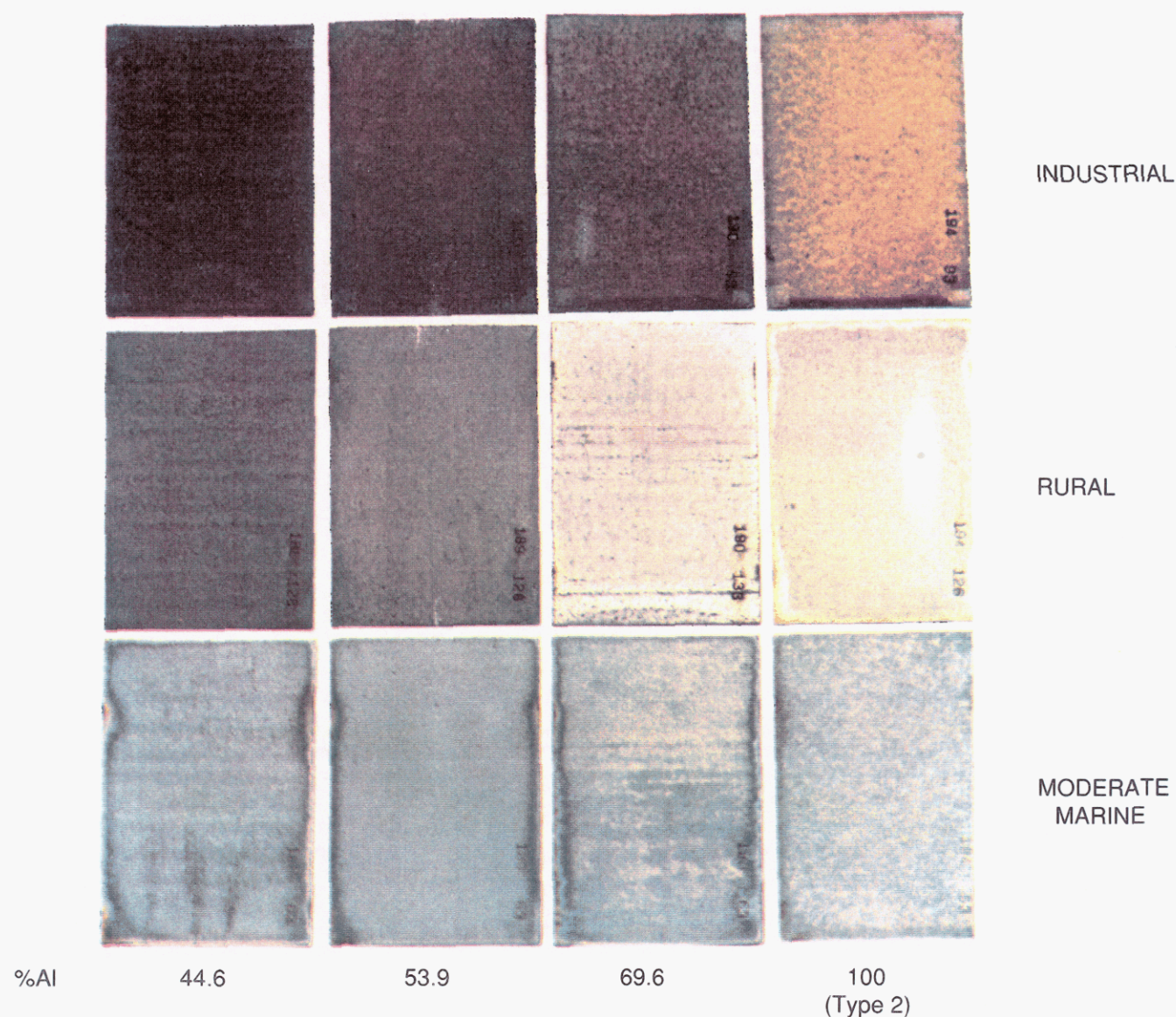


FIGURE 5
Appearance of skyward surfaces of test panels after 25-year exposure.

has already lasted about twice as long as conventional galvanized at these sites. Moreover, based on previously reported extrapolations of 13-year quantitative thickness-loss data, it has been predicted that this coating will outlast conventional galvanized of equivalent thickness by factors of 3 to 5 in these environments.⁸

With regard to 5% Al alloy coatings, the above results indicate little, if any, improvement over conventional galvanized in moderate marine, rural, and industrial environments. Although it has been more than 10 years since the initiation of atmospheric tests of Galfan and

Superzinc was reported, there have been no recent reports on the behavior of the 5% Al alloy coatings in these tests.

Appearance After 25 Years

After 25 years of testing, the only specimens remaining that were not rusted were those exposed at the moderate marine, rural and industrial sites with coatings containing 44.6% and more Al (Figure 5). All other test panels were removed because of extensive rusting. In many cases, the entire steel panel was completely consumed by rust.

At the industrial site, all test panels were discolored by deposits

from a nearby steel plant. This discoloration is only superficial and should not be mistaken for rust.

At the moderate marine site, a slight amount of edge attack was noted where the test panels contacted the specimen holders on the test rack. This was attributed to crevice corrosion of the steel at these locations caused by the salt environment.

Conclusions

Twenty-five-year atmospheric corrosion tests conducted in severe marine, moderate marine, rural, and industrial environments for steel sheet coated with a series of Al-Zn alloy coatings have conclusively

demonstrated the excellent durability of the 55% Al-Zn Galvalume coating composition. Compared to conventional galvanized of equivalent coating thickness, the results indicate that Galvalume sheet will last at least twice as long in all environments.

References

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