CHEMICAL SPECIFICATIONS OF ZINC AND ZINC ALUMINUM ALLOYS: TABLE 1

PROPERTIES OF ZINC ALLOYS

The Mechanical and physical properties of the castings, and to a lesser extent their corrosion properties, are closely linked to the specific alloy type, the casting process and quality of the castings produced, the amount of aging or service life of the component and the level of impurities, amongst others. Both CU and MG increase strength properties, reduce ductility and inhibit intergranular corrosion. Iron is present as small $FeAl_3$ particles and does not influence mechanical properties unless it exceeds 0.1%. When limited to the specified amounts shown in ASTM B86 and B791, Pb, Sn, and Cd do not cause intergranular corrosion or the lowering of physical and mechanical properties. Higher levels of these impurities must be avoided. Other impurity elements, such as Cr, Ni, Mn, Th, In, Sb, As, Bi and Hg, do not normally occur in sufficient quantities in zinc casting alloys to be of concern.

TABLE 1

Chemical Specification (per ASTM) (% by Weight)														
	#3		#5		#7		#2		ZA-8		ZA-12		ZA-27	
	Ingot	Casting	Ingot	Casting	Ingot	Casting	Ingot	Casting	Ingot	Casting	Ingot	Casting	Ingot	Casting
Al	3.9-4.3	3.7-4.3	3.9-4.3	3.7-4.3	3.9-4.3	3.5-4.3	3.9-4.3	3.7-4.3	8.2-8.8	8.0-8.8	10.8-11.5	10.5-11.5	25.5-28.0	25.0-28.0
Mg	.03-.06	.02-.06	.03-.06	.02-.06	.01-.020	.005-.020	.025-.05	.020-.060	.020-.030	.010-.030	.020-.030	.010-.030	.012-.020	.010-.020
Cu	.10 max	.10 max	.70-1.10	.70-1.20	.10 max	.10 max	2.7-3.3	2.6-3.3	0.9-1.3	.8-1.3	0.5-1.2	0.5-1.2	2.0-2.5	2.0-2.5
Fe (max)	.035	.05	.035	.05	.075	.05	.075	.05	.065	.075	.05	.075	.070	.075
Pb (max)	.004	.005	.004	.005	.0030	.003	.004	.005	.005	.006	.005	.006	.005	.006
Cd (max)	.004	.004	.003	.002	.0020	.002	. 003	.003	.005	.003	.005	.003	.005	.003
Sn (max)	.002	.002	.0015	.002	.0010	.001	.001	.002	.002	.003	.002	.003	.002	.003
Ni (other)x^{10}	-	-	-	-	.005-.020	.005-.020	-	-	-	-	-	-	-	-
Zn	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.

CORROSION RESISTANCE

All zinc – based alloys have excellent resistance to corrosion in a variety of environments. In general terms, the presence of aluminum in the alloys enhances the well-known corrosion resistance of zinc, which is the main constituent of the alloys.

Many trials with the family of ZA alloys in particular were made in those environments where engineers requested specific data. Accelerated test results provide guidelines for assessing probable performance in other solutions or environments. Where specific data on Zamak alloys is lacking, information on the corrosion properties of Special High Grade Zinc (99.99% pure) is provided as a guideline of the likely performance of Zamak alloy castings.

SALT ENVIRONMENTS

The relative corrosion behavior of ZA-8, ZA-12, ZA-27 and No.3 alloy in salt spray test, as compared to that of pure zinc and 380-aluminum alloy, is given in Figure 1. This chart should be used for comparison purposes only between the various alloys shown, as salt spray life has no direct relation to any actual physical environment. For aluminum levels of up to 12%, the zinc based alloys perform as well as of slightly better than pure zinc. Because of its higher aluminum level, ZA-27 behaves more like an aluminum alloy.

