English version

ULTIMHEAT® MUSEUM

Jacques Jumeau

Technology of components used in heating.

Chapter 21

Corrosion resistance of aluminum enclosures

	Pt (Platinum/ Platine)	Au (Gold/ Or)	Ti (Titanium / Titane)	AISI 316L(passive/passif)	Ag (Silver/ Argent)	Ni (Nickel/ Nickel)	Ni Cu 30 (Monel 400)	NiCr15 Fe8 (Inconel 600)	Cu55 Zn23 Ni22 (Arcap)	Cu (Copper/ Cuivre)	Al10 Sn66 Pb34	Cu Zn34 (Brass/ Laiton)	Cu88 Sn12 (Bronze)	Sn (Tin/ Etain)	Pb (Lead / Plomb)	Al Cu Mg1(Duralumin)	Mild steel / Acier doux)	Al Si 10Mg (Alpax H)	Al 99.5 (Aluminum)	Hard steel/ Acier dur	Al Mg5 (Duralinox)	ADC12 (Aluminum alloy)	Cd (Cadmium/ Cadmium)	Fe (Steel / Fer)	Cr (Chromium/ Chrome)	Al Mg Si0.7 (Almasilium)	Sn75 Zn25	Zn (Zinc/ Zinc)	Al PVD (Physical vapor deposition)	Mg (Magnesium)
Pt (Platinum/ Platine)	0	130	250	250	350	430	430	430	450	570	600	650	770	800	840	940	1000	1065	1090	1095	1100	1100	1100	1105	1200	1200	1350	1400	1400	1900
Au (Gold/ Or)	130	0	110	110	220	300	300	300	320	410	470	520	610	670	710	810	870	935	960	965	970	970	970	975	1070	1070	1230	1270	1270	1820
Ti (Titanium / Titane)	250	110	0	0	110	180	180	180	200	320	350	400	520	550	590	690	750	815	840	845	850	850	850	855	950	950	1100	1150	1150	1700
AISI 316L(passive/passif)	250	110	0	0	110	180	180	180	200	320	350	400	520	550	590	690	750	815	840	845	850	850	850	855	950	950	1100	1150	1150	1700
Ag (Silver/ Argent)	350	220	100	100	0	80	80	80	100	220	250	300	420	450	490	590	650	715	740	745	750	750	750	755	850	850	1010	1050	1050	1600
Ni (Nickel/ Nickel)	430	300	180	180	80	0	0	0	20	110	170	220	340	370	410	510	570	635	660	665	670	670	670	675	770	770	930	970	970	1520
Ni Cu 30 (Monel 400)	430	300	180	180	80	0	0	0	20	110	170	220	340	370	410	510	570	635	660	665	670	670	670	675	770	770	930	970	970	1520
NiCr15 Fe8 (Inconel 600)	430	300	180	180	80	0	0	0	20	110	170	220	340	370	410	510	570	635	660	665	670	670	670	675	770	770	930	970	970	1520
Cu55 Zn23 Ni22 (Arcap)	450	320	200	200	100	20	20	20	0	120	150	200	320	350	380	490	550	615	640	645	650	650	650	655	750	750	910	950	950	1500
Cu (Copper/ Cuivre)	570	440	320	320	220	140	140	140	120	0	30	80	200	230	270	370	430	495	520	525	530	530	530	535	630	630	780	830	830	1380
Al10 Sn66 Pb34	600	470	350	350	250	170	170	170	150	30	0	50	170	200	210	310	400	465	490	495	500	500	500	505	600	600	760	800	800	1350
Cu Zn34 (Brass/ Laiton)	650	520	400	400	300	220	220	220	200	80	50	0	120	150	190	290	350	415	410	445	450	450	450	455	550	550	710	750	750	1300
Cu88 Sn12 (Bronze)	770	640	520	520	420	340	340	340	320	200	170	120	0	30	70	170	230	295	320	325	330	330	330	335	430	430	590	630	630	1180
