Materials – Designation system

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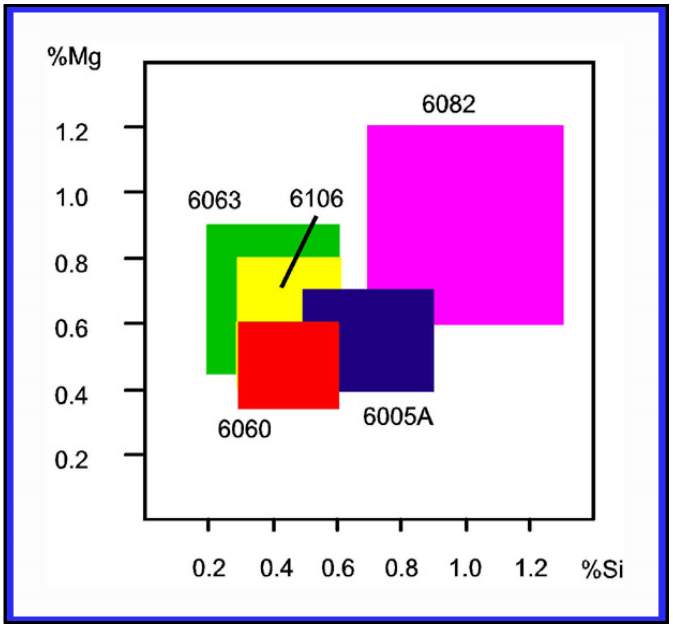
3.1 Designation system for wrought and cast alloys and tempers



Background

There are about **10 major alloying elements** of the Periodic System, which, in concentrations of between 0.1 and a few wt.-%, can be used to change significantly the properties of pure aluminium according to needs of the producer, fabricator or user.

Consequently, there is an abundance of aluminium alloys, which are currently in use. There are about **500 internationally registered** wrought and cast aluminium alloy compositions, from which only little more than **a dozen** are used for the manufacture of **automotive** components and cars.

To select and specify an alloy with specific properties for a given application, its composition and state of heat treatment (temper) must be defined. This is achieved by a standardised designation system for the **alloy composition** as well as for the **temper**.

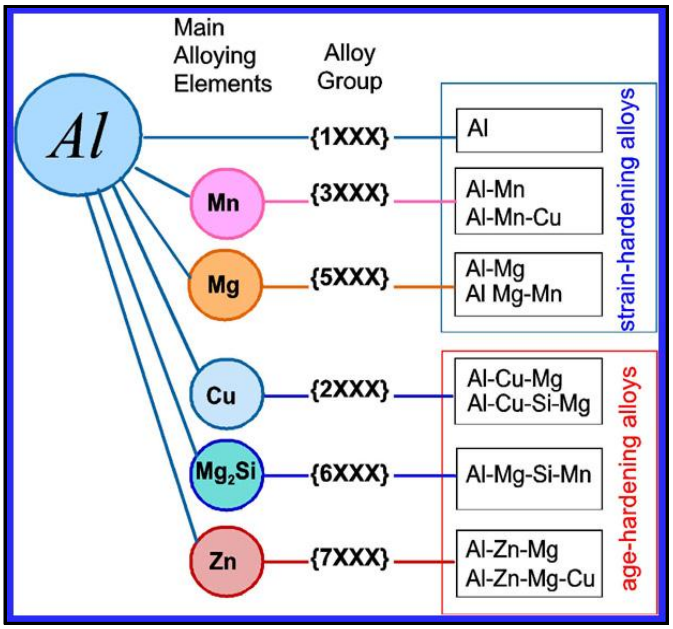
The global character of the European Market demanded a common designation system in lieu of various national varieties. For its simplicity and flexibility the designation system for wrought alloys created 1954 by the North American **Aluminum Association (AA)** was adopted in 1970 by the **International Organisation for Standardization (ISO)**.

In 1985 the member states of the European Community agreed to adopt harmonised European standards in place of respective national ones. For wrought aluminium, the AA designation system was adopted by the **Comité Europeén de Normalisation (CEN),** but for cast alloys a separate designation standard was developed.

Since the new **CEN standards for aluminium alloy and temper designation** have replaced previous European national standards, they will be adopted - where applicable - in this **Automotive Manual** and are described briefly hereafter for wrought and cast aluminium alloys.

3.2 Wrought alloys

3.2.1 Designation system for wrought alloys



Definitions

Wrought aluminium and aluminium alloys: these alloys are primarily intended for the production of wrought products by **hot and/or cold working**, i.e. rolling, extruding, forging and drawing.

They are cast in ingots by **direct chill (DC) casting** or strip casting processes prior to hot and/or cold working.

Wrought aluminium alloys can be divided into groups of **heat-treatable** and **non-heat-treatable alloys**:

- Heat-treatable alloys are capable of being strengthened by suitable **thermal treatment**.
- Non-heat-treatable alloys cannot be strengthened substantially by thermal treatment. Their basic strength is determined by the alloying content, but can be increased significantly by work-hardening and in some cases also by grain size refinement.

