Designation Systems for Wrought Aluminium, Wrought Aluminium Alloys, Casting Alloys and Other Metallurgical Aspects

The Four-digit Designation System for the Identification of Wrought Aluminium And Wrought Aluminium Alloys

This system is a four-digit numerical system in which the first digit indicates the alloy group as follows:

Aluminium – 99 percent minimum and greater

Aluminium Alloys – grouped by major alloying elements

Copper 2XXX
Manganese 3XXX
Silicon 4XXX
Magnesium 5XXX
Magnesium and Silicone 6XXX
Zinc, Magnesium, Copper 7XXX
Other elements 8XXX
Unused 9XXX

In the 1XXX group, the last two of the four-digits indicate the minimum aluminium percentage. These digits are the same as the two digits to the right of the decimal comma in the minimum aluminium percentage when it is expressed to the nearest 0,01 percent. The second digit indicates modifications in impurity limits or alloying elements. If the second digit is zero, it indicates unalloyed aluminium having natural impurity limits; integers 1 to 9 indicate special control of one or more individual impurities or alloying elements.

In the 2XXX to 8XXX groups, the last two digits have no special significance other then to identify different aluminium alloys in the group. The second digit indicates alloy modifications. If the second digit is zero it indicates the original alloy; integers 1 to 9 indicate consecutive alloy modifications. The designation system enjoys wide acceptance throughout the world and South Africa has adopted the system too.

Designation System for Aluminium Alloy Castings And Foundry Ingot

In South Africa, several conventions, mainly of foreign origin, have been used to describe casting alloys.

It is quite likely that South Africa will adopt the CEN designations, which most closely match the local practices.

Temper Designation System

This system defines the sequence of basic treatments used to achieve the various tempers. The temper designation follows four-digit Aluminium Alloy Designation, the two being separated by a hyphen.

The basic temper designation consists of a letter. Sub-divisions of the basic temper are indicated by one or more digits following the letter.

Wrought Alloys

Cold Worked Symbols:
F As fabricated (i.e. rolled, extruded or forged)

O Annealed, recrystallized

H.. Strain hardened (H followed by two or more digits)

H series – First digit represents the process
H1. Strain hardened only
H2. Strain hardened then partially annealed
H3. Strain hardened and then stabilised* (*a low temperature annealing process plus minus 125oC)
H4. Strain hardened and then stoved

H series – Second digit represents the final degree of strain hardening
H.9 Extra hard
H.8 Full hard (result of approximately 75 percent reduction of area)
H.6 Temper material is mid-way in tensile strength between 4 and 8 temper
H.4 Temper material is about mid-way in tensile strength between full hard H.8 and fully annealed material O.
H.2 Material is mid-way between H.4 and O material. Odd figures 1,3,5,7 designate intermediate strengths exactly between those for the adjacent even figures 0,2,4,6,8.

Wrought and cast Alloys (Except Ingot)

Heat Treatment Symbols:
F As fabricated or cast*

O Annealed, soft*

T Thermally treated to produce stable tempers other than F, O and H
T1 Controlled cooling from casting temperature and then naturally aged*
T3 Solution heat-treated, cold worked and then naturally aged to a stable condition*
T4 Solution heat-treated and then naturally aged to a stable condition*
T5 Controlled cooling from an elevated temperature process (or casting process) and then artificially aged*
T6 Solution heat-treated and then artificially aged*
T64 Solution heat-treated and then artificially underaged*
T7 Solution heat-treated and then artificially overaged (stabilised)*
T8 Solution heat-treated, cold worked and then artificially aged
T9 Solution heat-treated, artificially aged and then cold worked

Note: Treatments marked * are applicable to casting alloys. Several other heat treatment symbols with more digits are also in use. (Details are available).

Heat Treatment – Metallurgical Aspects
In high-purity form aluminium is soft and ductile. To increase its strength various elements can be added to produce various alloys (see the four-digit numerical system).

Non-heat-treatable alloys
The non-heat-treatable alloys are those in which the mechanical properties are determined by the amount of cold work introduced (e.g. by rolling, drawing, etc.) after the last annealing operation. (See Cold Worked Symbols above). Usually the 1 000, 3 000, 4 000 and 5 000 alloys are non-heat-treatable.
The properties obtained by cold work are destroyed by subsequent heating and cannot be restored except by additional cold work.

Heat-treatable alloys
The heat-treatable alloys are those in which the mechanical properties may be improved by heat-treatment. In contrast to the non-heat-treatable alloys the increased strength is obtained with little sacrifice of ductility. Heattreatable alloys have the further advantage that they can be re-heat-treated after annealing to restore their original
properties.

The various elements used in alloying, singly or in combination, show increasing solid solubility in aluminium with
increasing temperatures. These alloys can therefore be subjected to thermal treatment to improve their strength.