Sn (Tin/ Etain)	800	670	550	550	450	370	370	370	350	230	200	150	30	0	40	140	200	265	290	295	300	300	300	305	400	400	560	600	600	1150
Pb (Lead / Plomb)	840	710	590	590	490	410	410	410	380	270	240	190	70	40	0	100	160	225	250	255	260	260	260	265	360	360	520	660	560	1110
Al Cu Mg1(Duralumin)	940	810	690	690	590	510	510	510	490	370	340	290	170	140	100	0	60	125	150	155	160	160	160	165	260	260	420	560	560	1010
Mild steel / Acier doux)	1000	870	750	750	650	570	570	570	550	430	400	350	230	200	150	60	0	65	90	95	100	100	100	105	200	200	360	400	400	950
Al Si 10Mg (Alpax H)	1065	935	815	815	715	635	635	635	615	495	465	415	295	265	225	125	65	0	25	30	35	35	35	40	135	135	295	355	355	885
Al 99.5 (Aluminum)	1090	960	840	840	740	660	660	660	640	520	490	440	320	290	250	150	90	25	0	5	10	10	10	15	110	110	270	310	310	860
Hard steel/ Acier dur	1095	965	845	845	745	665	665	665	645	525	495	445	325	295	255	155	95	30	5	0	5	5	5	10	105	105	265	305	305	855
Al Mg5 (Duralinox)	1100	970	850	850	750	670	670	670	650	530	500	450	330	300	260	160	100	35	10	5	0	0	0	5	100	100	260	300	300	850
ADC12 (Aluminum alloy)	1100	970	850	850	750	670	670	670	650	530	500	450	330	300	260	160	100	35	10	5	0	0	0	5	100	100	260	300	300	850
Cd (Cadmium/ Cadmium	1100	970	850	850	750	670	670	670	650	530	500	450	330	300	260	160	100	35	10	5	0	0	0	5	100	100	260	300	300	850
Fe (Steel / Fer)	1105	975	855	855	755	675	675	675	655	535	505	455	335	305	265	165	105	40	15	10	5	5	5	0	95	95	255	295	295	845
Cr (Chromium/ Chrome)	1200	1070	950	950	850	770	770	770	750	630	600	550	430	400	380	260	200	135	110	105	100	100	100	95	0	0	160	200	200	750
Al Mg Si0.7 (Almasilium)	1200	1070	950	950	850	770	770	770	750	630	600	550	430	400	380	260	200	135	110	105	100	100	100	95	0	0	160	200	200	750
Sn75 Zn25	1350	1230	1110	1110	1010	930	930	930	910	790	760	710	590	650	520	420	360	295	270	265	260	260	260	225	160	160	0	40	40	590
Zn (Zinc/ Zinc)	1400	1270	1150	1150	1050	970	970	970	950	830	800	750	630	600	560	460	400	335	310	305	300	300	300	295	200	200	40	0	0	550
Zn Al4 (Zamak3/Zamac 3)	1400	1270	1150	1150	1050	970	970	970	950	830	800	750	630	600	560	460	400	335	310	305	300	300	300	295	200	200	40	0	0	550
Al PVD (Physical vapor deposition)	1400	1270	1150	1150	1050	970	970	970	950	830	800	750	630	600	560	460	400	335	310	305	300	300	300	295	200	200	40	0	0	550
Mg (Magnesium)	1900	1820	1700	1700	1600	1600	1600	1600	1520	1500	1390	1300	1180	1150	1110	1010	950	885	860	850	850	850	850	845	845	845	590	560	560	0

