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55% Al-Zn COATED SHEET: DEVELOPMENT, MANUFACTURE & COMMERCIALIZATION

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SYNOPSIS

The development and selection of the 55% Al-Zn composition, as a corrosion resistant coating for sheet steel, is discussed. The actual test data demonstrating that the selected composition does indeed provide the optimum long term durability is presented. The manufacturing process and product characteristics are discussed followed by an overview of the marketing efforts which resulted in the successful market acceptance of this new product. Finally, a summary of the worldwide licensing activities is presented.

INTRODUCTION

55% Al-Zn coating technology was first commercialized in the USA in 1972. It has since enjoyed tremendous growth around the world. The coated sheet technology is licensed by BIEC International Inc. which is a subsidiary of Broken Hill Proprietary (BHP) Company Limited of Australia.

Currently, 29 companies worldwide have been licensed to produce the product. The coating composition is 55% by weight aluminum, 43.5% zinc and 1.5% silicon. The product is sold under various trade names such as Galvalume, Zincalume, Aluzinc etc.

Production methods for 55% Al-Zn coated sheet are generally similar to those used for continuous hot dip galvanizing. However, modifications in equipment design and operating practices are required for the production of 55% Al-Zn coated sheet.

Excellent atmospheric corrosion resistance, heat resistance and paintability have allowed the 55% Al-Zn coated sheet to penetrate many markets, the largest of which is the metal building industry. The product is however finding increasing use in other applications like appliances, automotive and many domestic applications.

The worldwide production of 55% Al-Zn coated sheet has grown tremendously. The current annual production capacity is 2.5 millions tons and cumulatively, over 21 million tons have been produced to date. The production is expected to increase further due to the overall strong demand for highly corrosion resistant steel product, new coating facilities which are currently under construction and ambitious marketing efforts.

DEVELOPMENT HISTORY

The history of 55% Al-Zn coated sheet dates back to 1964 when Bethlehem Steel Corporation initiated a research program to evaluate twelve different Al-Zn binary alloys as coatings for steel sheet. The composition of the Al-Zn alloys investigated ranged from 0-70% aluminum (Table 1). The test material was produced on a pilot coating line. After extensive laboratory evaluation through accelerated tests, the product was exposed outdoors in several different environments for long term testing.

After five years of atmospheric testing in various environments, the 55% Al-Zn composition was chosen as the coating with optimum durability. Now 25-year exposure data from the same test series have confirmed the superior durability of the 55% Al-Zn alloy in all environments.

PRODUCT EVALUATION

In evaluating the corrosion resistance of the various Al-Zn binary alloy coatings, two distinct trends were observed between the corrosion resistance and the aluminum content of the coating (Figure 1). Generally, for coatings with aluminum content ranging from 0-20% Al, the corrosion resistance fell as the aluminum content increased except for a small improvement in

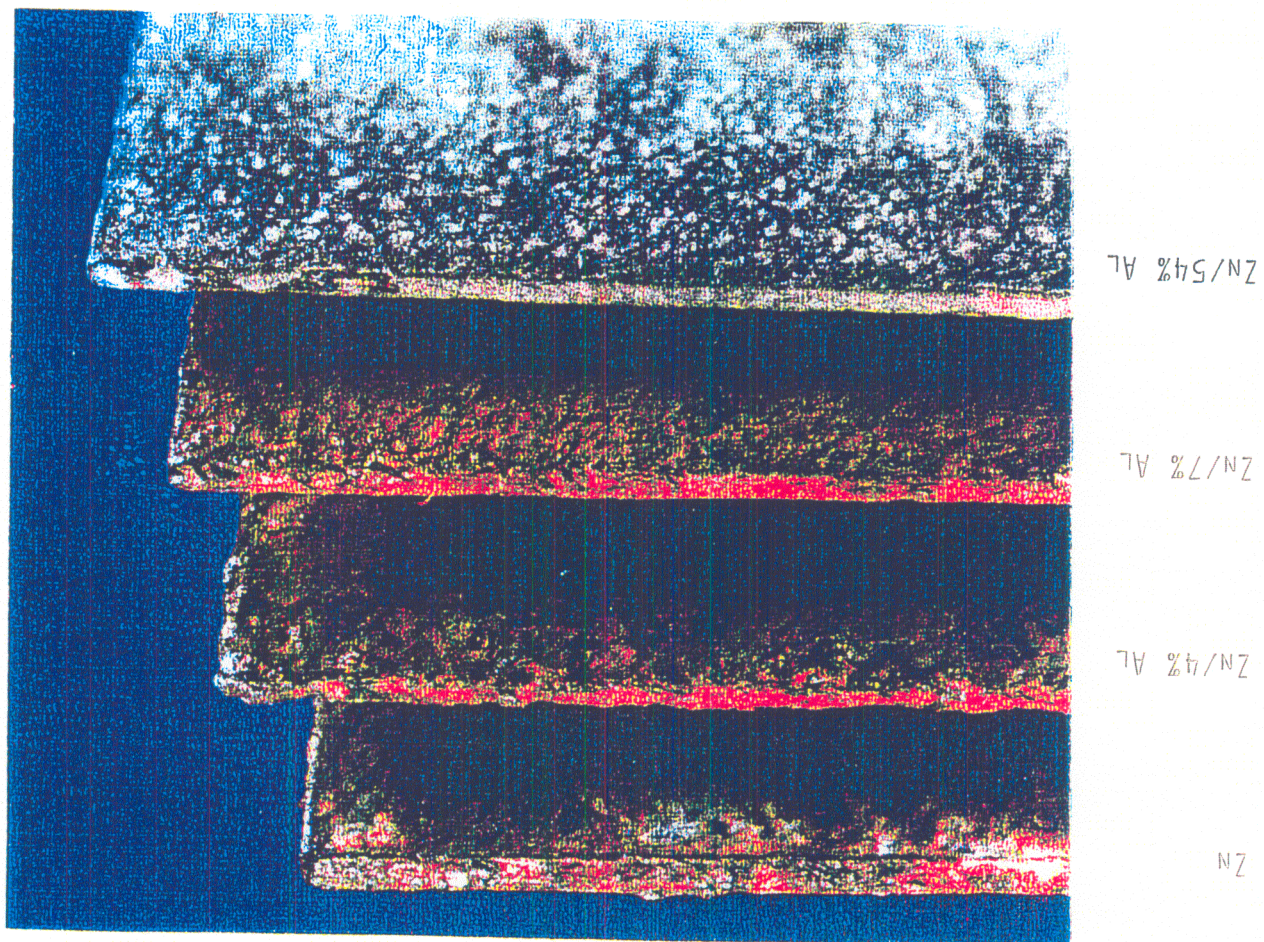


Figure 7. Cut edge protection offered by various coated sheet products after seventeen years exposure at a marine site (Kure Beach, NC, 25 meter lot)

corrosion resistance around 5% Al. Contrary to the above, a direct relationship between corrosion resistance and aluminum content was observed for coatings with higher aluminum content (20-70% Al); the corrosion resistance of these coating compositions improved with increasing aluminum content.

