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55% Al-Zn ALLOY COATED SHEET STEEL: THE VERSATILE, LONG LASTING BUILDING PANEL STEEL

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SUMMARY

55% Al-Zn alloy coated sheet steel has established its niche as a bare and painted building panel product because of its excellent atmospheric corrosion resistance. The 30 year and 25 year test results detailed here demonstrate the superior corrosion resistance of 55% Al-Zn over conventional galvanized sheet. Field surveys of low slope, bare 55% Al-Zn roofs in the Eastern half of the US confirm the prediction from R&D tests that 55% Al-Zn roofs will last well beyond 20 years. Building construction applications in the US for both bare and prepainted 55% Al-Zn new and retrofit roofing are described and illustrated.

INTRODUCTION

Since its commercial introduction by Bethlehem Steel Corporation almost 25 years ago, GALVALUME sheet steel (55% Al-Zn alloy coated sheet steel) has been established in the US as the premier steel product for bare and painted building panels. The product was later licensed to steel companies around the world, beginning with JLA/BHP in Australia in 1975 and then to European, Asian and Latin American steel companies in the intervening 20 years. As was the case for the product in the US, 55% Al-Zn coated sheet steel (referred to as 55% Al-Zn hereafter) has established its worldwide marketing niche as a bare and painted building panel product.

55% Al-Zn has an aluminum-zinc alloy coating that provides excellent atmospheric corrosion resistance in a wide range of environments under many diverse conditions. The coating is applied to steel sheet by the continuous hot dip coating process. The alloy coating of aluminum and zinc gives a unique combination of long term corrosion resistance and galvanic protection at scratches and cut edges.

THE COATING

The coating nominally contains 55% Al and 45% Zn by weight. Considering the volume composition, the coating contains about 80% Al and 20% Zn, making it an aluminum-like coating.

In the US, 55% Al-Zn is produced with two coating weights for building panel applications which are covered by ASTM Specification A792/A792M. The coating weights are 150g/m^2 (AZ150) and 165g/m^2 (AZ165), which are equivalent to a nominal coating thickness of 20µm and 23µm on each side, respectively.

ATMOSPHERIC CORROSION RESISTANCE

The excellent corrosion resistance of 55% Al-Zn is achieved by combining the barrier protection of an aluminum coating with the galvanic protection of a zinc coating. The unique metallic coating structure shields the steel base from moisture and contaminants while providing sacrificial protection at scratches and cut edges. Zinc-rich regions, which are distributed uniformly in the barrier aluminum-rich layer, galvanically protect the steel when it becomes exposed to the elements at scratches and edges.

The superior performance of 55% Al-Zn has been proven after 30 years of testing at sites around the US. Table 1 shows the composition of early pilot line Al-Zn coatings made at Bethlehem Steel's Research Laboratory in the mid-1960s. Coatings 20 to 25µm thick were continuously applied on 0.4mm thick by 152mm wide sheet. Figures 1 to 4 plot the performance (time to first rust) of these compositions at the severe marine, moderate marine, rural and industrial locations.

At the severe marine test site (Figure 1), Zn coatings (galvanized) show first rust after four to five years, whereas coatings in the range of 45 to 70% Al show rust after 15 years for a threefold improvement over ordinary Zn coatings.

Similar features are noted at the moderate marine, rural, and industrial locations (Figures 2 through 4, respectively).

At the moderate marine and rural sites, coatings in the range of 45 to 70% have already lasted twice as long as a zinc coating. At the industrial site, the degree of improvement is threefold.

Based on 13-year quantitative weight-loss data, the life of the 55% Al-Zn coating was estimated to be 35, 41 and 53 years respectively in the moderate marine, rural, and industrial environments.

Twenty year test results on commercially produced 55% Al-Zn samples made by Bethlehem Steel indicate that production material is even more corrosion resistant than pilot line material.