0-300 mV | 301-500 mV | 501-800 mV | > 800 mV

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Corrosion resistance

Outdoor use of aluminum enclosures

The plastic enclosures and their weather resistance are treated. We will deal here with the corrosion resistance of aluminum housings and accessories. The aluminum used in enclosures is available in two grades: ADC12 boxes for AC currents and 44,300 for flameproof enclosures. Both grades have good resistance to corrosion inside and outside.

Chemical composition

Material and standards	Si	Cu	Mg	Zn	Mn	Fe	Ni	Sn	Ti	Al
EN AC 44300 DIN 1706 AlSi12(Fe)	10.5-13.5	<0.10	-	<0.15	<0.55	<1	-	-	<0.15	Remainder
ADC12 (JIS H5302:2000)	9.6-12.0	1.5-3.5	<0.3	<1.0	<0.5	0.6-0.9	<0.5	<0.2	-	Remainder

Galvanic corrosion, also called Bimetallic Corrosion

Protective housings may be subject to a special phenomenon which reduces their lifespan, up to the perforation of the envelope or complete locking of the closing screws. This is galvanic corrosion.

Although most standards specify that appropriate safeguards must be taken to avoid galvanic corrosion on aluminum boxes, none advocates any solution or imposes materials or precise compositions of alloys.

Galvanic (Bi-Metallic) corrosion is an electrochemical phenomenon that occurs when dissimilar metals are in contact in the presence of an electrolyte (e.g. water, sea water). This will cause additional corrosion that can occur with other phenomena and uncoupled metals, and its progression is usually much faster.

A difference of potential appears between the two metals depending on both the metal and the solution. Two metals or two different alloys in contact with the same medium generally take two different potentials. If both metals are electrically connected, their difference of potential generates electrochemical reactions and an electric current flow.

The most negative metal (least noble) is positively polarized and the most positive metal is negatively biased. In the vast majority of cases, this configuration is an increase of the corrosion rate of the corrodible metal most (most negative), and a decrease in the rate of corrosion of the least corrodible metal (most positive).

Joint conditions necessary for the appearance of a galvanic corrosion couple.

Galvanic corrosion is a function of several different factors that need to be carefully evaluated when assessing the likelihood to have galvanic corrosion.

The simultaneous requirements for bi-metallic corrosion are as follows:

- An electrolyte bridging the two metals
- Electrical contact between the two metals.
- A difference in potential between the metals to enable a significant galvanic current
- A sustained cathodic reaction on the most noble of the two metals.

NB: If the metals are dry, bimetallic (galvanic) corrosion cannot occur.

Electrolyte

The conductivity of electrolyte will also affect the degree of attack.

When the conductivity of the electrolyte is low, the corrosion is localized to the contact zones between the two metals.

When the conductivity of the electrolyte increases, the corroded surface increases.

Electrical contact between metals

If the electrical contact is prevented between the two metals by interposing an insulator (aluminum oxide, phosphating, paint, oil, etc ...), the current does not run and there is no corrosion.

Electrical potential difference between metals

The higher the value, the greater the electromotive force of the phenomenon. A difference of hundreds of millivolts is likely to result in galvanic corrosion, but a 200-300mV difference is unlikely to be a problem.
The galvanic corrosion potentials of various metals and alloys are listed in a table which gives the metal electrical potential values and are usually measured with respect to the Standard Calomel Electrode (S.C.E.).
“Anodic” metals such as magnesium, zinc and aluminum are more easily corroded metals than “cathodic” ones (titanium, silver, gold).
Corrosion is proportional to the potential difference between two metals.
The values to be considered are the potentials of the metals and alloys which form the couple with respect to the medium in question. These potentials are experimental values and must be distinguished from the standard potentials of thermodynamic tables. Experimental potentials are strongly influenced by parameters such as temperature, agitation and ventilation. In addition, some metals can take two different potentials when in the same environmental conditions according to whether they are active or passive (case of stainless steels in contact with sea water, for example).
These considerations show that it can be difficult to predict trends without the need for experimentation, as many parameters are likely to reverse the polarity of some galvanic couples.

