55%AL-ZN COATED SHEET STEEL (GALVALUME®) – ONE OF THE FASTEST GROWING STEEL PRODUCTS[1]

W. Dieter Bender[2]
Adriano Scheid[3]

Abstracts
This paper describes the key properties of 55%Al-Zn coated sheet steel that led to the remarkable worldwide growth of this highly corrosion resistant product. The presentation at the seminar will be made with an MS PowerPoint presentation showing pictures and word slides depicting the product's nature, applications, development, corrosion protection mechanism, commercial benefits, and other features that contributed to this product's noteworthy growth. We will answer the question of why 55%Al-Zn sheet steel has a useful life that is 4 to 6 times longer than plain galvanized sheet steel with equal coating and steel thickness exposed to the same atmospheric environment.
Key words: Galvanizing; Galvalume®; Corrosion; Coated sheet steel.

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[2] *Commercial Manager L.A. – BIEC Ineternational Inc. / USA*
[3] *Research and Product Engineer – CSN / Brazil*

1. WHAT IS 55%AL-ZN COATED SHEET STEEL?

55%Al-Zn coated sheet steel is a light-gauge (0.25 to 1.55 mm thick) corrosion resistant steel sheet produced in the form of coils up to 1,600 mm wide and weighing as much 25 tons each. Cold-rolled sheet steel is coil coated with an alloy of aluminum and zinc instead of pure zinc, as applied to traditional galvanized sheet steel. The result is a coating that offers significantly more corrosion protection of the steel than the pure zinc coating of hot-dip galvanized sheet. Conservatively, in most environments, this means 4 to 6 times longer protection before corrosion visibly attacks with red rust the steel sheet substrate.

By weight, the coating alloy composition is 55% aluminum, 43.5% zinc and 1.5% silicon. Given that the density of aluminum is only 38.5% the density of zinc, the coating is composed on a volume basis mainly of aluminum (75%). This gives 55%Al-Zn sheet steel its highly reflective bright appearance with a unique shiny white spangle.

The product was originally developed at the Homer Labs of Bethlehem Steel Corporation in the 1960's. The company searched for a metal coating that offers both a strong and stable barrier protection, as found with aluminum-coated steel sheet, and a sufficiently strong galvanic protection, as offered by zinc-coated (galvanized) sheet, to protect the steel when the barrier is damaged by cuts and scratches.

In the mid 1970's, Bethlehem Steel began licensing the technology for producing 55%Al-Zn sheet steel, first in Australia and then worldwide through Bethlehem International Engineering Corporation (BIEC). Today, the product, which is generically known as 55%Al-Zn sheet steel, is marketed by over 40 licensees under various trade names such as: Galvalume®, Aluzinc®, Algafort®, Zalutite®, Zincalume®, Zincalit®. CSN began producing the product in Curitiba in May 2003 as BIEC's first licensee in Brazil.

While much of 55%Al-Zn sheet steel is used bare, that is, without an additional color coating, a large portion is marketed today as pre-painted coils with innovative and lasting colors of organic paint. Although this is done primarily for architectural reasons, the additional coating of paint adds protection to the metal coating and the steel sheet.

2. WHERE IS 55%AL-ZN SHEET STEEL USED? [5,6]

55%Al-Zn sheet steel is used in the construction, appliance manufacturing, and other industries for cladding and structural purposes.

2.1 Construction Industry:

By far, the principal user of 55%Al-Zn sheet steel is the construction industry where it is used mainly in the form of long, roll-formed panels for roofing and siding of buildings. This represents about 75% of all consumption of 55%Al-Zn sheet steel. Large industrial and commercial sector buildings, such as factories, shopping centers, distribution warehouses, and hangars, use the largest share of production. However, the use for residential construction is also growing with innovative designs of roof panels and tiles with long-lasting colors.

