CLIFFS

ALUMINIZED STEEL TYPE 2

DRAINAGE PIPE DURABILITY ESTIMATION

Technical Bulletin

UNIFORM PERFORMANCE

Field tests on Aluminized Steel Type 2 corrugated pipe field tests show its performance is relatively consistent throughout its environmental ranges of application.

PROVEN SUPERIORITY IN NORMAL ENVIRONMENTS

FHWA-sponsored studies that contrast Aluminized Steel Type 2 with CALTRANS graph galvanized indicate a considerable durability advantage for Aluminized Type 2.

DURABILITY GUIDELINES FOR PIPE INSTALLATION DESIGN ENGINEERS, BASED ON CLEVELAND-CLIFFS FIELD STUDIES

Cleveland-Cliffs field studies performed on 30, 42 and 50 year old Aluminized Steel Type 2 pipes have established the minimum service life at 75 years for 16 gauge material within the recommended pH 5 – 9 and resistivity ≥ 1500 ohm•cm environmental ranges.[1] The deepest pitting observed in the studies occurred near these recommended pH/resistivity limits. Pitting depth was 24 mils, which can be related to certain penetration rates for the coating and the steel substrate. Approximately 2 mils of coating was penetrated by the deepest 30 year pitting, the average penetration time would be about 10 years and the average penetration rate would be about 0.2 mils/year. For the remaining 22 mils of steel substrate, the average penetration rate would be about 0.55 mils/year (22 mils/40 years). These worst-case rates for the recommended pH/resistivity ranges project to 104 years for first pit penetration through a 16 gauge pipe wall, supporting the designation of an estimated 100 year service life at 16 gauge through the modified range. Rates for steel substrate penetration calculated from 30 year studies are quite low due to galvanic retardation provided by the coating. The low magnitude of the rates was further confirmed in studies on pipes 42 – 50 years of age.

The 50 year durability assesment confirmed that Aluminized Steel Type 2 performance provides 75 year minimum service life throughout the recommended pH/resistivity ranges.[2] Nonetheless, its durability superiority factor compared to galvanized steel is variable due to galvanized performance variability. The superiority factor is lower in milder environments, where galvanized steel performs well. However, the Aluminized Type 2 superiority factor increases with severe conditions encountered as the limits of pH 5 – 9 and resistivity ≥ 1500 ohm•cm are approached.[3]

[1] A service life of 100 years would apply to the 16 gauge pipes within the recommended pH, having resistivity ≥ 5000 ohm•cm.

[2] In addition, 100 years of service life should be attained when the pH is from 6 – 8 for resitivities ≥ 1500 ohm•cm or when pH is 5 – 9 and resistivity ≥ 5000 ohm•cm.

[3] A 75 year service life would apply to pH 4.5 – 5.0 provided resistivity ≥ 5000 ohm•cm.

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Product Description

Figure 1 illustrates the degree of superiority of Aluminized Steel Type 2 pipe over galvanized steel pipe in the recommended environmental ranges of pH 5 – 9 and resistivity ≥ 1500 ohm•cm. The figure below utilizes the traditional CALTRANS graph for estimation of galvanized service life, based on known pH/resistivity values and on the gauge multiplier. Aluminized Steel Type 2 performance data are superimposed on the graph at the appropriate pH/resistivity values to contrast the two materials. The figure then provides an estimate of Aluminized Type 2 service life through multiplication of the appropriate superiority factor by the galvanized steel estimate. The variability of the Aluminized Type 2 superiority factor and the degree of conservatism of the minimum 75 year service life estimate throughout these pH/resistivity ranges are illustrated.