Aggravation or reduction factors

Area ratio of the two metals: the worst case is when a large cathode surface (the most positive material) is electrically connected to a small anode surface (metal most negative). The corrosion rate of the most negative metal can be multiplied by 100 or by 1000.
For instance, the assembly of a disc thermostat aluminum cup (dia 16mm) on a stainless steel tank will cause a quick corrosion of the cup if the necessary joint conditions are fulfilled.
On the other side, stainless steel screws closing an aluminum case will be much less subject to corrosion if the contact surfaces are minimized.

Resistance to corrosion of noble metals

- Regardless of its potential, the corrosion resistance of the most noble metal significantly influences the behavior of bimetallic couples. If the most noble metal corrodes, its corrosion products may, by motion, accelerate the corrosion of the most corroding metal. For instance, copper, yet considered as a noble metal and whose galvanic couple with aluminum is small, produces oxides that can corrode aluminum, which is a critical parameter in the design of earth terminals on aluminum housings that accommodate copper conductors.

If the noble metal couple is not corroding (Gold, Platinum), it will not present a risk of galvanic corrosion regardless of the metal that will be associated.

Sacrificial metal coatings

By applying to the cathode a sacrificial coating having a potential similar to or near that of the anodic member, the galvanic corrosion is reduced.
<u>Main design rules:</u>
- The sacrificial element should be on the anodic side and smaller.
- Be careful to use fasteners that have intact coatings.

Examples:
- Cadmium plating on steel fasteners holding 2024-T4 aluminum plates, will sacrifice the cadmium instead of corroding the Aluminum. (Potential difference 100 to 200mV).
- Zinc plating on steel fasteners will sacrifice the zinc instead of corroding the Aluminum (Potential difference 100 to 200mV).

Do not use nickel plated on steel fasteners as the potential difference (450mV) between nickel and alminum is too high and will corrode aluminum.
Note: The current trend is the search for an alternative to cadmium because of its toxicity, and its prohibition by the RoHS European Directive.

Some special cases of bimetallic electrochemical couples

Corrosion risks with galvanized steel and stainless steel in contact
Galvanized steel in contact with stainless steel is not normally considered to be a serious corrosion risk, except possibly in severe (marine type) environments.
In these situations, precautions such as insulating barriers are usually considered adequate to avoid bimetallic corrosion in most practical situations.

Galvanic corrosion between stainless steel and aluminum
The corrosion potentials of the stainless steels are "cathodics" and located in the "noble" area. The corrosion potentials of aluminum are "Anodic" and located in the "non-noble" area, with a large potential difference. This means that there will be no galvanic corrosion on stainless steel when placed in contact with aluminum while aluminum will corrode.
Although aluminum is anodic to stainless steel, large relative surface areas of aluminum to stainless steel can be acceptable, depending on local conditions. Stainless steel fasteners in aluminum plates or sheets are normally considered safe, whereas aluminum rivets or bolts holding stainless steel parts together is an unwise combination, as there is a practical risk of corrosion.
Even with no insulation between the metals, there should be little risk of corrosion, in continental weather conditions.
In contrast, in a marine environment, severe localized pitting corrosion to the aluminum treads has been observed where un-insulated stainless steel bolts were used to secure the treads in place.
On the same ladder however, bolts with sound insulating washers did not show any pitting on the surrounding aluminum.