The growth of 55%Al-Zn sheet steel in construction is accelerated as more and more architects discover the unique possibilities of creating innovative design effects with the unique properties of steel sheet. This construction material offers the highest strength to weight ratio of all common and cost-effective building materials. Furthermore, the vastly improved metal and organic coatings recently developed to protect steel from corrosion have given confidence to architects and builders that steel sheet can be used reliably without fear of premature corrosion. Architects everywhere are now increasingly learning how to handle effectively and trust the properties of steel as a versatile and durable aesthetic building material while exposed to atmospheric elements.

Most of the tonnage of 55%Al-Zn sheet steel is presently consumed for cladding of buildings such as roofing and siding. However, an increasing portion of the production also goes to producing roll-formed structural elements such as studs and beams, often replacing lumber. Another significant application is for insulated sandwich panels used to insulate buildings in hot or cold climates. Other construction uses include cladding of mobile homes, heating and air conditioning ducts and pipes, highway signs, fences, garage doors, frames for doors and windows, interior dividers, electrical distribution trays and panels, and cladding of insulation material for heated or cooled vessels and pipes.

A good portion of 55%Al-Zn sheet steel is also consumed for farm buildings, machines and equipment in the agricultural sector. This includes silos, barns and sheds, water tanks, heating and drying equipment, and components of farming equipment. Roofing and siding for buildings used for animal confinement (chicken, pigs and cattle) are often used but are economical only when properly designed with adequate ventilation of the corrosive fumes produced by the confined animals. Another word of caution in the use of 55%Al-Zn sheet steel is to avoid the contact of the coating with wet alkaline substances such as wet concrete and alkaline soil. Such materials tend to attack the aluminum in the 55%Al-Zn sheet steel coating and thus limit the corrosion protection of the steel. In such cases it may be preferable to use plain galvanized steel.

2.2 Appliance Manufacturing Industry:

The second largest use of 55%Al-Zn sheet steel is in the appliance manufacturing industry. This industry uses about 15% of all 55%Al-Zn sheet steel production. Most of this tonnage is used for large items such as refrigerators, laundry equipment (washers and dryers), stoves and water heaters. This industry uses almost exclusively pre-painted material, often without any further painting requirement. Some 55%Al-Zn sheet steel is also used in small appliances such as toasters, light fixtures and housing of electrical equipment such as audio and video equipment, and computers.

2.3 Other Industry Applications:

55%Al-Zn sheet steel is also used in other manufacturing industries such as the transportation, agricultural, electrical, heating and air conditioning sectors. This consumes about 10% of the production of 55%Al-Zn sheet steel.

The transportation sector has successfully used 55%Al-Zn sheet steel for components inside and under the hood of trucks, buses, and cars as well as for other vehicles. This includes coated sheet steel used for floors, seats, heat shields, clamps, and mufflers for vehicles. In Sweden, a military truck cab was built with 55%Al-Zn sheet steel. Another use has been for trailers and containers.

3. HOW IS 55%AL-ZN SHEET STEEL PRODUCED? [1,2,3,4,8]

55%Al-Zn sheet steel is produced with continuous hot-dip coating lines similar to the coating lines used for producing hot-dip galvanized sheet. The principal differences are:

- more intensive cleaning of the incoming strip,
- modified speed and temperatures in the annealing furnace,
- a ceramic, induction-heated pre-melt pot,
- a ceramic, induction-heated main coating pot,
- modified wiping speed and quality
- accelerated cooling of the coated strip,
- modified strip surface and chemical treatments;

everything else on the coating line is more or less the same.

4. HOW MUCH HAS BEEN PRODUCED WORLDWIDE?

By 1972, many years of intensive research and performance evaluations with accelerated laboratory tests and outdoor exposure test sites left no doubt about the amazing corrosion protection advantage of 55%Al-Zn sheet steel. It had proved to be many times superior to plain galvanized sheet steel, and Bethlehem Steel's management considered it an extraordinary technology breakthrough and unique market advantage over its competitors. The company projected a huge market potential and planned to exploit this exclusive advantage by Bethlehem alone.