In the twenty-five years of outdoor exposure testing, the time to initial appearance of more than two percent red rust was recorded (Figure 2). In the severe marine environment (Figure 2a), coating durability initially increased as the aluminum content increased in the range 0 to 7.4%. Further increase in aluminum content from 12.2 to 35.1% was observed to be detrimental to the coating's corrosion resistance. Of particular importance is the significant increase in corrosion resistance that occurred at 44.6% Al and above. In this environment, the 55% Al-Zn coating offered a better than three fold improvement in durability over conventional galvanized. The same trends were observed in moderate marine, rural and industrial environments (Figures 2 b through d); aluminum amounts below 35% generally showed a detrimental effect on the coating's corrosion resistance whereas a significant improvement in corrosion resistance was observed above 44.6% Al.

These results are being reconfirmed on actual building installations around the world, especially in the U.S., Australia and Europe where roofs more than 20 years old are demonstrating excellent performance.

MANUFACTURE OF 55% Al-Zn COATED SHEET

The 55% Al-Zn coated sheet is produced on non oxidizing, continuous anneal, hot dip coating lines to a wide variety of strength levels for various applications. These hot dip coating lines are similar to those used for conventional galvanizing. Many of the lines producing 55% Al-Zn product are dual purpose lines where both 55% Al-Zn coated and galvanized sheets can be produced. The steel grades used for 55% Al-Zn coated sheet production are similar to those used for galvanized products and applications. Aluminum-killed as well as continuously cast, re-nitrogenized, interstitial-free and niobium-containing steels have all been successfully used for the production of 55% Al-Zn coated sheet.

The Al-Zn alloy is contained in an induction heated refractory-lined pot. The 55% Al-Zn coating composition is maintained in a premelt pot, by either using ingots of premixed alloy or ingots of Al-Si alloy and zinc in the correct proportion. The molten alloy from the premelt pot is fed into the main pot. The premelt pot ensures a uniform bath composition and a constant metal level in the main pot.

The in-line cleaned and annealed strip is immersed in the bath of molten 55% Al-Zn alloy maintained at approximately 600°C. On exiting the bath, the sheet passes through an air wiping system

which, in addition to removing excess molten coating, also ensures the application of the desired weight and coating uniformity. The coating is then cooled under controlled conditions to achieve the desired coating microstructure which is specified to enhance the product's corrosion resistance. A schematic of the pot configuration is shown in Figure 3.

The 55% Al-Zn coated sheet is produced with a standard coating weight of 150g/m² which is equivalent in thickness to a 275 g/m² coating of zinc. For very severe applications, higher coating weights could be used. In Australia, BHP produces a product with a coating weight of 100 g/m². However, this product is only used for internal applications, such as appliances, but is not suitable for exterior use where superior long term corrosion resistance is required. The light coating provides a very smooth surface which is attractive for critical paint finishes and provides adequate corrosion resistance for indoor applications.

A chromate passivation treatment, and oil if necessary, is applied at the end of the coating line to prevent moisture-induced staining during coil storage or transit. The chromate also enhances the luster of the product and delays discoloration due to natural weathering effects.

Where additional coating ductility is required for severe forming operations, the 55% Al-Zn coated sheet can be box annealed off-line to produce extra deep drawing grades.

COATING CHARACTERISTICS

Microstructure

A cross section of the 55% Al-Zn coating (Figure 4) reveals the two-phase dendritic microstructure. An aluminum-rich phase comprises approximately 80% of the volume with the balance comprised of an interdendritic zinc-rich phase. Silicon particles can also be seen in the coating. Small amounts of silicon are used in the molten coating bath to control the thickness of an intermetallic or alloy layer which forms at the interface between the coating and steel substrate. The composition of this alloy layer is 48% Al, 24% Fe, 14% Zn, 11% Si and acts as a barrier against corrodents that may eventually penetrate the overlying coating.

Corrosion Mechanism

After twenty-five years of actual outdoor exposure testing, the 55% Al-Zn coated sheet has continued to demonstrate its excellent corrosion resistance. This performance is related to the unique microstructure of the alloy coating as described above. During the early stages of atmospheric exposure, the zinc-rich interdendritic areas preferentially corrode while providing galvanic protection to the steel. These areas fill up with the insoluble corrosion products and reduce subsequent corrosion. The circuitous nature of this intermetallic network is a key factor in providing this excellent corrosion resistance. The alloy layer is very resistant to corrosion and acts as a physical

barrier to stopping any corrosion that eventually penetrates the overlay.

Ductility

The 55% Al-Zn coating is more ductile than conventional hot dipped galvanized. The 55% Al-Zn coating can withstand up to 12% uniaxial strain before fracture whereas the galvanized coating will fracture at around 7% uniaxial strain. Consequently, during roll forming, the 55% Al-Zn coating will be more resistant to fractures than the G-90 galvanized coating.

PERFORMANCE HISTORY

Outdoor Exposure

Test panels from the initial Bethlehem Steel pilot line experiment, after eighteen years exposure in a variety of environments, are shown in Figure 5. Figure 5a shows the panels with coating compositions ranging from 0 to 16% aluminum while Figure 5b shows compositions with higher aluminum contents. The superior performance of the 55% Al-Zn coating is readily obvious from this figure. After 18 years exposure at the marine sites, all panels below 44.6% aluminum have corroded and have been taken out of test. Panels with more than 44.6% aluminum are still on exposure at the moderate marine, industrial and rural sites and are still free of rust.