Mechanical methods of reducing galvanic corrosion between aluminum and stainless steel
- Isolating the two materials by means of an electrical insulating material, like plastic, wherever practical.
- Avoid relatively small areas of the less noble metal (Aluminum) and large areas of the more noble metal (Stainless steel).
- The same metal or more noble (Cathodic, higher number in the table) metals should be used for small fasteners and bolts.
- Avoid crevices in stainless steel: In the presence of crevices stainless steels may feature less noble potentials due to oxygen depletion within the crevice. Therefore, coupling a relatively large aluminum area with a small creviced area of a stainless steel part may result in rapid attack of the material within the crevice leading to stainless steel corrosion.
- Exclude electrolyte from around the bimetallic junction e.g. by painting. Paint both metals where possible: if impractical paint the most noble metal.
- Seal: insure that faying surfaces are water-tight.
- Apply corrosion-inhibiting pastes or compounds under screw heads or bolts inserted into dissimilar metal surfaces whether or not the fasteners have been previously plated or otherwise treated.
- In some instances, it may be feasible to apply an organic coating to the faying surfaces prior to assembly. This would be applicable to joints which are not required to be electrically conductive.
- Where practicable or where it will not interfere with the proposed use of the assembly, the external joint should be coated externally with an effective paint system.
- Avoid threaded joints for materials far apart in the galvanic series.

Galvanic couple limitation by aluminum and stainless steel protection with chemical conversion surface treatments
Steel and Stainless steel phosphate coating
The phosphate coating is a conversion process used to form layers obtained by a reaction of the substrate with a selected medium. It is particularly applied to carbon steels and stainless steels. In the case of steel parts, phosphate coating is used primarily to enhance the adhesion of paints.
We distinguish between thin layers of phosphates (0.2-0.8 g/m²) mainly composed of iron phosphates, phosphate layers of average thickness (1.5-4 g/m²) containing zinc phosphate, and heavy phosphate layers (7-30 g/m²).

The latter, consisting of iron, zinc and manganese phosphates, can be used as anticorrosive coating, even in the absence of paint.

In the case of aluminum-stainless steel assemblies, thick and medium phosphate coating on steel parts is recommended.

However, the ideal is to treat the two structures by phosphate coating, separately since the processes are different for aluminum and steel.

Aluminum phosphate coating

Aluminum phosphating has taken an important place in surface treatments due to the combined use of this metal with steel in the automotive industry.

The metal is immersed in a solution of phosphoric acid in which it corrodes.

In the attack of aluminum, the hydrogen is released, causing a local increase of pH and thus the deposition of sparingly soluble triphosphates. Other ions can be added to baths, Zn but also Mn and Ni. The layers obtained, unlike phosphochromate layers that are amorphous, are formed of small crystals of

Zn phosphate (Mn Ni). Germination of these crystals is facilitated by immersing the metal in a solution of colloidal titanium phosphate.

Aluminum Anodization

Anodizing consists in strengthening the natural oxide film by anodic oxidation. The thick anodizing provides a good galvanic insulation.

Joining metals by non-metallic materials

To be suitable for joining to metals, non-metallic materials must be:

- Free of corrosive agents (salts)
- Free of acid or alkaline materials (neutral pH)
- Free of carbon or metallic particles,
- Must not be subject to bio-deterioration.
- Must not support fungal growth.
- Must not absorb or wick water.

Do not use: non-metallic materials that will initiate corrosion of metals to which they are joined, e.g., cellulosic reinforced plastics, carbon or metal loaded resin materials, asbestos-cement composites.

Electrochemical couples between aluminum alloys

(Names highlighted in yellow or blue) and other base metals, in a 2% saline solution.

There is no appearance of significant corrosion when the galvanic couple value is less than 300Mv.