Test panels 0.53mm thick with an AZ165 coating weight were exposed at the same locations as in the pilot line study and designed to measure corrosion losses on the skyward – and groundward – exposed surfaces. For comparative purposes, panels of commercially produced 0.53mm thick galvanized sheet with a Z275 coating weight were also tested. Corrosion data from these tests were fitted to exponential equations which were then used to estimate the life of 25µm thick coatings. Tables 2 and 3 show the calculated life in years for galvanized and 55% Al-Zn respectively.

For applications such as metal roofing, the coating life of the skyward surface is of greatest interest. Ratios of the life of the skyward surfaces calculated for 55% Al-Zn to those for galvanized are given in Table 4. Based on these ratios, the 55% Al-Zn coating will have four to 19 times the life of an equal-thickness galvanized coating. On average, 55% Al-Zn will outlast galvanized by a factor of nine.

An often-asked question about 55% Al-Zn coating is its ability to protect cut edges. Figure 5 shows the appearance of 55% Al-Zn and galvanized after 20 years at the industrial site. 55% Al-Zn is free of rust and stain at the cut edge. In contrast, the cut edge on galvanized is red rusted and the entire zinc coating is corroded away.

Similar performance was observed on OT bends. 55% Al-Zn is free of red rust at the bend at the corrosive industrial site (Figure 6). In addition, there is a white deposit which appears to result from the sacrificial corrosion of the coating. In contrast, the galvanized coating has completely sacrificed itself to protect the underlying steel, so that it is no longer able to provide any protection.

Superior performance of 55% Al-Zn has also been confirmed after up to 20 years of testing in various locations around Europe. For example, the Swedish Corrosion Institute has found that 55% Al-Zn outperforms galvanized sheet of equivalent thickness three to seven times in marine and industrial atmospheres in Sweden.

UNPAINTED 55% Al-Zn ROOF PERFORMANCE

A survey of 82 unpainted 55% Al-Zn low slope (5° slope or less) roofs up to 22 years old in the Eastern half of the US confirms the prediction from R&D tests that 55% Al-Zn roofs will last well beyond 20 years. The buildings were located in the industrial North and along the South Gulf and Atlantic Coasts. Northern buildings were mostly subjected to acid rain and corrosive microenvironments from nearby factories. Salt-laden air and heavy morning dew usually covered buildings in the South. Also, most roofs were standing seam, which are near-flat and increase the time of wetness from rain and dew. Furthermore, nearly flat roofs are not readily washed by rain, causing corrosive deposits to accumulate on roof panels.

55% Al-Zn roofs are in excellent condition. After 20+ years the 55% Al-Zn coating is intact and protecting the steel substrate from corrosion. Based on their appearance, properly installed and maintained 55% Al-Zn roofs are projected to last 30 or more years before requiring major maintenance such as field painting (Figure 7).

A similar inspection of unpainted low-slope 55% Al-Zn roofs was recently completed on buildings up to 15 years old in the UK, France, Sweden, Benelux and Germany. Again, the performance of these 55% Al-Zn roofs parallels that of roofs in the US. The 55% Al-Zn roofs in Europe are in excellent condition and are expected to last longer than 20 years.

PREPAINTED 55% Al-Zn

Prepainted 55% Al-Zn building panels are also favoured by many manufacturers, architects and building owners. The combination of long-lived 55% Al-Zn and modern high performance paint systems gives a functional, durable, eye-appealing building panel product.

Various types of paints are applied in a wide range of colour and finishes on a continuous paint line. Processing on the paint line includes cleaning, pretreating, priming, painting and baking of the paint all in one continuous process. Two coats of paint are normally applied to both sides of 55% Al-Zn; a corrosion inhibitive primer and a top coat. The primer is applied at a thickness specified by the paint manufacturer (typically about 5µm). The top coat thickness varies depending on paint type and end use. Paint types include polyesters, silicone polyesters, fluorocarbons and plastisols.