Corrosion Loss

The corrosion loss data for the various Al-Zn binary alloy compositions were calculated from another set of pilot-line produced test panels after thirteen years' outdoor exposure in various environments. The corrosion loss vs. time results for G-90 galvanized, 55% Al-Zn coated and aluminum-coated type 2 are shown in Figures 6 a through d. The figure shows good, long term corrosion resistance of the 55% Al-Zn coating and also confirm the corrosion mechanism described above. Initially, a relatively higher corrosion loss is observed for the 55% Al-Zn coating as the zinc-rich portion of the coating is consumed while providing sacrificial or galvanic protection to the cut edges. During this stage, the 55% Al-Zn coated sheet behaves more like the galvanized material. After about three years, the corrosion loss for the 55% Al-Zn coating slows down considerably which is reflected by the change in the corrosion-time curve (Figure 6 a & b) to a more horizontal slope where its behavior is similar to the aluminum-coated product which has twice the coating thickness of the 55% Al-Zn coated sheet. At this transition point, the corrosion mechanism changes from an active, zinc like behavior to a passive, aluminum like behavior. This trend is not as obvious in the marine environments where in the presence of chloride ions, aluminum also provides galvanic protection. In all cases, the corrosion loss for the 55% Al-Zn coating was significantly below that of G-90 galvanized coating.

The annual corrosion loss for each material in each environment was determined by dividing the total corrosion loss by the time of exposure (Table 2). For the 55% Al-Zn coating, the corrosion losses were calculated by determining the density of the corroding species, determined from the weight and chemical analyses of the coatings before and after exposure. Based on the ratios of these corrosion rates, the 55% Al-Zn coating is expected to outlast an equivalent thickness galvanized coating by at least two to four times over a range of environments.

Cut edge protection

The 55% Al-Zn coating provides good protection for steel at cut edges (Figure 7). After seventeen years' exposure at the severe marine site, the cut edge protection of the 55% Al-Zn coating is superior to that offered by galvanized and low aluminum containing coatings. This level of protection is particularly important in applications where sheared edges will be exposed or where localized damage to the coating may occur during fabrication or service.

COMMERCIALIZATION

The rapid growth of 55% Al-Zn coating has primarily been due to three basic features. First, the economics of the coating are favorable compared to galvanized. The coating composition is 55% aluminum by weight but almost 80% aluminum by volume. Thus the alloy has a lower density which translates in to a coating metal

cost saving compared to galvanized. For a 25 μm coating thickness (G-90 equivalent), 150 gm/m^2 of 55% Al-Zn coating is required as against 285 gm/m^2 for G-90 galvanized.

Secondly, there is a growing interest in corrosion resistant materials such as 55% Al-Zn coated sheet. Superior corrosion resistance is critical due to concerns over appearance, maintenance costs, waste, recycling and an overall better environment.

Finally, the versatility of 55% Al-Zn coated sheet is very attractive. The product has been successfully used in applications requiring not only corrosion resistance but also high temperature resistance, flexibility, formability and paintability.

MARKETING EFFORTS

Extensive marketing efforts have resulted in the successful market acceptance of 55% Al-Zn coated sheet. Joint efforts by world wide producers under InterZac (Acronym for International Zinc Aluminum Coaters Association) are further complimented by efforts of regional producers (NamZAC, EuroZAC, PacZac) where more focused marketing programs are developed and implemented. Tasks forces formed within these groups conduct various activities ranging from developing accelerated tests to

publishing brochures, getting approvals from various regulatory and standards institutions and holding educational seminars for producers and consumers of 55% Al-Zn coated sheet.

LICENSING

BIEC International is the developer and sole licensor of the 55% Al-Zn coated sheet technology. As of April 1994, 29 companies from 21 countries around the world have licensed the technology to produce 55% Al-Zn coated sheet. Many of the world's largest galvanizers are among them (Table 3). The product is sold under different trade names around the world which are also included in the Table. Salient features about the licensed lines are as follows:

1. In all, 29 companies are or will produce the 55% Al-Zn coated product on 39 lines. Of that total, 30 lines are currently in production.

2. Of the 39 lines, 22 are converted from galvanizing while 17 are new lines specially designed for 55% Al-Zn coated product. The large number of conversions of various types of existing galvanizing lines demonstrate the flexibility and adaptability of the 55% Al-Zn coating process.

3. Currently, there are 23 dual purpose lines in production. Such lines can produce both galvanized and 55% Al-Zn coated product.

CONCLUSION

The 55% Al-Zn coating composition provides the optimum balance between galvanic protection and long-term durability. The initial selection of this composition has been vindicated by twenty five years of actual outdoor exposure testing in different environments and also by the combined experience of twenty nine licensees worldwide.

55% Al-Zn coated sheet has been accepted by producers and users around the world. In fact it is now the fastest growing steel product in the world today. Production capacity for 55% Al-Zn coated sheet is increasing rapidly and the multiple marketing programs organized by producers around the world are accelerating its market acceptance and use in many applications.

TABLE 1
COATING COMPOSITIONS INVESTIGATED

No.	Coating Composition			
	Wt %			
	Al	Si	Pb	Zn
1	0.2	0	0.2	99.6
2	1.0	0.03	0	98.97
3	4.0	0.12	0	95.88
4	7.4	0.22	0	92.38
5	12.2	0.37	0	87.43
6	16.6	0.50	0	82.9
7	21.0	0.63	0	78.37
8	24.9	0.75	0	74.35
9	35.1	1.05	0	63.85
10	44.6	1.34	9	54.06
11	53.9	1.62	0	44.48
12	69.6	2.01	0	28.39
Commercial Products				
1	0.2	0	0.1	99.7
2	100	0		0

TABLE 2

**RATIOS OF AVERAGE CORROSION RATES OF
55% Al-Zn COATED AND CONVENTIONAL GALVANIZED SHEET**

<u>Site</u>	Ratio of Average Corrosion Rates	
	<u>Galvanized: 55% Al-Zn Coated</u>	
Kure Beach, NC, 25-m lot (Severe marine)	4.2	
Kure Beach, NC, 250-m lot (Moderate marine)	2.3	
Bethlehem, PA (Industrial)	6.2	
Saylorsburg, PA (Rural)	3.4	