The production of 55%Al-Zn sheet steel began at Bethlehem Steel's Sparrows Point plant in Baltimore, MD / USA in 1972. Despite the clear technological advantage of the product and lofty sales predictions, the market did not respond as expected. After four years of production and intensive sales efforts, Bethlehem shipped cumulatively only 138,000 metric tons (Mt), and annual shipments actually fell in 1975 to a paltry 18,000 Mt. Clearly, mayor potential consumers were reluctant to commit their production processes to a new product while depending on only one worldwide supplier. It did not matter how well they actually understood the technical advantages of 55%Al-Zn sheet steel.

This situation made It clear that the North American market would not take off as lofty as expected until several competing producers would offer the product to their customers. Some Bethlehem managers saw clearly the need of

sharing and licensing the technology to competing producers and others did not. Eventually, in 1975, the debate culminated in a reluctant agreement to license the technology to John Lysaght of Australia who shared the vision of the great potential of 55%Al-Zn sheet steel for his country. Bethlehem's managers opposed to licensing saw no threat to their North American market from a producer on the other side of the world.

John Lysaght had nearly monopoly power of galvanized sheet production in Australia, and he mounted an aggressive marketing campaign to convert the Australian galvanized sheet market to 55%Al-Zn sheet steel. He widely taught architects and trained workers how to work with the new product, and he broadly promoted a good understanding of the extraordinary corrosion protection advantages of 55%Al-Zn sheet steel when compared with traditional galvanized sheet. Then he sold both 55%Al-Zn sheet steel and galvanized sheet with the same coating thickness at the same price per square meter and left the obvious choice to the consumer of what they should buy. The market response was extraordinary. By 1980, after only five years of production, John Lysaght was already selling 260,000 Mt of 55%Al-Zn sheet steel per year in Australia while steadily growing. This was 2.2 times the annual shipments then made by Bethlehem Steel on the North American market. John Lysaght was well on his way of converting the Australian coated sheet market to 55%Al-Zn sheet steel.

Meanwhile, in Bethlehem, by 1980, the evidence of the advantage of technology licensing kept mounting. The company formed Bethlehem International Engineering Corporation (BIEC) to sell Bethlehem Steel's engineering expertise and technologies worldwide. Soon, several licensing agreements were reached with European and North American steel producers, and the market started to grow at a faster pace while benefiting all producers involved. By 1985, about 6 Million Mt of 55%Al-Zn sheet steel had been shipped worldwide.

In 1986, Bethlehem Steel sold all the technology-licensing rights for 55%Al-Zn sheet steel to BHP of Australia, which had meanwhile acquired John Lysaght's coating business. BIEC became thus a subsidiary company of BHP Steel and later of BlueScope Steel under the name of BIEC International Inc. The company eventually changed its headquarters from Pennsylvania to Washington State on the US West Coast, which is closer to Australia. Today, in 2006, BIEC international Inc. has sold 48 licenses on all continents, and worldwide cumulative shipments of 55%Al-Zn sheet steel have reached 70 Million Mt. The current worldwide annual production has reached 6 million metric tons per year. In Japan alone, seven licenses have been sold to producers in that relatively small country.

5. WHY IS 55%AL-ZN SHEET STEEL GROWING SO FAST? [6,7,8]

There are many reasons why 55%Al-Zn sheet steel is one of the fastest growing steel products worldwide. The main advantage, of course, is its outstanding long-term corrosion protection. However, it is also easily formed for diverse construction purposes and it offers energy conservation possibilities -- all at a competitive cost. The combination of these factors is encouraging architects to be increasingly confident in specifying steel and 55%Al-Zn sheet steel as part of their creative expressions for industrial, commercial and

residential buildings. Similar reasons apply to the use of the product in other industries such as appliances, automotive parts, and agricultural applications.