Prepainted 55% Al-Zn has exhibited excellent corrosion resistance in a variety of accelerated and atmospheric tests and on buildings. It has demonstrated equal or better performance than prepainted G275 galvanized in corrosion at flat areas, paint damaged areas, formed areas and roof drip edges.

55% Al-Zn AROUND THE WORLD

55% Al-Zn is also being used successfully for roofing and cladding, both bare and painted, in all kinds of environments around the world. Globally, 40 companies are licensed to make the product. It is estimated that about 85 per cent of worldwide production is used for building panels.

Since its commercial introduction in 1972 over 30Mt have been produced cumulatively (Figure 8). Currently, about 3Mt/y are being produced worldwide and 1Mt/y in North America. Translating this production to annual usage for building panels, an estimated 600Mm^2/y are being used worldwide and 200Mm^2/y in North America.

In North America in particular, new and innovative uses for 55% Al-Zn building panels on non-residential buildings are being discovered every day by architects, building owners and contractors. The annual size of the non-residential roofing market is estimated to be about 500Mm^2, most of which is comprised of traditional non-metallic roof systems, ie built-up and single-ply roofing. The metal roofing share of this market is small, about 10 per cent or 15 per cent, but is growing fast. Bare and painted 55% Al-Zn comprise a significant share of this metal roofing market.

Bare 55% Al-Zn low slope standing seam roof (SSR) systems are being used as a replacement for traditional flat non-metallic roofs. Their light weight and high strength translate into lower cost roof and building structural systems and their long life provides significant life cycle cost savings over non-metallic systems.

Metal building systems manufacturers or Design and Build companies in the US have made 55% Al-Zn SSR their roof systems of choice on their buildings. In 1995 these companies accounted for 65 per cent of all sales in the low rise, non-residential market. This key market segment consists of one and two storey community, commercial and industrial buildings up to 15,000m^2. The 31 companies that make up the Metal Building Manufacturers Association accounted for 36Mm^2 out of 54Mm^2 of new building space completed in this low rise market segment in 1995. Figures 9 to 11 show typical examples of these buildings.

Another fast growing segment of the non-residential market that uses 55% Al-Zn in the US is retrofit roofing over flat non-metallic roofs. 55% Al-Zn SSR is installed directly over flat, leaking non-metallic roofs with minimal tear-off required and little or no interruption to activities

in the building. A lightweight low slope structural system is attached to the existing flat roof onto which bare 55% Al-Zn SSR is installed. Alternatively, steep slope sub-assemblies are used with colourful prepainted 55% Al-Zn SSR which enhance the appearance of the building and make the roof a prominent design feature. Figures 12 and 13 are examples of low slope and high slope retrofit roofing.

Architects in the US have also learned to use steep pitched prepainted 55% Al-Zn architectural SSR on non-residential buildings. These roofs are installed with slopes of 3:12 or greater and are usually applied over solid wood or metal decks rather than directly to the roof purlins such as low slope bare 55% Al-Zn SSR. They function as water-shedding systems and are specified on visually exposed roofs, mansards and facias. Figures 14 and 15 show typical architectural 55% Al-Zn SSR.

The residential roofing market in the US is even bigger than the non-residential market and offers greater opportunities for metal roofing. It is estimated to be about 1,700Mm^2. Low cost asphalt shingles dominate this market, while metal roofing currently comprises an estimated 2 per cent or 3 per cent of the market. As is the case with non-residential roofing, usage of residential metal roofing is growing and 55% Al-Zn roofing is participating in this growth. Metal roofing manufacturers are offering residential developers and home owners a wide variety of products, including profiled panels, along with tile, shake and shingle facsimiles. Figures 16 and 17 show typical examples of profiled and tile facsimile prepainted 55% Al-Zn residential products.