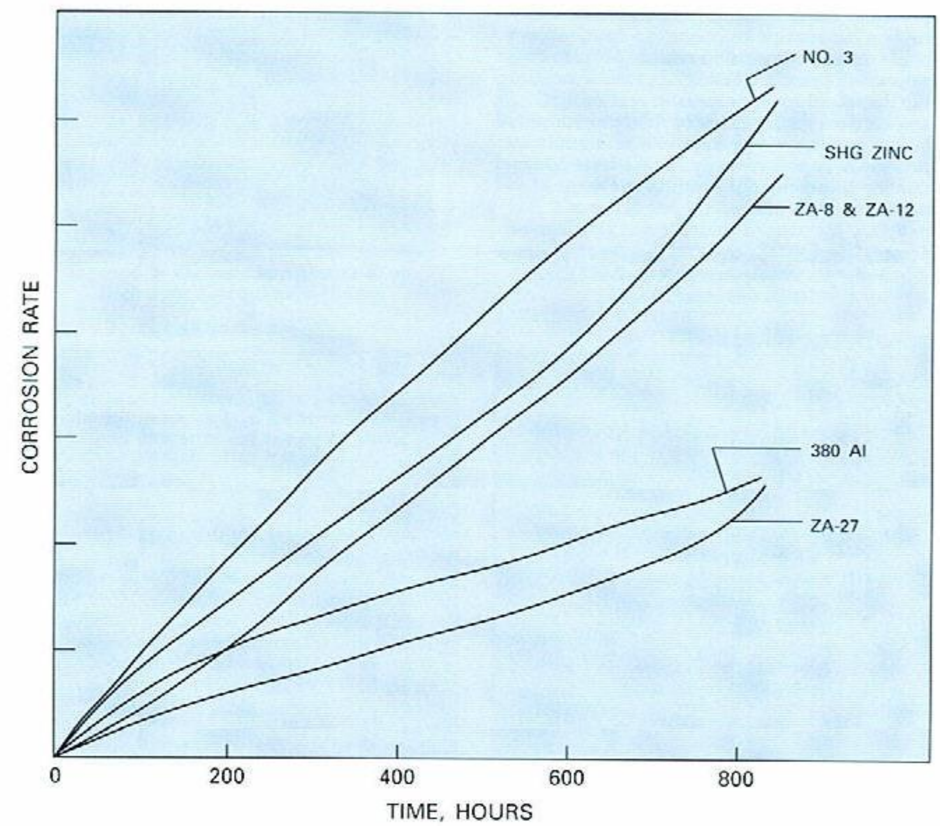

FIGURE 1

Relative corrosion rates in salt spray testing (ASTM B-117) of No. 3 (pressure die cast), ZA-8, ZA-12 and ZA-27 (permanent mould cast) in comparison to pure zinc and A380 (pressure die cast).

EFFECT of pH

Figure 2 shows the effect of pH on the corrosion rates of ZA-27 in relation to zinc and aluminum. In mild acidic solutions (pH range of 4.0 to 7.0), the ZA alloys are more corrosion resistant than SHG zinc or the Zamak alloys, with the ZA-27 alloy performing better that ZA-8 and ZA-12 due to its higher aluminum content. In alkaline solutions the ZA-27 alloy begins to corrode significantly as the pH of the solution approaches 12.0. The performance of the Zamak alloys approximates that of SHG zinc. A preferential attack of the zinc-rich phase occurs in acidic solutions while the aluminum-rich phase is preferentially attacked in highly alkaline solutions.

The practical pH range of applications for zinc alloys lies between 5 and 11.5. *It is important to note that this data was generated in distilled water and that the performance under scale-forming conditions may widen this application range of pH.*