5.1 Outstanding Long-Term Corrosion Protection [5,8]

When talking about corrosion protection of steel sheet, there are two issues to consider: (1) surface protection and (2) edge protection.

5.1.1 Surface Protection

The 55%Al-Zn sheet steel coating offers a long-lasting and stable barrier that protects the steel sheet from corrosive elements. This is similar to the excellent barrier protection offered by an aluminum coating. As mentioned earlier, the coating volume of 55%Al-Zn sheet steel is composed 75% of aluminum with zinc-rich regions imbedded and well dispersed throughout the coating. Most of the zinc is locked in and held in reserve, surrounded by solid and stable aluminum. This protects the locked-in zinc from reacting with the environment until the moment that these pockets of zinc are exposed because of some cut or scratch of the coating. It is then that the newly exposed zinc held in reserve springs into action to provide its remarkable galvanic protection to the suddenly exposed steel sheet substrate.

The aluminum-rich surface of the coating reacts with the corrosive elements of the environment and forms a solid and stable film that protects the aluminum below from further corrosion. Meanwhile, the small zinc-rich areas on the surface of the coating react with the environment yielding a powdery zinc corrosion residue. This residue may be blown or washed away by wind and rain but often remains locked in the small crevices left by the unprotected and vanishing surface pockets of zinc. The effect of these locked-in, or trapped, residues of zinc has the benefit of providing some additional protection to the coating of 55%Al-Zn sheet steel.

On the other hand, plain galvanized sheet coating is composed only of zinc. This also offers an excellent barrier protecting the steel from the corrosive elements of the environment. If a cut or scratch damages the coating, there is an ample supply of zinc to galvanically protect the steel as long as some zinc coating is left on the surface. The problem is that this wonderful zinc barrier continuously shrinks proportional to time. All the zinc on the surface is always exposed reacting with the corrosive elements of the environment. The powdery corrosion residues of zinc's reaction with the environment are soluble and blown or washed away with wind and rain. Hence, the zinc's coating thickness is continuously reduced at a speed that depends on the severity of the corrosive elements in the environment. Eventually, the never perfectly even zinc coating is nearly gone and red rust spots begin to appear on the surface of the steel sheet.

This difference in the surface protection performance of the coatings explains why 55%Al-Zn sheet steel last so much longer than plain galvanized sheet with equal coating thickness before red rust appears. Saying that it lasts 4 to 6 times longer is quite conservative as clearly demonstrated with laboratory tests sites around the world and inspections of roofs still going strong after over 30 years of exposure.

5.1.2 Edge Protection

When sheet steel is cut, it leaves the edges of steel exposed without the protection of a coating barrier. This happens at the drip edge of a roof or the bottom of siding made with coated sheet steel. Unless such edges are protected after the cut with some paint or otherwise, the steel edge exposure leads to the onset of edge corrosion. This is particularly troublesome and unsightly with metal-coated sheet painted with a beautiful color of organic paint. The edge corrosion products expand and lift the film of organic paint and expose a ragged edge of corroding sheet steel. Even though this may only be a few millimeters, it is still cause for concern to architects and builders.

With galvanized sheet, the onset of edge corrosion is initially a bit delayed as the plentiful availability of adjacent zinc coating protects the steel with its beneficial galvanic reaction. However, as the zinc is consumed with its sacrificial reaction of protecting the steel, there is no further protection left to stem the advance of the edge corrosion. The powdery corrosion residues of zinc are blown or washed away by wind and rain leaving ever more steel edge exposed for further corrosion.

With 55%Al-Zn sheet steel, the onset of edge corrosion happens a bit sooner because there is less zinc available adjacent to the cut to protect the steel through sacrificial galvanic reaction. However, the progression of the edge corrosion is soon arrested because of the solid and stable aluminum structure of the coating, which is eventually left with holes and crevices of consumed zinc on the surface of the cut, looking like a Swiss cheese. Again, some of the corrosion residues of zinc get locked in, or trapped, in these crevices, which has the beneficial effect of further arresting the progression of edge corrosion of 55%Al-Zn sheet steel.