CONCLUSION

The outstanding atmospheric corrosion resistance of 55% Al-Zn has been established after over 30 years of testing and 25 years of field service. This excellent performance has led to its primary use as a superior bare and painted building panel product. Rapid growth of 55% Al-Zn is expected to continue around the world as building construction companies recognize its benefits for building panels and new producers come on stream to meet the needs of existing users and to supply material for new applications in building and construction markets.

REFERENCES

Townsend, H E and Borzillo, A R. (1996) Materials Performance, April 1996, 31-36.

AUTHOR BIOGRAPHY

Herbert E Townsend received a BS in Metallurgical Engineering from Drexel University (1963) and a PhD in Materials Science and Engineering from the University of Pennsylvania (1967). He is currently a Senior Research Consultant for Bethlehem Steel Corporation, where he has specialized in the development of corrosion-resistant steel products for 30 years. He is currently chairman of the auto-steel partnership's corrosion task force. He is also a registered professional engineer and has authored over 70 technical articles and 18 US Patents.

Angelo R Borzillo is a consultant for BIEC International Inc. He is also President of the ZAC Association, the worldwide association of GALVALUME sheet producers and Programme Director of the GALVALUME Sheet Producers of North America. Mr Borzillo is co-inventor of GALVALUME sheet steel and has participated in and managed research, operating, marketing and licensing programs at Bethlehem Steel and BIEC since the product's inception 34 years ago.

Table 1 Compositions of Al-Zn alloy coatings applied to steel sheet on a pilot-scale hot dip coating line.

Composition (Wt %)		
Al	Si	Pb
0.2	0	0.2
1.0	0.03	0
4.0	0.12	0
7.4	0.22	0
12.2	0.37	0
16.6	0.50	0
21.0	0.63	0
35.1	1.05	0
44.6	1.34	0
69.6	2.01	0

Table 2 Calculated coating lives for galvanized sheet (commercial production panels – 20 year test results).

Site	Surface	A	B	Calculated Coating Life, years
Rural	Skyward	2.004	0.8507	20
	Groundward	0.3447	1.1547	41
	Combined	1.007	0.9297	35
Industrial	Skyward	2.004	0.9593	14
	Groundward	0.6383	1.0727	31
	Combined	1.371	0.9355	22
Moderate marine	Skyward	2.961	0.8307	13
	Groundward	0.9880	1.1392	17
	Combined	1.9232	0.8505	20
Severe marine	Skyward	—	—	4
	Groundward	1.2686	1.2105	12
	Combined	—	—	4

A and B are the coefficients in the Equations $C = AT^B$ for a least squares regression of the corrosion data.

Coating life is calculated by use of the Equation $T = (C/A)^{1/B}$ and the above values of A and B for a coating thickness (T) of 25 µm.

Skyward and combined lives for the severe marine site are based on actual failure times.

Table 3 Calculated coating lives for 55% Al-Zn (commercial production panels – 20 year test results).

Site	Surface	A	B	Calculated Coating Life, years
Rural	Skyward	0.9833	0.5461	373
	Groundward	0.5266	0.3147	213
	Combined	0.4743	0.7183	249
Industrial	Skyward	0.4877	0.8782	89
	Groundward	0.3954	0.5754	1350
	Combined	0.4985	0.7703	161
Moderate marine	Skyward	0.7660	0.7472	106
	Groundward	0.5978	0.9758	46
	Combined	0.8056	0.7708	86
Severe marine	Skyward	0.4153	1.5129	15
	Groundward	0.5851	1.1761	24
	Combined	1.0743	0.9046	32

A and B are the coefficients in the Equations $C = AT^B$ for a least squares regression of the corrosion data.

Coating life is calculated by use of the Equation $T = (C/A)^{1/B}$ and the above values of A and B for a coating thickness (T) of 25 μm.

Table 4 Ratios of coating lives for skyward surfaces (commercial production panels – 20 year test results).