TABLE 3
WORLDWIDE LICENSEES & THEIR TRADEMARKS

Company (Country)	No. of Lines	Location	Converted or New	Single or Dual Purpose	Trademark
Bethlehem (U.S.A.)	3	Sparrows Point, Md Sparrows Point, MD Sparrows Point, MD	C C N	S S D	GALVALUME
BHP (Australia)	4	Port Kembla, NSW Port Kembla, NSW Western Port, QLD Western Port, QLD	C C N C	S D S S	ZINCALUME
Svenskt Stal (Sweden)	1	Borlänge	C	S	ALUZINK
National (U.S.A.)	1	Portage, IN	C	D	GALVALUME
LTV (U.S.A.)	1*	Indiana Harbor, IN	C	D	GALVALUME
Galvalange (Luxembourg)	2	Dudelange	N N	D D	ALUZINC
U.S. Steel (U.S.A.)	1	Irvin Works, PA	C	D	GALVALUME
Nippon/Daido Steel (Japan)	1	Amagasaki	N	D	GALVALUME
Dofasco (Canada)	1	Hamilton, Ontario	C	D	GALVALUME
Ensidesa (Spain)	1	Aviles	C	D	ALGAFORT
British Steel (U.K.)	1	Shotton	N	D	ZALUTITE
Union Steel (Korea)	1	Busan	C	D	GALVALUME
Sumitomo (Japan)	1	Wakayama	C	D	GALVALUME
La Magona (Italy)	1	Piombino	C	D	ZINCALIT
IMSA (Mexico)	1	Monterrey	C	D	ZINTRO-ALUM
COMESI (Argentina)	1	Buenos Aires	C	D	CINCALUM
Yodogawa (Japan)	1	Ichikawa	C	D	GALVALUME
Hoogovens (Netherlands)	1	IJmuiden	N	D	GALVALUME

Company (Country)	No. of Lines	Location	Converted or New	Single or Dual Purpose	Trademark
Hoesch (Germany)	1	Eichen	C	D	GALVALUME
An Mau (Taiwan)	1	Kaohsiung	N	D	GALVALUME
CSH (Chile)	1	Talcahuano	N	S	ZINC-ALUM
Wheeling-Nisshin (U.S.A.)	1	Follansbee, WV	N	D	GALVALUME
Kawatetsu (Japan)	1	Tamashima	C	D	GALVALUME
NKK (Japan)	1	Kihin Works	N	D	GALVALUME
Cherepovets (Russia)	1	Cherepovets	N	D	GALVALUME
Karaganda (Kazakhstan)	1*	Temirtau	N	D	
Magnitogorsk (Russia)	1*	Magnitogorsk	N	D	
SAIL (India)	1*	Bokaro	C	D	
BHP New Zealand (New Zealand)	1*	Glenbrook	C	D	
Double G (U.S.A.)		Jackson, MS	N	D	
BHP Indonesia (Indonesia)	1*		N	D	
BHP SupraCote	1*		N	D	

• Not yet in production

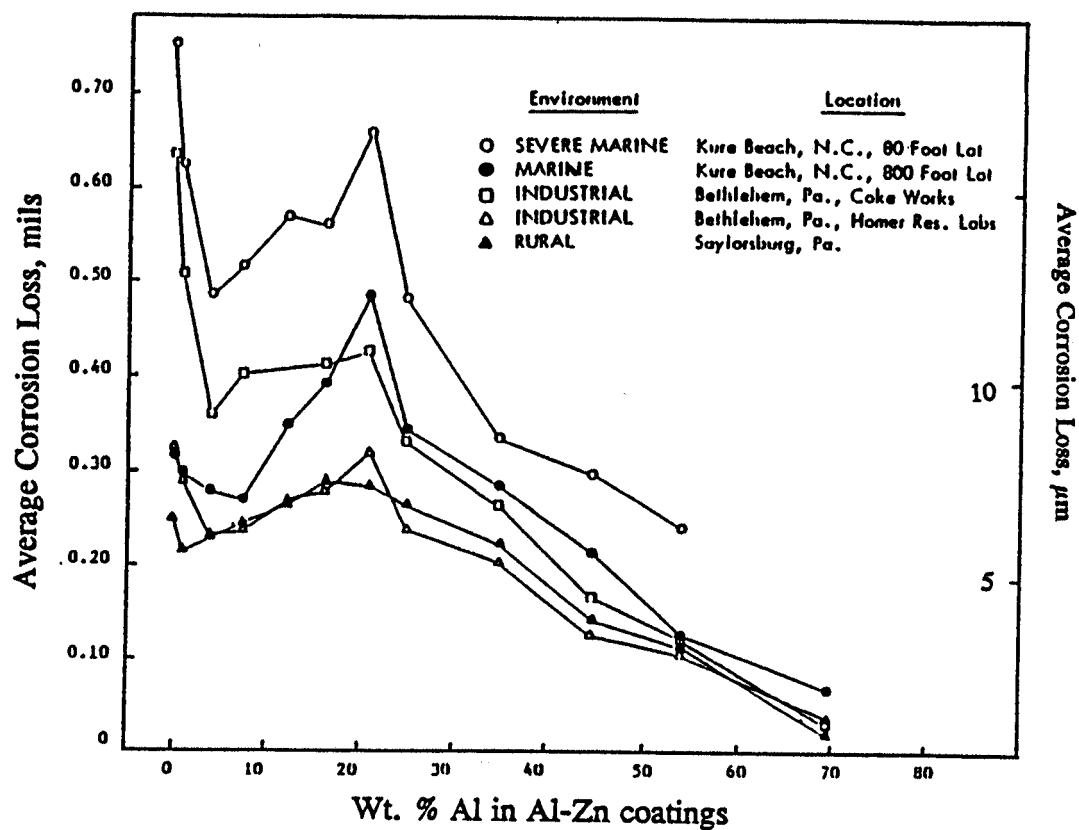


Figure 1. Effect of coating composition on the atmospheric corrosion resistance of Al-Zn alloy coated steels.