This insight and experience with edge corrosion, shows that cut 55%Al-Zn sheet steel performs in the long run better than plain galvanized sheet. In the beginning of the process it may appear that 55%Al-Zn sheet steel offers less protection than galvanized sheet. However, it soon becomes evident that the progression of “edge creep” is arrested with 55%Al-Zn sheet steel while it continues steadily with plain galvanized sheet. This is an important understanding to justify the assertion that pre-painted 55%Al-Zn sheet steel offers better edge protection than pre-painted galvanized sheet.

5.2 Economic Advantages of 55%Al-Zn Sheet Steel [5]

The production of 55%Al-Zn sheet steel offers two distinct economic advantages compared with the production of galvanized sheet. One advantage is the revenue advantage and the other is the cost advantage.

5.2.1 The Revenue Advantage

A ton of 55%Al-Zn sheet steel, by virtue of its lighter coating with aluminum, has the property of yielding more square meters than galvanized sheet with equal coating thickness. Hence, if the producer sells 55%Al-Zn sheet steel at the same price per square meter than galvanized sheet, he will be able to collect more revenue per ton. For instance, for a 0.45 mm thick-coated sheet this amounts to 4.0% more revenue per ton.

5.2.2 The Cost Advantage

Depending on the prices of aluminum and zinc, the producer of 55%Al-Zn sheet steel may also enjoy a cost advantage. A rough rule of thumb has been that when the price of a Kg of aluminum is not more than 1.8 times the price of zinc, there exists a production cost advantage for producing 55%Al-Zn sheet steel. The reason is that a 0.02 mm coating on both sides of a square meter of 55%Al-Zn sheet steel requires 82.5 grams of aluminum and 65.2 grams of zinc. This is the result of considering the difference in densities of the coating metals. Meanwhile, a square meter of galvanized sheet with equal coating thickness requires 285 grams of zinc. Hence, on a square meter basis, the price of aluminum could be as much as 2.65 times the price of zinc to yield the same coating cost per square meter.

On a cost per ton basis, the calculation is a bit more complex because a ton of 55%Al-Zn sheet steel has more square meters and more cost of steel. Also the operating costs of coating 55%Al-Zn sheet steel are slightly higher than producing galvanized sheet, mainly because of higher energy costs. Nevertheless, there has historically been a slight cost advantage per ton for most producers making 55%Al-Zn sheet steel instead of making galvanized sheet with equal coating thickness.

The traditional price relationship between aluminum and zinc has been that aluminum prices per Kg were typically about 1.5 times higher than zinc. Today this relationship has been reversed to a point where a Kg of zinc actually commands a higher price than aluminum. The cost advantage per ton of making 55%Al-Zn sheet steel has thus become ever more interesting.

These revenue and costs advantages of producing 55%Al-Zn sheet steel provide an important incentive to producers for increasing their production of 55%Al-Zn sheet steel. Moreover, the economic advantages above discussed are more significant as the average gauge of the sheet steel is further reduced with improved steel-making technologies. This is another important reason why 55%Al-Zn sheet steel is one of the fastest growing steel products.

5.3 Less Use of Increasingly Scarce and Costly Zinc

Zinc is becoming an ever more scarce commodity as consumption rises and less is produced because of a decreasing world-wide availability of economical zinc deposits and increasing environmental concerns for mining and refining zinc. The recent high prices of zinc reflect this development and predictions abound of an increasing “zinc gap” that will make it ever more costly to use zinc in the construction industry. 55%Al-Zn sheet steel uses 77% less zinc per square meter than galvanized sheet with equal coating thickness while providing at the same time significantly more corrosion protection. This fact will have a significant impact on accelerating the future growth of production of 55%Al-Zn sheet steel. The recent high price per Kg of zinc, being actually higher than a Kg of aluminum, has led to an increasing interest worldwide for new plants to produce 55%Al-Zn sheet steel.