Site	Ratio of Coating Life, 55% Al-Zn to Galvanized Sheet
Rural	18.7
Industrial	6.4
Moderate Marine	8.2
Severe Marine	3.8
Average	9.3

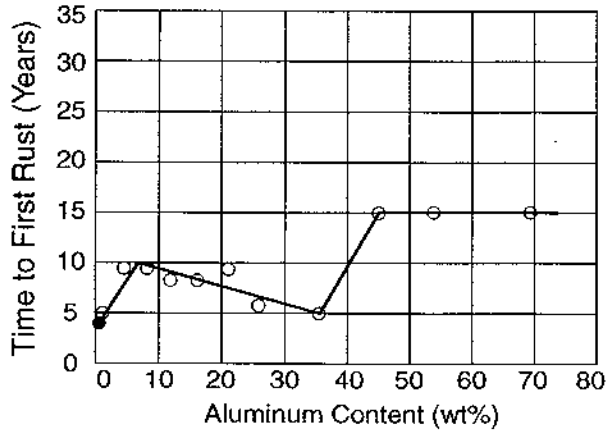


Figure 1: Effect of Al content on coating life in a severe marine environment. Open circles: pilot-line product. Solid circle: commercial product.

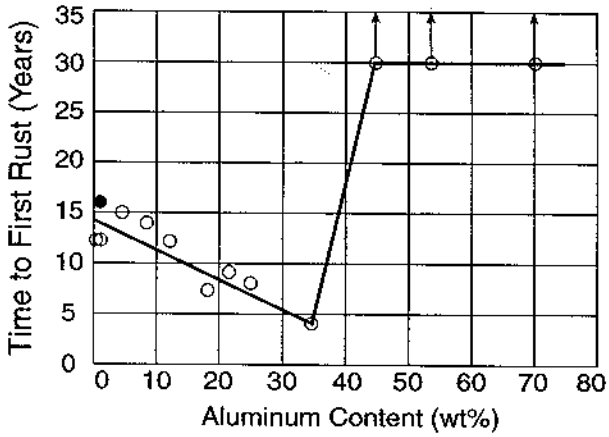


Figure 2: Effect of Al content on coating life in a moderate marine environment. Open circles: pilot-line product. Solid circle: commercial product. Arrows indicate that there is no failure for this composition and the test is continuing.

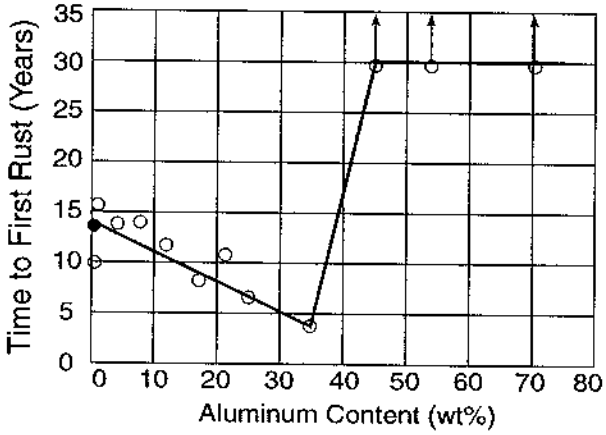


Figure 3: Effect of Al content on coating life in a rural environment. Open circles: pilot-line product. Solid circle: commercial product. Arrows indicate that there is no failure for this composition and the test is continuing.

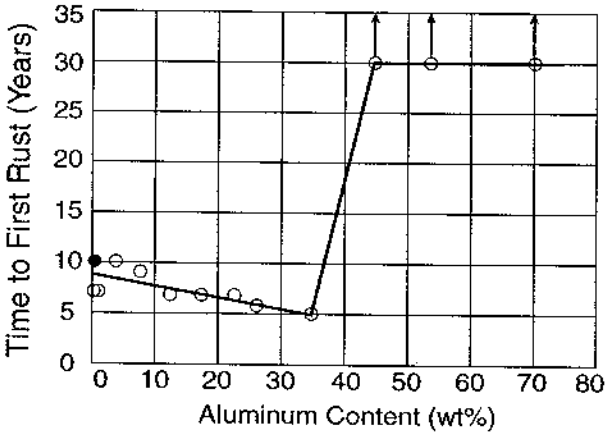


Figure 4: Effect of Al content on coating life in an industrial environment. Open circles: pilot line product. Solid circle: commercial product. Arrows indicate that there is no failure for this composition and the test is continuing.