	Pt (Platinum/ Platine)	Au (Gold/ Or)	Ti (Titanium / Titane)	AISI 316L(passive/passif)	Ag (Silver/ Argent)	Ni (Nickel/ Nickel)	Ni Cu 30 (Monel 400)	NiCr15 Fe8 (Inconel 600)	Cu55 Zn23 Ni22 (Arcap)	Cu (Copper/ Cuivre)	Al10 Sn66 Pb34	Cu Zn34 (Brass/ Laiton)	Cu88 Sn12 (Bronze)	Sn (Tin/ Etain)	Pb (Lead / Plomb)	Al Cu Mg1(Duralumin)	Mild steel / Acier doux	Al Si 10Mg (Alpax H)	Al 99.5 (Aluminum)	Hard steel/ Acier dur	Al Mg5 (Duralinox)	ADC12 (Aluminum alloy)	Cd (Cadmium/ Cadmium)	Fe (Steel / Fer)	Cr (Chromium/ Chrome)	Al Mg Si0.7 (Almasilium)	Sn75 Zn25	Zn (Zinc/ Zinc)	Al PVD (Physical vapor deposition)	Mg (Magnesium)
Pt (Platinum/ Platine)	0	130	250	250	350	430	430	430	450	570	600	650	770	800	840	940	1000	1065	1090	1095	1100	1100	1100	1105	1200	1200	1350	1400	1400	1900
Au (Gold/ Or)	130	0	110	110	220	300	300	300	320	410	470	520	610	670	710	810	870	935	960	965	970	970	970	975	1070	1070	1230	1270	1270	1820
Ti (Titanium / Titane)	250	110	0	0	110	180	180	180	200	320	350	400	520	550	590	690	750	815	840	845	850	850	850	855	950	950	1100	1150	1150	1700
AISI 316L(passive/passif)	250	110	0	0	110	180	180	180	200	320	350	400	520	550	590	690	750	815	840	845	850	850	850	855	950	950	1100	1150	1150	1700
Ag (Silver/ Argent)	350	220	100	100	0	80	80	80	100	220	250	300	420	450	490	590	650	715	740	745	750	750	750	755	850	850	1010	1050	1050	1600
Ni (Nickel/ Nickel)	430	300	180	180	80	0	0	0	20	110	170	220	340	370	410	510	570	635	660	665	670	670	670	675	770	770	930	970	970	1520
Ni Cu 30 (Monel 400)	430	300	180	180	80	0	0	0	20	110	170	220	340	370	410	510	570	635	660	665	670	670	670	675	770	770	930	970	970	1520
NiCr15 Fe8 (Inconel 600)	430	300	180	180	80	0	0	0	20	110	170	220	340	370	410	510	570	635	660	665	670	670	670	675	770	770	930	970	970	1520
Cu55 Zn23 Ni22 (Arcap)	450	320	200	200	100	20	20	20	0	120	150	200	320	350	380	490	550	615	640	645	650	650	650	655	750	750	910	950	950	1500
Cu (Copper/ Cuivre)	570	440	320	320	220	140	140	140	120	0	30	80	200	230	270	370	430	495	520	525	530	530	530	535	630	630	780	830	830	1380
Al10 Sn66 Pb34	600	470	350	350	250	170	170	170	150	30	0	50	170	200	210	310	400	465	490	495	500	500	500	505	600	600	760	800	800	1350
Cu Zn34 (Brass/ Laiton)	650	520	400	400	300	220	220	220	200	80	50	0	120	150	190	290	350	415	410	445	450	450	450	455	550	550	710	750	750	1300
Cu88 Sn12 (Bronze)	770	640	520	520	420	340	340	340	320	200	170	120	0	30	70	170	230	295	320	325	330	330	330	335	430	430	590	630	630	1180
Sn (Tin/ Etain)	800	670	550	550	450	370	370	370	350	230	200	150	30	0	40	140	200	265	290	295	300	300	300	305	400	400	560	600	600	1150
Pb (Lead / Plomb)	840	710	590	590	490	410	410	410	380	270	240	190	70	40	0	100	160	225	250	255	260	260	260	265	360	360	520	660	560	1110
Al Cu Mg1(Duralumin)	940	810	690	690	590	510	510	510	490	370	340	290	170	140	100	0	60	125	150	155	160	160	160	165	260	260	420	560	560	1010
Mild steel / Acier doux	1000	870	750	750	650	570	570	570	550	430	400	350	230	200	150	60	0	65	90	95	100	100	100	105	200	200	360	400	400	950