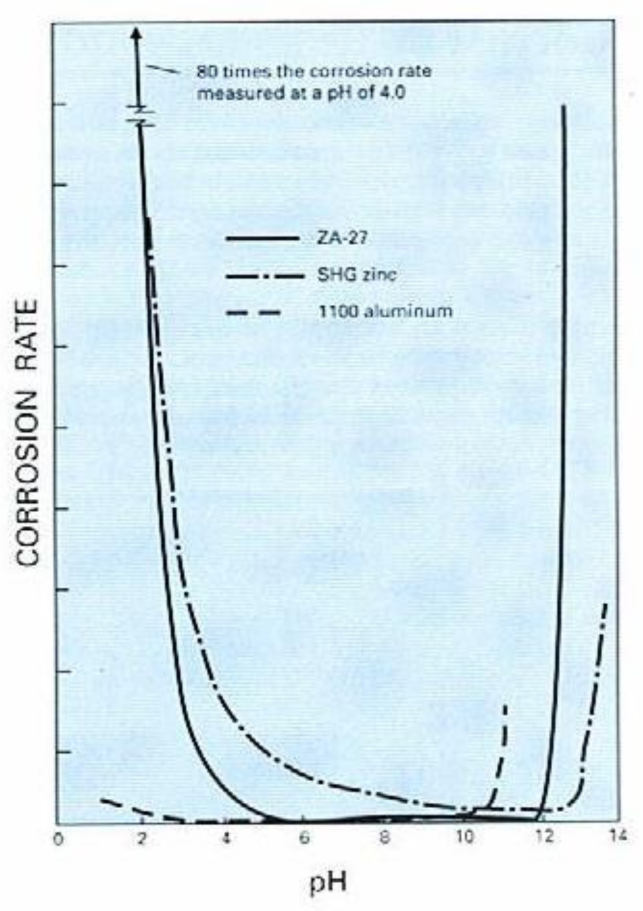

FIGURE 2

Corrosion rates in an aerated aqueous solution as a function of pH at ambient temperature. Based on immersion exposure ranging from 4 to 15 days.

CORROSION RESISTANCE IN WATER

Tap and Fresh Water

COLD: While the overall corrosion rate is low, the most important factor is the hardness of the water (whether of not the water is scale-forming). Corrosion rates are the lowest in hard waters, as low as 1.5 µm/year (.06 mil/year), because hard water deposits a protective scale on the metallic surface. Corrosion rates as high as 15µm/year (.6 mil/year) are possible in soft water.

As with other common metals, the corrosion rate of zinc increases with the aeration of the water. Dissolved oxygen and carbon dioxide both increase the rate of attack.

HOT: The corrosion rate of zinc is higher in hot water. In hard waters the scale, which forms at “hot” water temperatures in the range of 50^0 to 70^0 C, has a course-grained structure with less adhesion to the zinc surface. In this temperature range, corrosion rates are greater than that experienced at room temperature, or at temperatures closer to the boiling point (Figure 3). Therefore, caution should be exercised for applications involving prolonged exposure to “hot” waters, which do not contain suitable inhibitors. It should be noted, however, that numerous examples of successful applications of zinc alloys in contact with warm or hot water are documented.

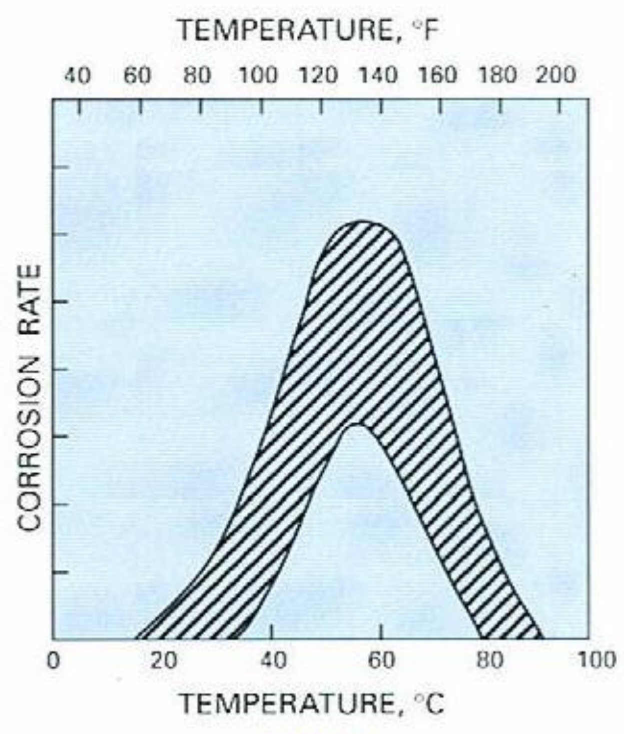

FIGURE 3

Effect of temperature on the corrosion rates of zinc alloys immersed in tap water.

GALVANIC CORROSION

Galvanic corrosion is a phenomenon that occurs when two different metals are in contact with each other in the presence of an electrolyte such as salt water. A current will be generated flowing from the anodic or baser metal to the cathodic or nobler metals. In essence the anodic material will actually plate itself on the cathode.

Galvanic corrosion can occur in some cases, even when dissimilar metals, which are not in direct contact, are connected by a common electrolyte. The severity of the galvanic corrosion is proportional to the conductivity of the electrolyte.

Exposure trials showed no significant galvanic corrosion attack after five years of atmospheric exposure on ZA alloys coupled to engineering metals such as copper, lead and mild steel. Zamak alloys would be expected to behave similarly.

Table 2 is a useful guide for assessing likely galvanic corrosion when coupled with a variety of metals and alloys.