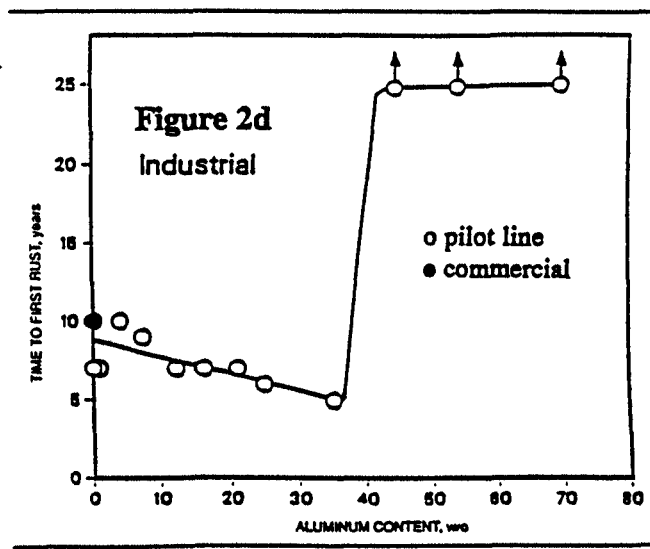
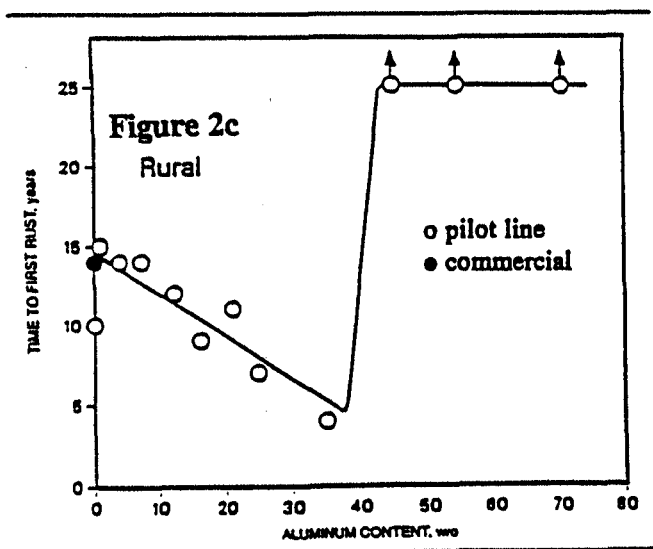
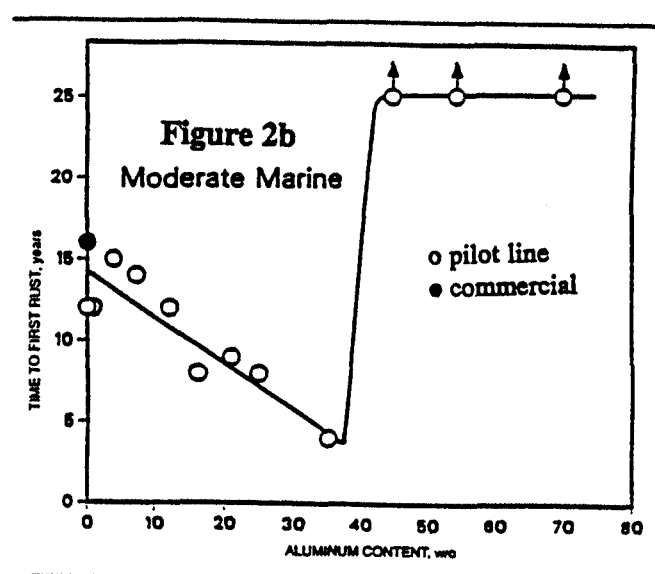
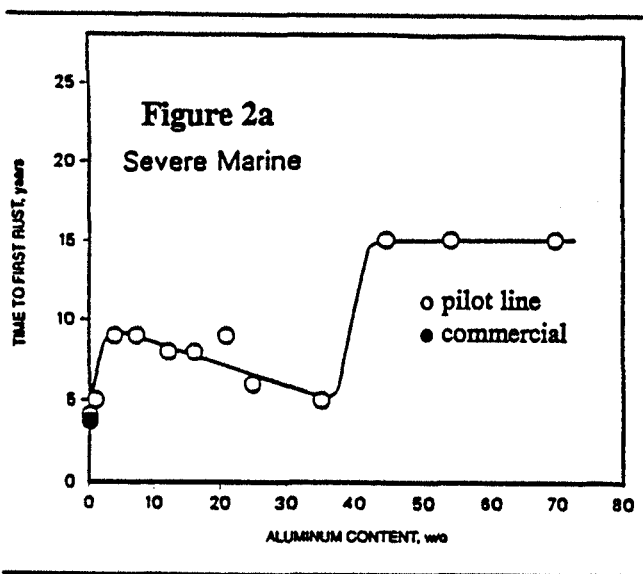


Figure 2. Effect of aluminum content on coating life in various environments after twenty five years outdoor exposure.

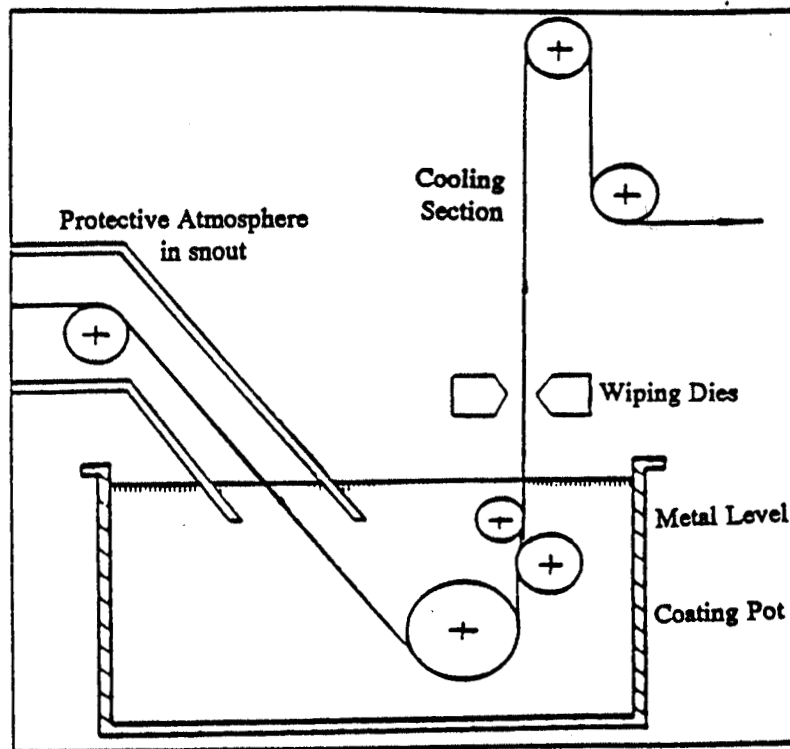


Figure 3. Schematic of hot dip coating process.