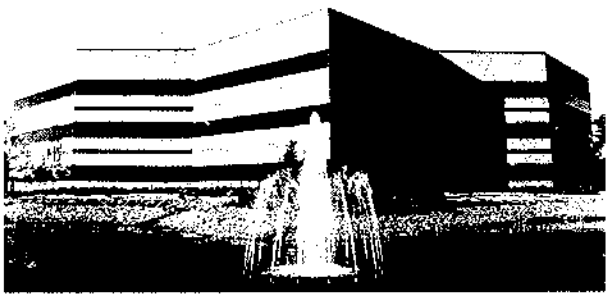


Figure 10: A low-rise, customized pre-engineered commercial building with a bare 55% Al-Zn standing seam roof.

Figure 11: A custom-look, Design and Build building with a bare 55% Al-Zn standing seam roof.

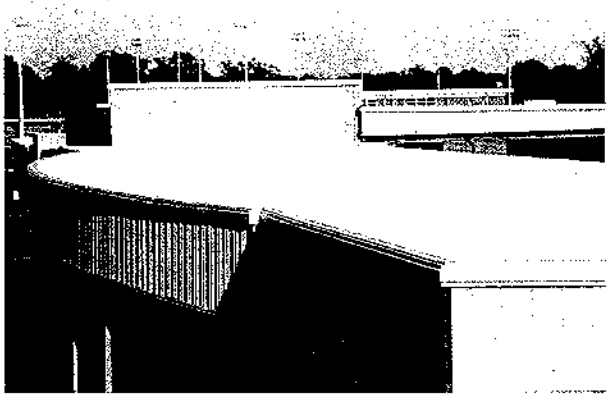


Figure 12: A bare, low-slope 55% Al-Zn retro fit standing seam roof installed over a leaking non-metallic built-up school roof.

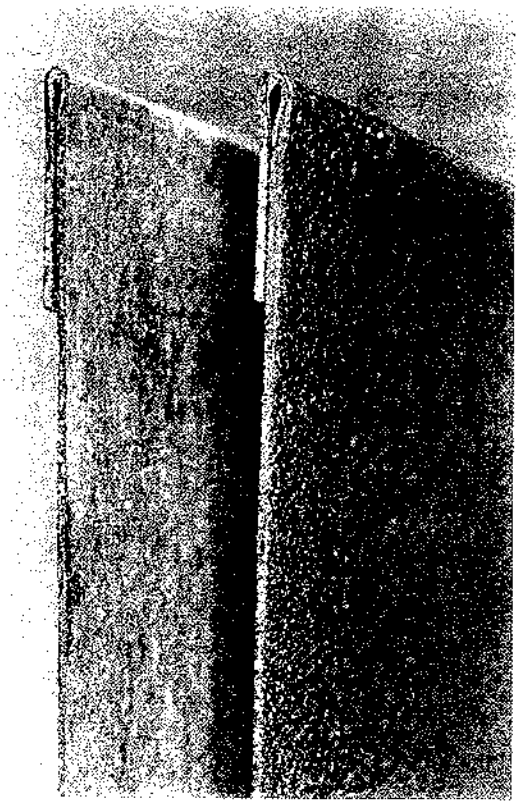
Figure 13: A prepainted, steep slope 55% Al-Zn retro fit roof installed over a leaking non-metallic hotel roof.

Figure 14: A steep slope, complex shaped, prepainted 55% Al-Zn roof on a visitors centre.