The first step, called solution heat treatment, is an elevated temperature process designed to put soluble elements into solid solution. This is followed by rapid quenching, usually in water, which momentarily “freezes” the structure for a short time and makes the material very workable. (This workable structure can be maintained by keeping the material at below freezing temperature.)

The quenched alloys are not stable at room temperature and precipitation of the constituents from the super saturated solutions begins. This so-called “ageing process” which makes the alloy considerably stronger, can last for long periods of time. It can be speeded up by heating for a controlled period of time to an elevated temperature
and this process is then called “artificially ageing” or “precipitation hardening”. This helps to achieve the highest strengths of the alloy. Some alloys will achieve their design strength by ageing at room temperature only, e.g. 2017A and 2024.

Annealing
This is a thermal treatment for the softening of alloys which have been hardened by cold work or by heat treatment and generally enables the metal to be cold worked. The metal should be heated to the annealing temperature and held at this temperature for a certain time. Slow cooling is required in most cases to prevent any possibility of partial solution heat treatment of the alloy. (For heat-treatable alloys only.)

The Use of Aluminium

- Selection Guide

Aluminium Alloys were developed separately across the world in various centres. Consequently different alloys with different naming systems have emerged. In 1982 it was agreed that the US four-digit system should become the international standard. This is the system South Africa has adopted for wrought alloys.

For casting alloys the comments about the CEN designation system, as given in Chapter 2, apply.

Because other literature may refer to other naming systems Tables 4 and 5 should enable conversion to the systems used in South Africa.

Construction and General Engineering Industry

The most common structural alloys readily available in South Africa and their common uses are listed:

Category& Alloy	Alloy Characteristics	Common Uses
Sheet and Plate		
3004	Non-heat-treatable. Good weldability, formability and corrosion resistance.	Roof sheeting, vehicle panelling.
5251	Non-heat-treatable. Medium strengthwork hardening alloy. Good weldability, formability and corrosion resistance.	Vehicle panelling, structures exposed to marine atmospheres.
*5454	Non-heat-treatable. Used at temperatures between 65 and 200oC. Good weldability and corrosion resistance.	Pressure vessels, road & rail tankers. Treadplate. Transport of Ammonium Nitrate.
*5083	Non-heat-treatable. Good weldability and corrosion resistance. High strength after welding. Very resistant to sea water and industrial atmospheres. A superior alloy for cryogenic use (in annealed condition.)	Pressure vessels and road transport applications below 65oC. Shipbuilding.Structures in general. Mining man cages and ore skips.
5754	Non-heat-treatable. Good weldability and excellent corrosion resistance against sea water.	Shipbuilding (super structures) and road transport applications. Equipment & containers in fish & other food industries.
Extrusions		
6063	Heat-treatable. Medium strength alloy. Good weldability and corrosion resistance. Used for intricate profiles.	Architectural extrusions (internal and external), window frames, irrigation pipes.
*6082	Heat-treatable. Medium strength.Good weldability and corrosion resistance.	Stressed structural members, bridges, cranes, roof trusses, beer barrels.
*6261	Heat-treatable. Properties very similarto 6082. Preferable as airquenchable, therefore has less distortion problems. Not notch-sensitive.	As 6082. Mancages and ore skips.
7020	Heat-treatable. Age hardens naturally, therefore will recover properties in heat-affected zone after welding. Susceptible to stress-corrosion. Good ballistic deterrent properties.	Armoured vehicles, military bridges, etc.

* Most commonly used alloys.

Electrical Industry

A. Bare Aluminium Conductors
A typical electric power system uses bare conductors from the strain bus in the generation plant substation to the transmission conductors and overhead ground wires to the distribution system and the neutral for service drops. The construction and properties of these conductors are covered by individual SABS, ASTM and BS specifications.

(a) Homogeneous designs of conductor
(b) Composite designs of conductors
(c) Expanded Core Designs

Alloy and Temper	Remarks
1350 H19	(a) Standard Round or Compact Round is most commonly known as 99,7EC. The most widely used grade for overhead conductors and cables. (b) and (c) Mainly Aluminium Conductor Steel Reinforced (ACSR).

B. Covered and Insulated Wire and Cable
(a) Covered aluminium line wires and cables.
(b) Insulated Conductors and Cables.

Alloy and Temper	Remarks
1350 (a) Covered line wires. H19	(b) Power and lighting, Single Conductors, Aerial cable assemblies, Multiple conductor power cables, Underground cables (0-600V), Insulated conductors (600V).

C. Bus Conductors

Alloy and Temper	Remarks
1350 H11	Extruded rod, bar, tube, pipe and shapes
6101A T6	
6061 T6	Extruded pipe
6063 T6	
1350 H12	Rolled bar

D. Magnet Conductors

Alloy and Temper	Remarks
1350	Round, square and rectangular. Tape, film and paper insulated.

E. Capacitor Foil

Alloy and Temper	Remarks
High purity alloys such as 1235, 1145, 1180, 1188, 1193, 1199	Available in a wide range of thicknesses and widths in a dry condition or in slick-finish or etched and anodised.