Another factor, which affects the rate of galvanic corrosion, is the proportional size of the anodic and cathodic materials. The worst conditions usually occur when a small anode is connected (physically or electrolytically) to a large cathode. For example, zinc bolts on a submerged, steel oil drilling platform will quickly corrode, as the zinc will attempt to galvanize the steel structure. Although not feasible for other reasons, steel bolts on a zinc oil-drilling platform would present a problem, as a sufficient quantity of zinc is present to plate the steel bolts without affecting the integrity of the structure.

Galvanic corrosion can be prevented by:

1. Insulating the dissimilar metals from contacting each other, by use of a non-conductive gasket material.
2. Breaking the electrolytic path between the two metals if they are not connected physically, by coating the components with a non-conductive finish.

INTERGRANULAR CORROSION

The introduction of 99.99% pure zinc (SHG – Special High Grade) as the base for zinc-aluminum casting alloys, effectively and completely eliminated intergranular corrosion under normal service conditions. However, intergranular corrosion can still occur under wet or damp conditions if zinc-aluminum alloys are exposed to temperatures above about 700C (1580F). When present above normal specification levels, Sn, Pb, In, Cd, Bi, Hg, and Th can promote intergranular corrosion, so every effort must be made to ensure that all zinc castings meet the appropriate ASTM standard. Copper and Magnesium are present in the alloys to help prevent intergranular corrosion. Zamak 7 is not recommended in hot and humid environments due to low quantities of CU and mg present in this alloy.

Impact strength can decrease though intergranular corrosion. At 60^0C (140^0F) in high humidity, the loss of impact strength is modest. At 95^0C (203^0F) in high humidity, intergranular attack is ten times greater and a significant loss of impact strength is possible.

In practice, caution should be exercised in the use of Zamak and ZA alloys in humid environments above 70^0C (158^0F) and impurities must be controlled to within specified limits. When in doubt, tests should always be conducted.

Lead, Cadmium, and tin at levels exceeding the limits shown in Table 1 can cause die cast parts to swell, crack, or distort. These defects can occur within 1 year. The maximum limit for lead, which can promote the occurrence of subsurface network corrosion, is 0.006%. Cadmium is detrimental in its effect at some concentrations and is neutral at others. As such, the maximum limit for cadmium is set at 0.005%. Tin, like lead, can promote subsurface network corrosion, and therefore is also restricted to the maximum safe limits of 0.005%.

Some tests such as those by ASTM (1961) have, measured loss of strength with time; both AG41A and AG40A were tested, and between 10 and 20 years of exposure, impact strength decreased rapidly for total losses of 78 and 69% respectively, in the outdoor industrial atmosphere and 33 and 38% in the outdoor rural atmosphere. Indoors, AC41A lost 52% (unlike AG40A, which remained unchanged). These decreases in mechanical properties were probably caused by Intergranular corrosion, to which die casting alloys produced 50 years or more ago were often very susceptible. Intergranular attack can reduce cross-sectional areas and create stress, raising notches, while not reducing the overall specimen dimensions.

When certain impurities are present and segregate to give phases that are very different electrochemically, corrosion will proceed rapidly along the boundaries of the phases. Cadmium, tin, lead, indium, and thallium are among the impurities that can be present unless controlled and are particularly harmful, but iron and nickel also must be controlled at low levels. Magnesium additions were developed early on as a beneficial addition for casting alloys, although other additions can be used; for example, the 5% aluminum alloy used for coating steel contains cerium and lanthanum.

Early die casters had great problems in avoiding brittle castings until the cause of this defect was determined. Nowadays, the regular production of 99.99+ % zinc gives die casters a good starting point, but to ensure that there is no pick up of impurities, they must still practice very good housekeeping and avoid metal purchases from unknown or less reputable sources. The current high purities of zinc used to make alloys have also enabled the magnesium content of the alloys to be reduced to about 0.04% while still preventing hot shortness of the alloys.

When zinc castings are to be installed permanently out of doors, a protective coating (e.g., paint or powder coating) should be applied to maintain appearance. Chromating prevents white corrosion products from forming in storage or in mild condensation conditions, but it is not sufficient to prevent loss of good appearance due to corrosion in long-term exposure. Anodizing is very effective in marine conditions, including seawater immersion.

NOTE:

Allied Metal Company buys and uses only LME approved sources of SHG zinc for the manufacturing and production of Zamak and ZA alloys. All chemistry and specification parameters for these alloys meet ASTM B240-13 “Standard Specification for Zinc and Zinc-Aluminum (ZA) alloys in INGOT form for Foundry and Die Castings.