FIGURE 1 – 30 YEAR FIELD DATA FOR ALUMINIZED TYPE 2 STEEL SUPERIMPOSED ON TRADITIONAL CALTRANS GRAPH

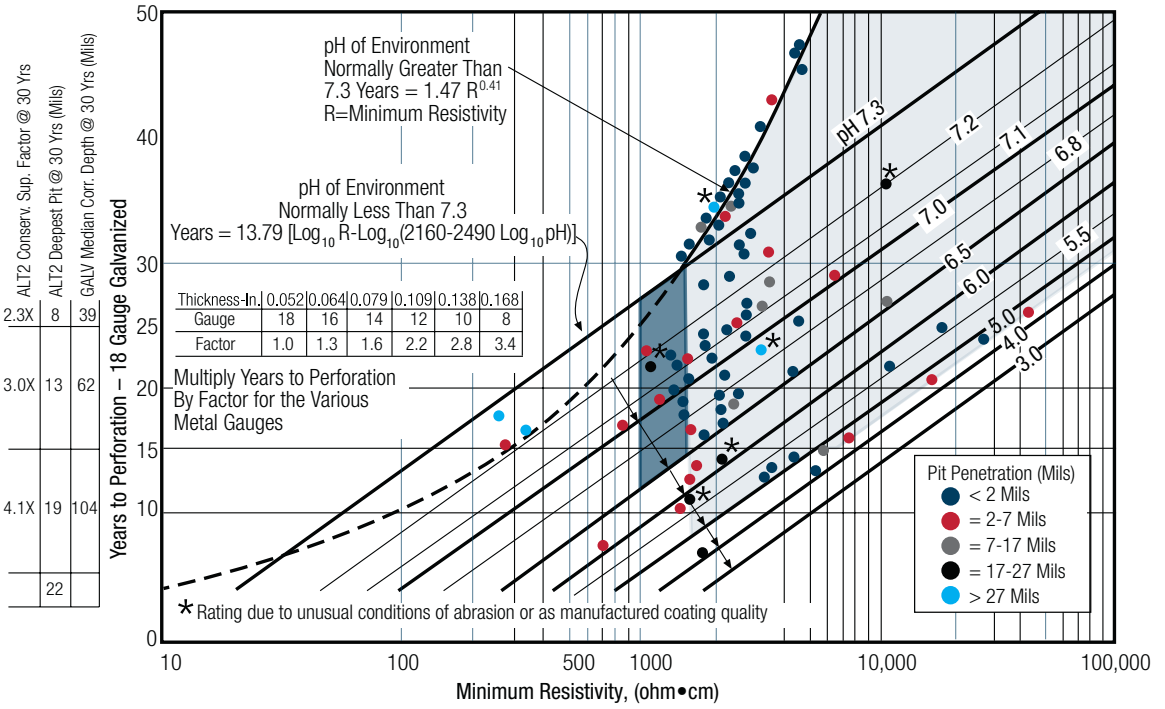

Figure 1: The 30 year field exposures reveal very low long-term pit penetration rates on Aluminized Type 2 due to galvanic retardation of pit growth by the coating; 42 – 43 year exposures further confirm the low magnitude of long-term pitting rates. Estimated times for pit penetration of pipe walls can be contrasted with estimates for corrosion penetration of galvanized according to the CALTRANS graph to give Aluminized Type 2 superiority factors. The estimates and superiority factors can be made applicable for pipe installation design purposes by contrasting the two materials over pH/resistivity ranges associated with service-life intervals on the graph.

To illustrate, within the 10 – 20 year service-life interval of the graph, the deepest Aluminized Type 2 pitting in 30 years was 19 mils, which corresponds to an 81 year minimum penetration time at 16 gauge (64 mils). This contrasts with a 13 year (10 x 1.3) minimum penetration time for galvanized at 16 gauge, giving a realistic Type 2 superiority factor of 6.2X. However, but for pipe installation design purposes, a conservative 4.1X factor is applied to the entire interval; this is based on contrasting the 16 gauge Type 2 minimum 81 year penetration time with a median 19.5 years (15 x 1.3) time for 16 gauge galvanized (81 ÷ 19.5 = 4.1X).

For the 20 – 30 year graph interval, the deepest Type 2 pitting was 30 mils, which projects to a minimum 16 gauge penetration time of 97.5 years and this contrasts with a median 32.5 years (25 x 1.3) for 16 gauge galvanized. The result is a conservative 3.0X superiority factor for the interval. The increased Aluminized Type 2 service life for this interval is indicative of increased conservatism in the general 75 year service life minimum as environmental conditions become milder.