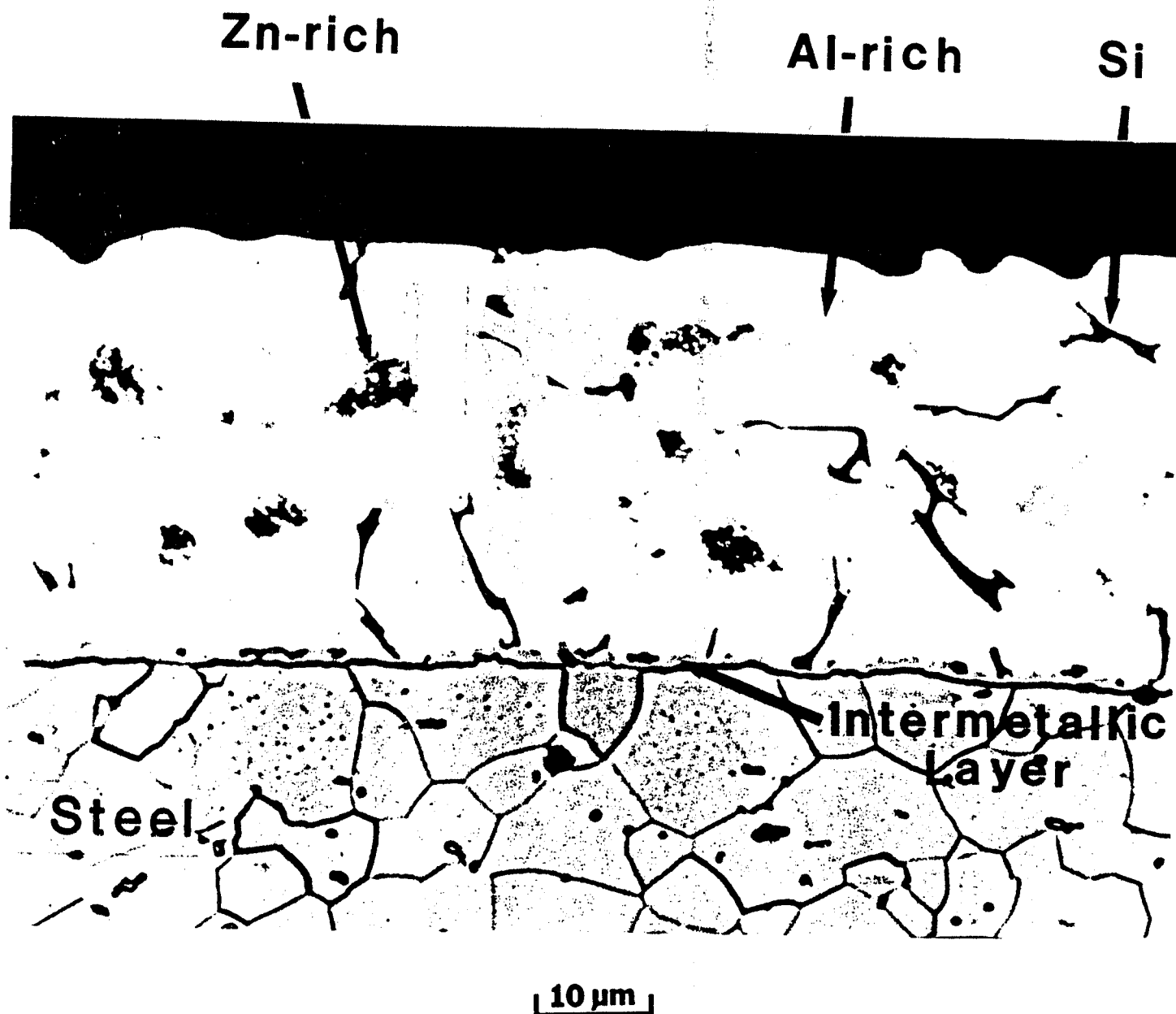


Figure 4. Typical cross-sectional photomicrograph of 55% Al-Zn coating.

Figure 5a.

Skyward surface appearance of coated sheets after 18-year atmospheric exposure in various climates (original panel size approximately 10 cm x 15 cm).