The **specification of** typical or minimum **properties** requires the combination of a unique **designation** for the **alloy composition** and for the **temper**, i.e. the state of the microstructure by thermo-mechanical treatment.

For optimum performance during hot and cold working, wrought alloys are tailored to the specific **semi-fabrication process**. Consequently, the properties of a specified alloy and temper may vary, dependent on the type and dimensions of the semi-product.

3.2.2 International designation systems for wrought alloys

American National Standard (ANSI)

(ANSI Standard H35.1(M)-1997)

The registration office for designations of aluminium and aluminium alloys and tempers is **The Aluminum Association** Inc., Washington, DC. (**AA**).

This standard is also the basis for wrought aluminium and aluminium alloy and temper designation standards of ISO and CEN, which therefore permits cross reference between these designation standards.
Alloys registered within the American National Standard are identified by the pre-fix "AA".

Example: AA 5754

International Organisation for Standardization (ISO)

The alloy and temper designation system of ISO/DIS 209 is basically identical with that of AA, but alloys are not preceded by the letters AA.

The current ISO alloy designation also uses **chemical symbols.** However, it has been recently decided to fully adopt the four digits alloy designation system and withdraw the chemical symbols system. The revised standards are not yet valid, but designation by chemical symbols acc. to the valid ISO standards are no more used.

Example: 5754

Comité Européen de Normalisation (CEN)

The European wrought alloy (EN standards **EN 573)** and temper (EN standards **EN 515)** designation system is basically identical with the ANSI (or AA) and ISO system.

Alloys standardized by EN 573-3 are also registered by the AA, but not all alloys registered by the AA are standardized by EN 573-3 and vice versa. Therefore, alloys designated according to EN must be preceded by the prefix **EN AW** (i.e. **A**luminium **W**rought).

Example: EN AW-5754 or EN AW-Al Mg3

3.2.3 Alloy designation system for wrought alloys (EN 573)

CEN Alloy Designation System

The EN designation system for wrought alloy composition is made up of the following:

- **EN** for European standard followed by a space
- Letter **A** for aluminium
- Letter **W** for wrought (followed by a dash)
- Alloy composition is specified either by
  - a) numericals (4 digits) or
  - b) by means of chemical symbols, followed in each case by a letter and/or digit(s) for temper designation

Example a): EN AW-5754-O
Example b): EN AW-Al Mg3-O

Numerical Alloy Designation

A 4-digit numerical system is used. The first digit indicates the alloy group as follows:

Definition of Alloy Group	Group	*)
Aluminium, 99.00 percent and greater	1XXX	(H)
Aluminium alloys grouped by major alloying elements		
Copper (Cu)	2XXX	(T)
Manganese (Mn)	3XXX	(H)
Silicon (Si)	4XXX	(H/T)
Magnesium (Mg)	5XXX	(H)
Magnesium and Silicon (Mg + Si)	6XXX	(T)
Zinc (Zn)	7XXX	(T)
Other elements (e.g. Fe, Li,....)	8XXX	(H/T)
Unused series	9XXX	(-)
*) H = work hardening (non-heat-treatable), T = heat-treatable		

The last two digits identify the aluminium alloy or indicate the aluminium purity. The second digit indicates modifications (1...9) of the original alloy or impurity limits.

3.2.4 Temper designation system for wrought alloys (EN 515)

Basic Considerations

The heat treatment (temper) designation system of **EN 515** is used for all forms of wrought aluminium and aluminium alloys. Property (mechanical or physical) limits apply to individual alloy-temper-product combinations.

- Basic temper designations consist of letters (F, O, H, W, T).
- One or more digits following the letter, where required, indicate sub-divisions of the basic tempers. These designate specific sequences of basic treatments.
- Additional digits are added to the designation, if some variation of the same sequence of basic thermo-mechanical operations should be applied to the same alloy, resulting in substantially different characteristics.

Note that ANSI H35.1(M) is not fully compatible with EN 515.

Definitions

For the purpose of the standard temper designations, the following definitions are applied.

Cold working: Plastic deformation of metal at such temperature and rate that strain-hardening occurs.

Strain-hardening: Modification of a metal structure by cold working resulting in an increase in strength and hardness with loss of ductility.

Solution heat-treating: A thermal treatment which consists of heating the products to a suitable temperature, holding at that temperature long enough to allow constituents to enter solid solution and cooling rapidly enough to hold the constituents in solution.

Ageing: Precipitation from supersaturated solid solution resulting in a change in properties of an alloy, usually occurring slowly at room temperature (**natural ageing**) and more rapidly at elevated temperatures (**artificial ageing**).

Annealing: A thermal treatment to soften metal by removal of strain-hardening or by coalescing precipitates from solid solution.

Basic Tempers

F Temper - As fabricated
- no mechanical property limits specified.

O Temper - Annealed
- to obtain the lowest strength temper.

H Temper - Strain-hardened
- cold worked after annealing (or after hot forming) or in combination with partial annealing or stabilizing

W Temper - Solution heat treated
- unstable temper, only with indication of ageing time at RT: e.g W 1/2 h.