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For the 30 – 50 year graph interval, the deepest Aluminized Type 2 pitting was 8 mils above 5,000 ohm•cm resistivity, which projects to a minimum 16 gauge Type 2 penetration time of 120 years, and this contrasts with a median 16 gauge galvanized penetration time of 52 years (40 x 1.3). The result is a conservative superiority factor of 2.3X. Cleveland-Cliffs does not attempt to project service life beyond 100 years and simply assigns > 100 years in this case.

The light blue shading in Figure 1 illustrates the fact that the superior performance of Aluminized Steel Type 2 extends to resistivities as low as 1000 ohm•cm and pH values as low as 6.5 in soils of arid climates or in waters where chloride and sulfate salts do not contribute substantially to low resistivity (< 200 ppm total).

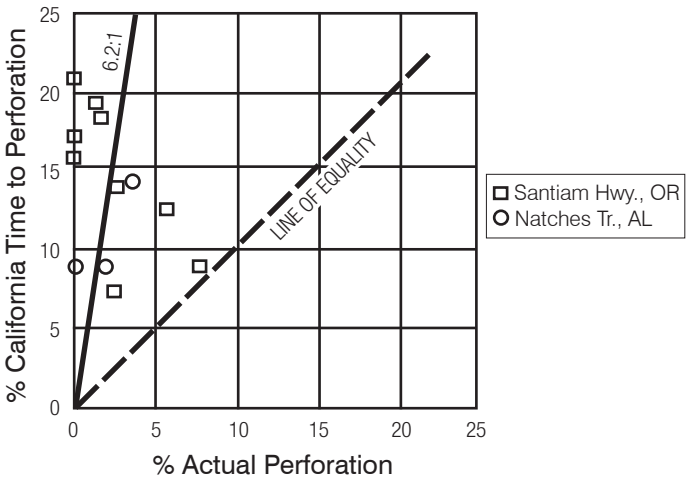
Figure 1 provides a convenient background to illustrate the basis for the 5 – 9 pH and ≥1500 ohm•cm resistivity limits recommended for Aluminized Type 2 pipe application. For normal conditions of environmental abrasion and material quality, there is no trend toward diminished performance sufficient to drop the 16 gauge first perforation time estimate below 75 years as the pH/resistivity limit is approached and exceeded. Indeed, there are good-performing pipes that bracket the limit and the perforation time estimate for the pipe at pH 4.0 (~10 times the acidity of pH 5.0) and resistivity 1850 ohm•cm is only slightly less than 75 years (70 years) at 16 gauge. Due to the stability of aluminum oxide, the estimated service life of 16 gauge Type 2 in environments with pH between 4.5 – 5.0 would be 75 years provided resistivity ≥5000 ohm•cm.

RESULTS OF FIELD STUDIES BY OTHERS

The degree of superiority of Aluminized Type 2 observed in the earliest pipe product continues in the modern helical pipe product; studies by various agencies confirm this. Definitive studies were conducted in FHWA-sponsored work by the U.S. Army Corps of Engineers using the CALTRANS graph for comparison; a local average superiority factor was developed. The work involved Aluminized Type 2 pipe on one highway project in Oregon and another in Alabama. The results, summarized in Figure 2, are for seven year old pipes studied in 1989. They apply to rather typical site environmental conditions of moderate-to-high resistivity and pH values just below 7.0. A few Alabama pipes were directly exposed to intermittent severe groundwater conditions arising in a localized watershed having extremely acidic subsoil; these pipes were not included in Figure 2. One Oregon pipe was influenced enough by abrasion that it performed worse than the rest of the pipes, but it was still included in Figure 2. The average, or arithmetic mean, behavior for all Type 2 pipes in Figure 2 was 6.2 times superior to the average galvanized performance depicted by the traditional CALTRANS graph.