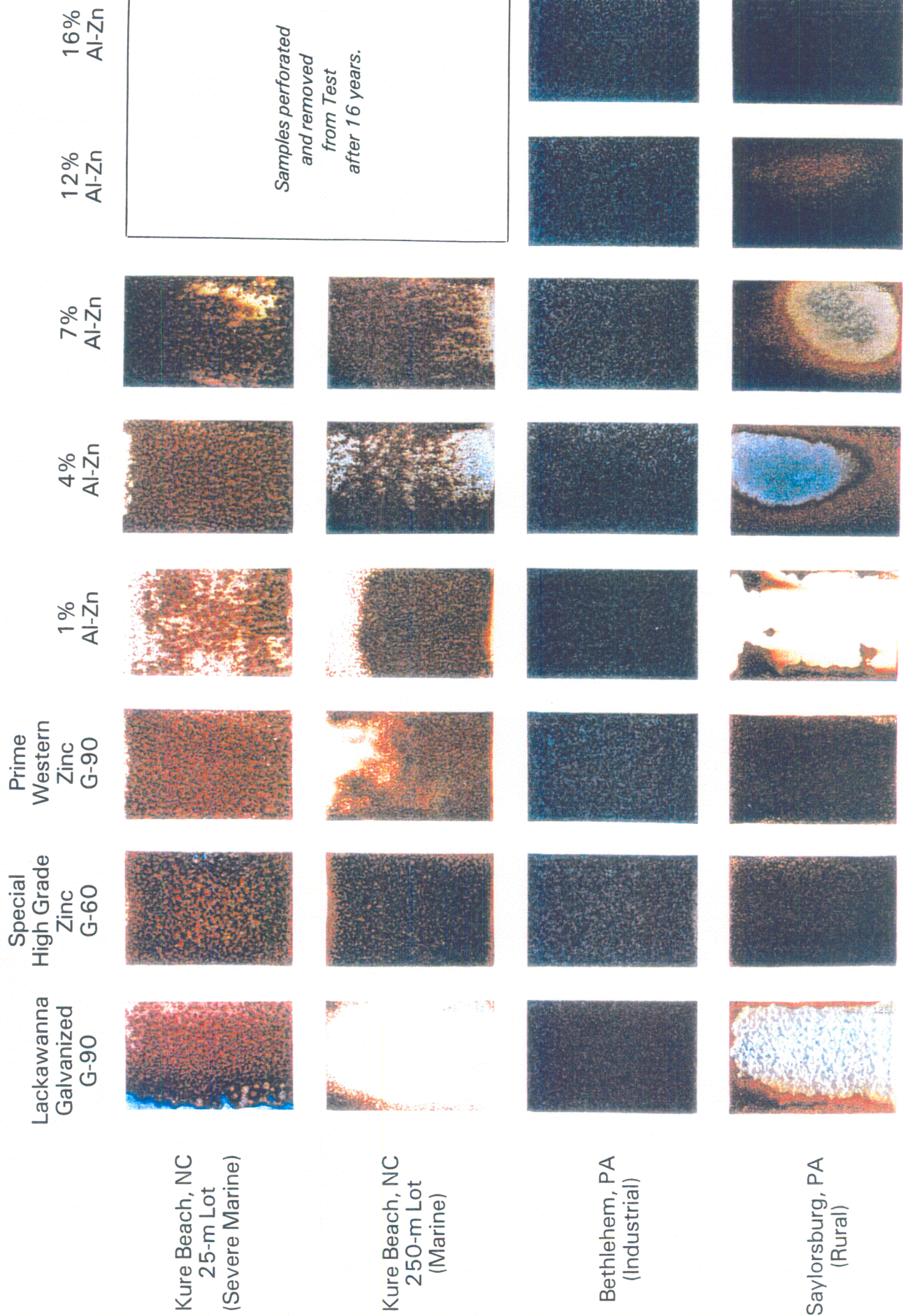
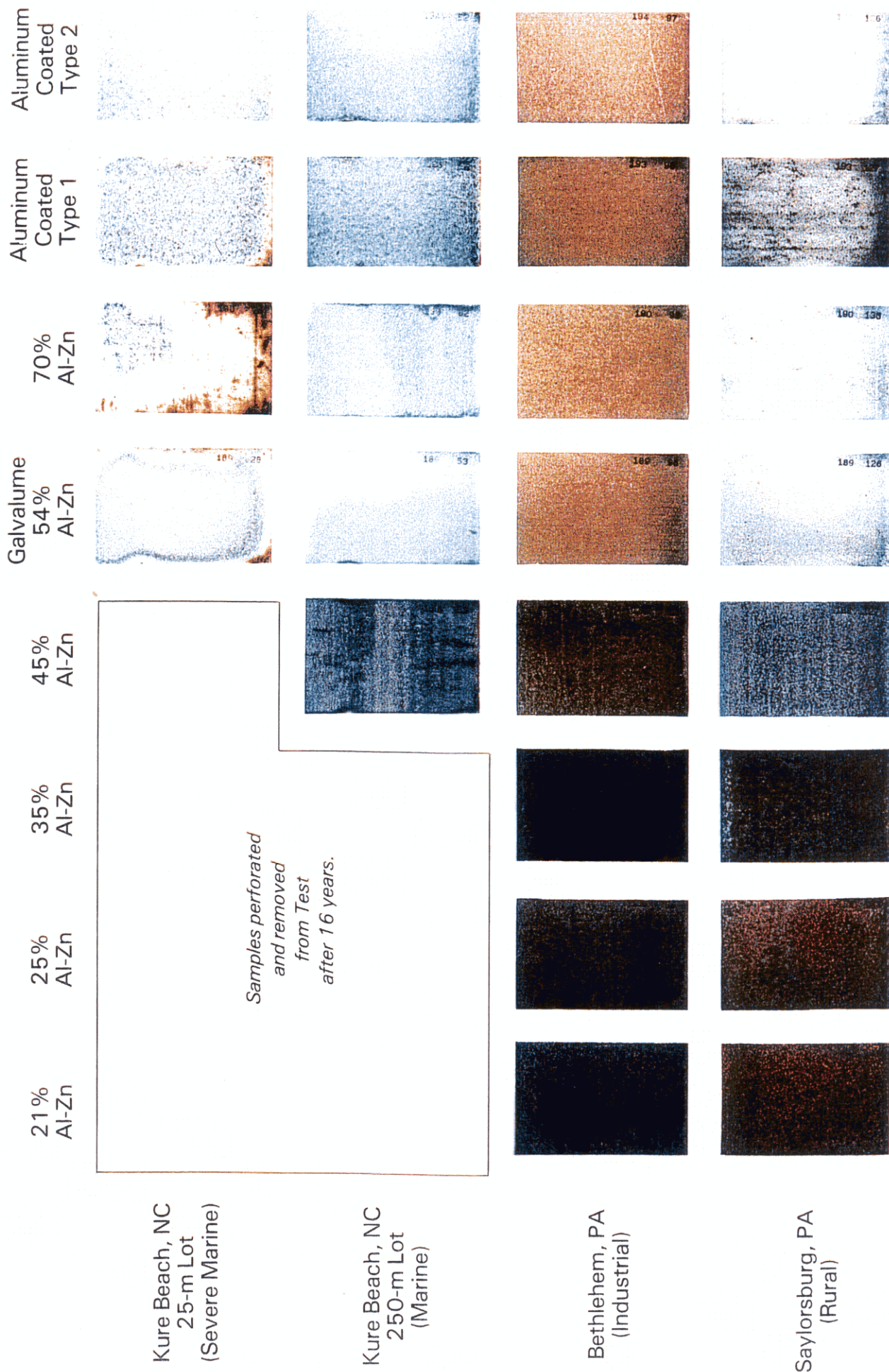


Figure 5b.