Figure 15: A steep pitched prepainted 55% Al-Zn architectural roof on a government building.

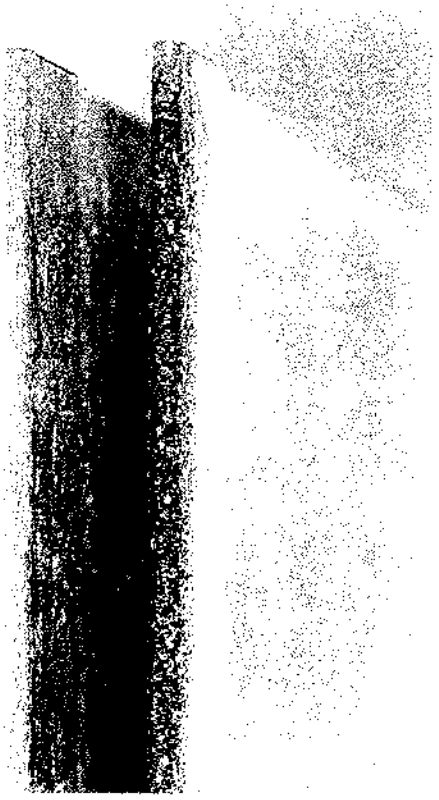
Figure 16: A steep pitched prepainted 55% Al-Zn residential roof on a home near the ocean.

Figure 17: A prepainted, tile facsimile 55% Al-Zn roof on a condominium near the ocean.



55% Al-Zn 20-yr industrial | Galvanized 20-yr industrial

Figure 5: Typical appearance of cut edges after 20-year industrial exposure.



55% Al-Zn 20-yr industrial | Galvanized 20-yr industrial

Figure 6: Typical appearance of 0T bends after 20-year industrial exposure.

Figure 7: Located in an area of paper mills in Wisconsin, USA, this 20 year old, one degree slope bare 55% Al-Zn standing seam roof is in excellent condition. Its life is projected to be 30 to 40 years.

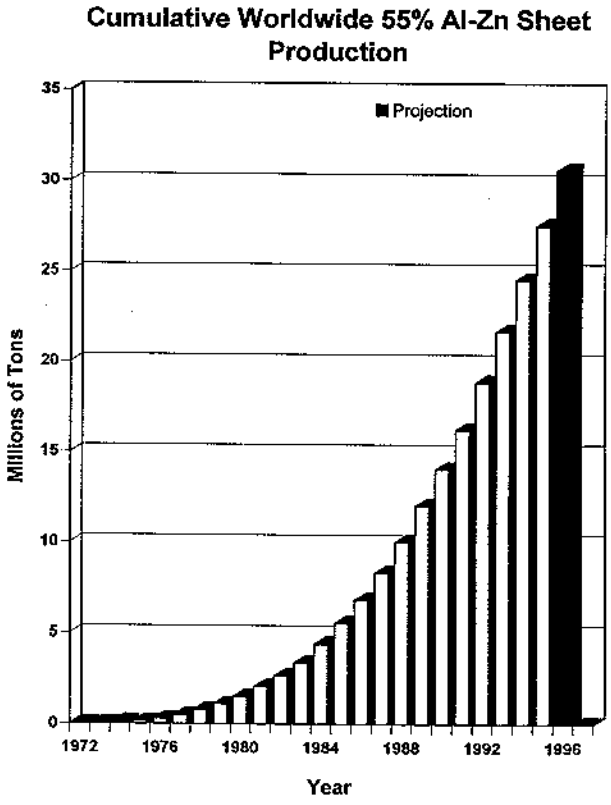


Figure 8: Building panel usage is fueling worldwide 55% Al-Zn sheet steel production. Globally, 40 companies are licensed to make the product.

Figure 9: Typical low-rise, pre-engineered industrial building with a bare low slope 55% Al-Zn roof.