In follow-up FHWA-sponsored studies, the Ocean City Research Labs (OCR) inspected pipes on the same Oregon/Alabama roadways at 14 years age and also included some pipes in Maine of comparable age. OCR excluded the two Alabama pipes identified by the Corps as exposed to the periodic influence of extreme watershed acidity and one Maine pipe exposed to severe abrasion. If one applies the Corps approach to the OCR data, the superiority factor would be about 5.7:1, which is quite close to the Corps value. OCR has applied least-squares regression to the data, which gives something more like a minimum than a mean superiority factor. The least-squares approach assigns undue weight to the influence of the abrasion-affected pipe in Oregon and one poorer performing pipe somewhat affected by the local acidic-soil watershed in Alabama.

FIGURE 2 – ALUMINIZED STEEL TYPE 2 CSP PERFORMANCE



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The degree to which pipe data points lie above the line of equality indicates the degree of superiority over CALTRANS-graph galvanized.

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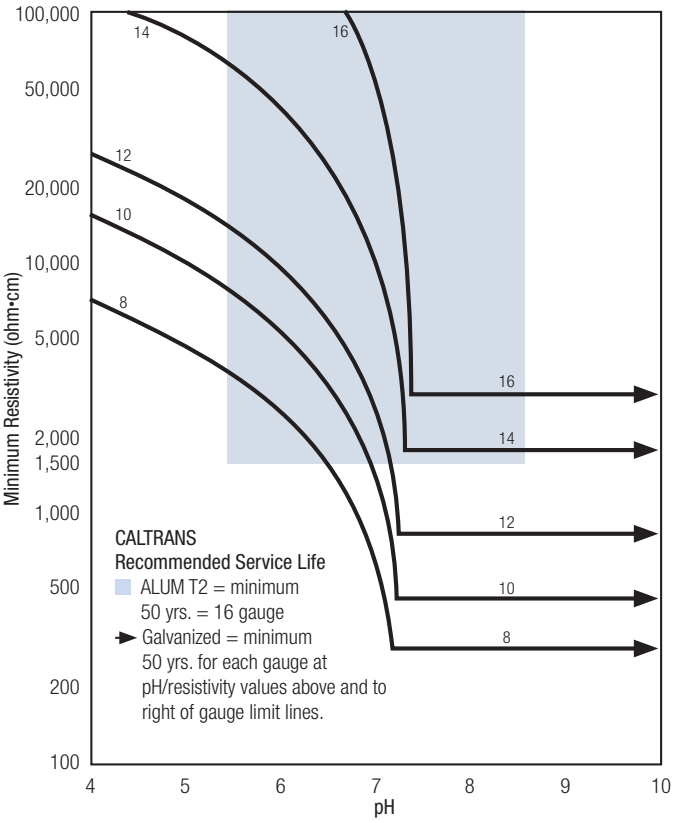
CALTRANS defined Aluminized Type 2 superiority in a comprehensive way. Using a modification of their traditional graph, they illustrated galvanized gauge requirements needed to match 16 gauge Type 2 performance over given pH/resistivity ranges. Their approach (See Figure 3) is conservative in that they do not attempt to estimate performance beyond the 50 year service life requirement of the state. Also, they conservatively contrast the two materials only over a restricted pH range of 5.5 – 8.5. They do depict performance down to the recommended 1500 ohm•cm lower limit. Further conservatism arises from their assumption that Type 2 and galvanized are comparable in durability in milder environments. But the CALTRANS method illustrates how the Aluminized Type 2 superiority factor increases with increasingly severe environmental conditions, out to the selected pH/resistivity limits. As these limits are approached, 16 gauge Type 2 performance exceeds that of all gauges of galvanized up to and including 8 gauge.

FIGURE 3 – CALTRANS GALVANIZED GAUGE REQUIREMENTS TO MATCH 16 GAUGE TYPE 2 PERFORMANCE



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, direct reduced iron, and ferrous scrap 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 supplier of steel to the automotive industry in North America. The Company is headquartered in Cleveland, Ohio with mining, steel and downstream manufacturing operations located across the United States and in Canada. For more information, visit www.clevelandcliffs.com.

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