Skyward surface appearance of coated sheets after 18-year atmospheric exposure in various climates (original panel size approximately 10 cm x 15 cm).



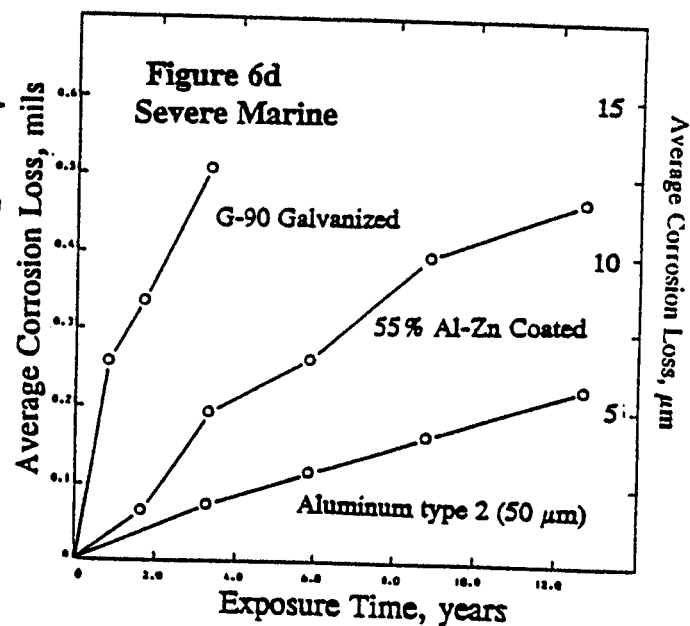
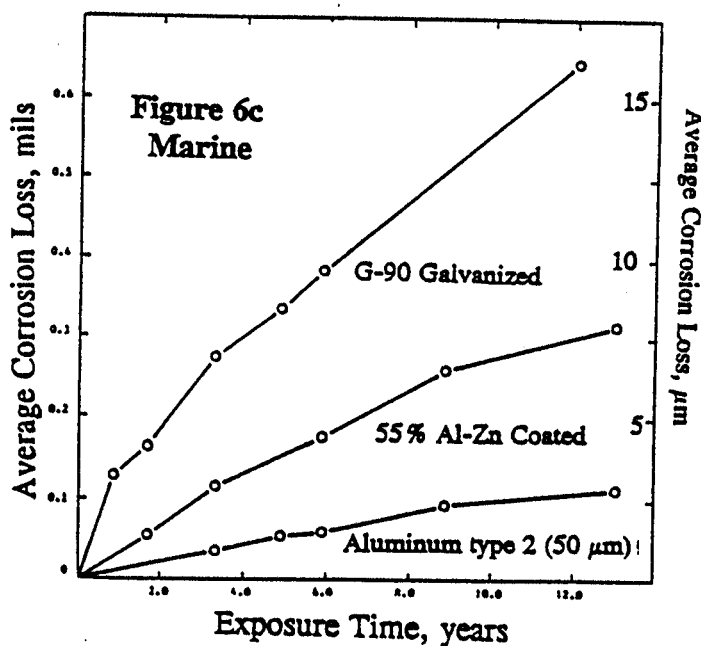
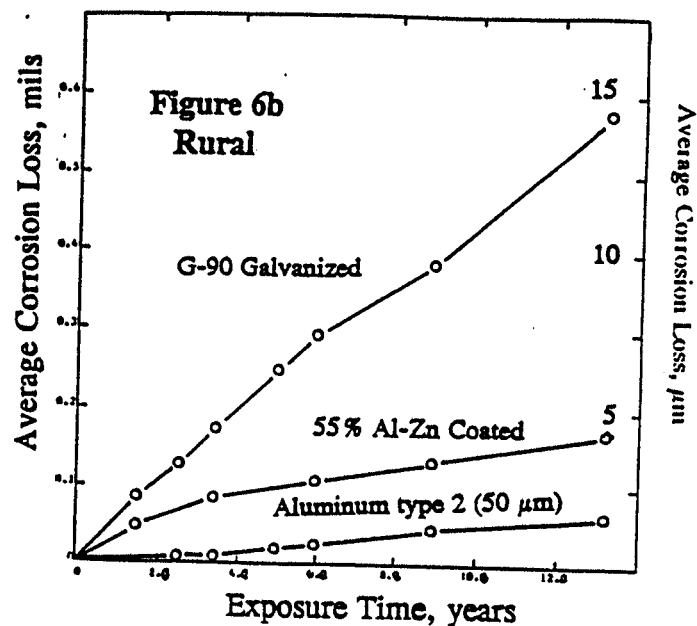
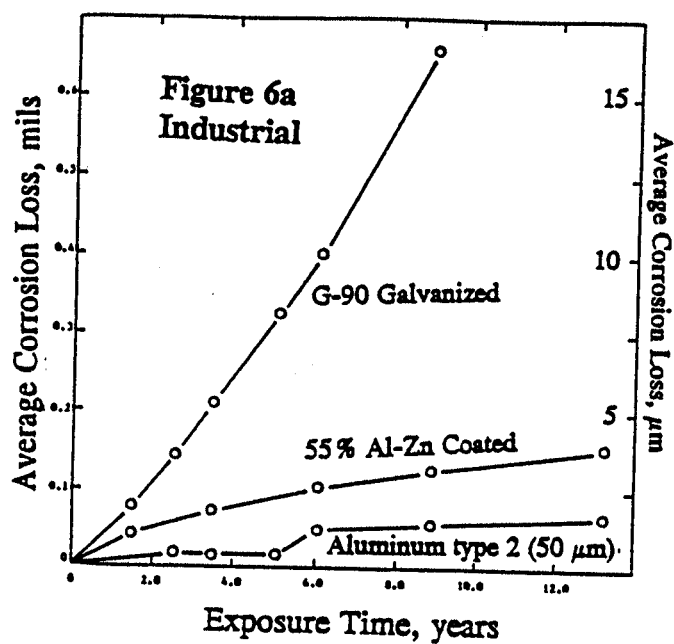


Figure 6. Corrosion resistance of G-90 galvanized, 55% Al-Zn coated and aluminum coated type 2 in various environments.