SOURCE:

Noranda Zinc Market Development
Toronto, Ontario, Canada
"Designing Zinc Casting for Corrosion Resistance"

ILZRO – International Lead Zinc Research Organization
Research Triangle Park, North Carolina
"Corrosion Resistance of Zinc and Zinc Alloys"
Frank C. Porter

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TABLE 2

Additional Corrosion of Zinc and Zinc Base Alloys Resulting from Contact with Other Metals or Carbon

Metal in contact	Environment: Atmospheric – Rural	Atmospheric – Industrial/urban	Atmospheric – Marine	Immersed – Fresh water	Immersed – Sea water
Aluminum and aluminum alloys	0	0 to 1	0 to 1	1	1 to 2
Aluminum bronzes and silicon bronzes	0 to 1	1	1 to 2	1 to 2	2 to 3
Brasses including high tensile (HT) brass (manganese bronze)	0 to 1	1	0 to 2	1 to 2	2 to 3
Cadmium	0	0	0	0	0
Carbon	0 to 1	1	1 to 2	0 to 2	2 to 3
Cast irons	0 to 1	1	1 to 2	1 to 2	2 to 3
Cast iron (austenitic)	0 to 1	1	1 to 2	1 to 2	1 to 3
Chromium	0 to 1	1 to 2	1 to 2	1 to 2	2 to 3
Copper	0 to 1	1 to 2	1 to 2	1 to 2	2 to 3
Cupro-nickels	0 to 1	0 to 1	1 to 2	1 to 2	2 to 3
Gold	(0 to 1)	(1 to 2)	(1 to 2)	(1 to 2)	(2 to 3)
Gunmetals, phosphor bronzes and tin bronzes	0 to 1	1	1 to 2	1 to 2	2 to 3
Lead	0	0 to 1	0 to 1	0 to 2	(0 to 2)
Magnesium and magnesium alloys	0	0	0	0	0
Nickel	0 to 1	1	1 to 2	1 to 2	2 to 3
Nickel copper alloys	0 to 1	1	1 to 2	1 to 2	2 to 3
Nickel-chromium-iron alloys	(0 to 1)	(1)	(1 to 2)	(1 to 2)	(1 to 3)
Nickel-chromium-molybdenum alloys	(0 to 1)	(1)	(1 to 2)	(1 to 2)	(1 to 3)
Nickel silvers	0 to 1	1	1 to 2	1 to 2	1 to 3
Platinum	(0 to 1)	(1 to 2)	(1 to 2)	(1 to 2)	(2 to 3)
Rhodium	(0 to 1)	(1 to 2)	(1 to 2)	(1 to 2)	(2 to 3)
Silver	(0 to 1)	(1 to 2)	(1 to 2)	(1 to 2)	(2 to 3)
Solders hard	0 to 1	1	1 to 2	1 to 2	2 to 3
Solders soft	0	0	0	0	0
Stainless steel (austenitic and other grades containing approximately 18% chromium)	0 to 1	0 to 1	0 to 1	0 to 2	1 to 2
Stainless steel (martensitic grades containing approximately 13% chromium)	0 to 1	0 to 1	0 to 1	0 to 2	1 to 2
Steels (carbon and low alloy)	0 to 1	1	1 to 2	1 to 2	1 to 2
Tin	0	0 to 1	1	1	1 to 2
Titanium and titanium alloys	(0 to 1)	(1)	(1 to 2)	(0 to 2)	(1 to 3)
Zinc and zinc base alloys	0	0	0	0	0

Key

0 Zinc and zinc base alloys will suffer either no additional corrosion, or at the most only very slight additional corrosion, usually tolerable in service.

1 Zinc and zinc base alloys will suffer slight or moderate additional corrosion which may be tolerable in some circumstances.

2 Zinc and zinc base alloys may suffer fairly severe additional corrosion and protective measures will usually be necessary.

3 Zinc and zinc base alloys may suffer severe additional corrosion and the contact should be avoided.

General notes: Ratings in brackets are based on very limited evidence and hence are less certain than other values shown.

The table is in terms of *additional corrosion* and the symbol 0 should not be taken to imply that the metals in contact need no protection under all conditions of exposure.

*Zinc is frequently used as a sacrificial coating on other metals. Additional corrosion will reduce the life of the coating.