Al Si 10Mg (Alpax H)	1065	935	815	815	715	635	635	635	615	495	465	415	295	265	225	125	65	0	25	30	35	35	35	40	135	135	295	355	355	885
Al 99.5 (Aluminum)	1090	960	840	840	740	660	660	660	640	520	490	440	320	290	250	150	90	25	0	5	10	10	10	15	110	110	270	310	310	860
Hard steel/ Acier dur	1095	965	845	845	745	665	665	665	645	525	495	445	325	295	255	155	95	30	5	0	5	5	5	10	105	105	265	305	305	855
Al Mg5 (Duralinox)	1100	970	850	850	750	670	670	670	650	530	500	450	330	300	260	160	100	35	10	5	0	0	0	5	100	100	260	300	300	850
ADC12 (Aluminum alloy)	1100	970	850	850	750	670	670	670	650	530	500	450	330	300	260	160	100	35	10	5	0	0	0	5	100	100	260	300	300	850
Cd (Cadmium/ Cadmium	1100	970	850	850	750	670	670	670	650	530	500	450	330	300	260	160	100	35	10	5	0	0	0	5	100	100	260	300	300	850
Fe (Steel / Fer)	1105	975	855	855	755	675	675	675	655	535	505	455	335	305	265	165	105	40	15	10	5	5	5	0	95	95	255	295	295	845
Cr (Chromium/ Chrome)	1200	1070	950	950	850	770	770	770	750	630	600	550	430	400	380	260	200	135	110	105	100	100	100	95	0	0	160	200	200	750
Al Mg Si0.7 (Almasilium)	1200	1070	950	950	850	770	770	770	750	630	600	550	430	400	380	260	200	135	110	105	100	100	100	95	0	0	160	200	200	750
Sn75 Zn25	1350	1230	1110	1110	1010	930	930	930	910	790	760	710	590	650	520	420	360	295	270	265	260	260	260	225	160	160	0	40	40	590
Zn (Zinc/ Zinc)	1400	1270	1150	1150	1050	970	970	970	950	830	800	750	630	600	560	460	400	335	310	305	300	300	300	295	200	200	40	0	0	550
Zn Al4 (Zamak3/Zamac 3)	1400	1270	1150	1150	1050	970	970	970	950	830	800	750	630	600	560	460	400	335	310	305	300	300	300	295	200	200	40	0	0	550
Al PVD (Physical vapor deposition)	1400	1270	1150	1150	1050	970	970	970	950	830	800	750	630	600	560	460	400	335	310	305	300	300	300	295	200	200	40	0	0	550
Mg (Magnesium)	1900	1820	1700	1700	1600	1600	1600	1600	1520	1500	1390	1300	1180	1150	1110	1010	950	885	860	850	850	850	850	845	845	845	590	560	560	0

0-300 mV | 301-500 mV | 501-800 mV | > 800 mV

Autres limitations dans l'utilisation des alliages d'aluminium
Afin d'éviter des risques d'inflammation dus aux chocs ou au frottement, les normes destinées au matériel antidéflagrant (IEC 60079-0) limitent l'usage de l'aluminium.

Pour les enveloppes destinées au groupe I:
Le poids total de l'aluminium + magnésium +titane ne doit pas dépasser 15% du poids total (ou 6% du poids total du magnésium +titane pour les alliages ne comportant pas d'aluminium), ce qui élimine, pour ce groupe, la plupart des alliages comportant de l'aluminium

Pour les enveloppes destinées au groupe II:
Pour la zone 0: le poids total de l'aluminium + magnésium +titane +zirconium ne doit pas dépasser 10% du poids total (ou 7.5% du poids total du magnésium +titane +zirconium pour les alliages ne comportant pas d'aluminium), ce qui élimine, pour ce groupe et cette zone la plupart des alliages comportant de l'aluminium.
- Pour la zone1: le poids de magnésium ne doit pas dépasser 7.5% du poids total.
Pour la zone 2: pas de spécifications particulières.