5.4 Steel is Becoming a Preferred Construction Material

Construction with steel is increasing worldwide as architects and builders discover the economic and technical advantages of using this material. With

the problem of adequate corrosion protection largely solved, builders are increasingly developing innovative ways, tools and machinery for using the advantages and flexibility of steel for construction. Here are some of the reasons for this trend.

5.4.1 High Strength to Weight Ratio of Steel

The high strength to weight ratio of steel sheet contributes to the current growth of architects discovering the advantages of building with coated steel. There is no other economical building material available that offers such an architectural advantage. While this applies to all steel products, the outstanding corrosion protection of 55%Al-Zn sheet steel makes it ever more attractive for architects to confidently use steel in their designs.

5.4.2 Easy Formability of Steel into Architecturally Pleasing Shapes

Sheet steel can be easily formed into all sorts of architecturally pleasing shapes and new tools and machines to do so are constantly being developed as more steel buildings are built. The improvements of stationary and mobile roll formers have been an important development for creative designs of panels for roofs and sidings. So have stamping and bending tools and machines for creating panels simulating different shapes such as terracotta roof tiles. These developments are an important contributor to the remarkable worldwide growth of building with sheet steel.

5.4.3 Steel is an Environmentally Friendly Material

Steel is inherently an environmentally friendly material as it eventually disintegrates with corrosion back to becoming part of iron oxide in the earth where it came from. With increasing concerns about environmental issues, more architects look favorably to the option of building with steel. This is and will be an important factor contributing to the growth of building with steel in general and with 55%Al-Zn sheet steel in particular.

5.4.4 Ease, Speed and Lower Cost of Construction with Steel

Building with steel also offers significant economic advantages during construction. Erection of the steel frames and panels is relatively easy, faster, and more labor cost efficient than building with other materials such as concrete. Many steel building components can be pre-fabricated and then erected on site.

5.5 Higher Temperature Resistance of 55%Al-Zn Sheet Steel [7]

The coating of 55%Al-Zn sheet steel has a much higher temperature resistance than the zinc coating of plain galvanized steel. The coating of 55%Al-Zn sheet steel retains its surface brilliance up to 320 ºC while galvanized sheet does it up to only 230 ºC. For this reason 55%Al-Zn sheet steel is used in high temperature sensitive applications of appliances such as stoves, dryers, toasters, and automotive heat shields and exhaust mufflers.

5.6 Higher Reflectivity of 55%Al-Zn Sheet Steel

The coating of bare 55%Al-Zn sheet steel is highly reflective, which has earned it an Energy Star rating in the USA. Federal, State and local US Government agencies are increasingly concerned with the environmental effects of heat islands in big cities and encourage the building with cool roofs. The reflective properties of solar radiation of 55%Al-Zn sheet steel yields a much cooler roof than other roofs. Cooler roofs reduce urban heat islands contributing to urban air pollution and reduce the energy required for cooling the interior of buildings. This environmental and energy conservation concern also contributes to the growth of building with 55%Al-Zn sheet steel.

6. CONCLUSION ABOUT THE FUTURE OF 55%AL-ZN SHEET STEEL?

For all the reasons above listed, 55%Al-Zn sheet steel is likely to have a bright future as several mega trends are working in its favor beside its own natural advantage of superior corrosion resistance. The developing “zinc gap” is likely to keep zinc prices high for the foreseeable future, which provides a significant economic advantage to both producers and consumers of 55%Al-Zn sheet steel. The trend of building with ever thinner steel sheet will also benefit the economic advantage of 55%Al-Zn sheet steel.
Furthermore, the use of steel in construction is likely to continue to increase as more architects become familiar with its possibilities. The development of improved tools and equipment for the building trade will further enhance this trend. Finally, the environmental and energy conservation concerns are also likely to intensify and benefit the use of 55%Al-Zn sheet steel.

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