F. Cast Aluminium Rotors

Squirrel cage induction motors are the most popular form of motor design for both household appliances and heavy industrial equipment. For smaller rotors the aluminium content is higher and conductivity approaches 60 percent IACS. For larger rotors containing a greater amount of silicon and iron the
conductivity may fall to 55 percent IACS (International Annealed Copper Standard).

Alloy	Rated Conductivity %IACS (Minimum)
Al 99,5	55

For high torque rotors with a conductivity of 37 percent IACS alloy Al Si 5 can be used and for a 24 percent IACS conductivity alloy CEN 46500 is applicable.

G. Rigid Aluminium Conduits

Rigid conduit offers a most effective means of installing concealed electrical wiring.

Alloy and Temper	Remarks
6063 T1	Normally Extruded conduit.

H. Aluminium Lighting Poles and Transmission Towers

Aluminium lighting standards may be tapered or uniform cross-section. The former is fabricated by spintapering (about 1 in 100) extruded 6063 tubes in T4 temper and then artificially ageing to the T6 temper.

Prefabricated metal transmission towers are used quite extensively. All aluminium towers normally use the excellent structural alloy 6061 in a T6 temper.

Foundry Industry

Alloy	Characteristics	Common Uses
44000	Low pressure die casting.	Alloy wheels
Rim Alloy (High purity) (Sr-modified)	Excellent toughness and corrosion resistance.	
43100 G Al Si 10Mg (SA 26) (LM 9) (A 360)	Excellent castability, pressure tightness and resistant to hot cracking. Can be electroplated and heat-treated.	General purpose casting alloy for cover plates and instrument cases where higher strength and hardness are needed.
44100 (LM 6) (SA 22) (A 413)	Exceptional casting teristics for thick and thin sections. Good corrosion resistance. Pressure tightness and resistant to hot tearing.	charac- Very wide use range, from pump parts in chemical plants to motorcar fittings.
47000 (LM 20) (SA 24) (A 413)	Similar to LM6 but improved hardness and machinability.	Suitable for thin intricate sections, street lighting and office equipment.
45400 (LM 22) (ISO: Al Si5 Cu3 Mn)	Heat-treatable. Resistance to hot tearing. Good machinability.	Good shock resistance and therefore used for heavy duty service road transport.
46500 (LM 24) (SA 44) (A 380)	Good surface finish. Resistant to hot tearing. Suitable for leak tight castings. Non-heat treatable. Fairly good corrosion resistance.	One of the most common die casting alloys used extensively in the motor trade for housing.
42000 (Lm 25) (SA 14) (A 356)	Heat-treatable. Suitable for thin castings. Also leak tight. Corrosion resistance good. Good weldability. Strength at elevated temperatures is good.	Used where high strength and good corrosion resistance is required, i.e. Food, Chemical, Marine, Electrical Industries. Also used for Armaments.
Al Si12 Cu1 Mg1 Ni1 Low Si Piston Alloy (M 124) (K1275)	High temperature strength, low coefficient of thermal expansion Good wear resistance.	Automotive and Diesel pistons, pulleys and sheaves.
Al Si18 Cu1 Mg1 Ni High Silicon Piston Alloy (M 138) (KS 2811)	Low coefficient of thermal expansion.High resistance to wear. Good strength at elevated temperatures.	High performance internal combustion engine pistons.
46500 (LM 24) (A 380.1) (ISO: AlSi8Cu3) (ADC 10)	Good pressure tightness. Good fluidity. Heat treatable. Good machinability.	Suitable for most engineering purposes where moderate mechanical properties are required.
46100 (LM 2) (ADC 12)	Non-heat-treatable. Machinability poor. Very easily cast into thin sections. Free from hot tearing. Can be anodised.	Essentially a die casting alloy and can be used for most pressure die casting applications.

Alloys shown in ( ) are approximate equivalents.
KS = Karl Schmidt LM = United Kingdom BS 1490
M = Mahle A = American International (AA)
ISO = ISO R115, 3522 ADC = Japan JIS5032

Packaging Industry

Alloy Characteristics	End Use
Good combination of formability and strength.	Beer and beverage can ends for two & three piece can construction.
Good formability, ductility and corrosion resistance.	Roll-on aluminium closures and caps for carbonated soft drinks, cordials, food and pharmaceutical applications.
Good corrosion resistance and workability. Very ductile in the annealed condition. Some 8006/3003/8011 used for specific applications.	Household foil, milk bottle capping, yoghurt / cream capping, can membranes and taggers. Table strip. Laminated to other substrates for Soup powders, margarine wraps, etc. Rigid foil containers.
99,7% purity for good impact extrusion formability.	Personal deodorant aerosols. Collapsible and aluminium tubes for toothpaste, cosmetic & pharmaceutical industries.

16.04.08 *Henning Johansen*