T Temper - Thermally treated to produce stable tempers other than F, O, or H
- solution heat treated and aged at room or intermediate temperatures with or without supplementary strain-hardening

3.2.5 H-Tempers for strain-hardening wrought alloys (EN 515)

H-Tempers

The designations (below) give a brief survey over the various temper designations for non-heat-treatable wrought aluminium and aluminium alloys. For more extensive information, please refer to EN 515.

First digit		
-H1	Strain-hardened only	
-H2	Strain-hardened and partially annealed	
-H3	Strain-hardened and stabilized by low temperature treatment	
-H4	Strain-hardened and subjected to paint bake cycle	
Second digit		
-HX2	Quarter hard	(Numerals 1, 3, 5, 7 designate
-HX4	Half hard	tempers inbetween those indicated
-HX6	Three quarter hard	at left)
-HX8	Full hard	(Numeral 9 for "extra hard" temper)
Third digit		
e.g. -HX11	Products which are slightly strain-hardened between O and HX1	
e.g. -H112	Hot worked products with mechanical property limits	
e.g. -HXX5	Welded tubes with prop'ty limits deviating from HXX temper of strip	

For mechanical property limits the user is referred to the respective product standards, e.g. EN 485-2 for sheet, strip and plate or special suppliers' information.

3.2.6 T-Tempers for heat-treatable wrought alloys (EN 515)

T-Tempers

The designations (below) give a brief survey over the various temper designations for heat-treatable wrought aluminium and aluminium alloys. For more extensive information, please refer to EN 515.

First digit (numerals 1 to 9; selected examples given below)	
T4	Solution heat treated and naturally aged to a stable condition
T6	Solution heat treated and artificially aged to maximum strength
T7	Solution heat treated and artificially overaged
T8	Solution heat treated, cold worked and artificially aged
T9	Solution heat treated, artificially aged and cold worked

Second digit	
TX1, 3 to 9	Variations of basic temper, usually indicating lower strength
T42, T62	Solution heat treated from O or F temper and aged
T61, T63, T65	Increasingly, but not fully, artificially aged for improved formability
T79....T73	Increasingly overaged for improved corrosion resist. and toughness
T66	6XXX alloys; better properties than T6 by special process control
T4+	6XXX alloys; better properties than T4 by special process, e.g. for improved paint bake response (non standardized designation)

For mechanical property limits the user is referred to the respective product standards, e.g.

- EN 485-2 for sheet, strip and plate,
- EN 755-2 for extruded products,
- EN 586-2 for die forgings,

or special suppliers information.

3.3 Cast alloys

3.3.1 Designation system for casting alloys

Definitions

Casting aluminium and **aluminium alloys** are primarily intended for the production of **castings** by solidification of the molten alloy in a mould.

The properties of castings are related to the composition of the castings alloy, but also significantly by the type of mould and mould filling processes, i.e. the **casting processes** employed. Casting alloys are tailored to the casting process.

For this reason the basic casting process used is part of the casting alloy designation system.

Contrary to the international systems of wrought aluminium alloy designation (AA, ISO, CEN), the designation systems for casting alloys and castings differ significantly.

In the efforts to develop a unified European designation system for casting alloys and castings the standards EN 1780 (designation of alloys) and EN 1706 (composition and mechanical properties, incl. temper designations) were developed, which deviate from the widely used ANSI (AA) system. To aid cross referencing, both systems are described in this chapter.

Specifically, the AA system defines 8 groups of casting alloys, whereas the EN system only differentiates between 4 alloy groups and excludes the tin containing bearing alloys.

3.3.2 Designation system for casting alloys – EN 1780

Alloy Designation System

The EN designation system for wrought alloy composition is made up of the following:

- **EN** for European standard,
- Letter **A** for aluminium
- Letter **C** for casting
- Alloy composition is specified either by
  a) **numericals** (5 digits) or
  b) by **chemical symbols**, followed by a letter for the casting process and possibly by a letter and/or digit(s) for temper designation

Example:
EN AC-42000KT6 (alloy Al 7%SiMg for chill or permanent mould casting, aged to T6 temper)

a) Numerical Alloy Designation: *A 5 digit numerical system is used.*

Definition of Casting Alloy Groups	1st digit	2nd digit	generic
Aluminium alloys grouped by major alloying element			
Copper (Cu)	2xxxx	21xxx	AlCu
Silicon (Si)	4xxxx	41xxx	AlSiMgTi
		42xxx	AlSi7Mg
		43xxx	AlSi10Mg
		44xxx	AlSi
		45xxx	AlSi5Cu
		46xxx	AlSi9Cu
		47xxx	AlSi(Cu)
		48xxx	AlSiCuNiMg
Magnesium (Mg)	5xxxx	51xxx	AlMg
Zinc (Zn)	7xxxx	71xxx	AlZnMg

The 3rd digit is arbitrary and defines the generic alloy modification. The 4th digit is generally 0. The 5th digit is always 0 for CEN alloys, but never 0 for aerospace alloys.

b) Alloy designation by chemical symbols:

- Al followed by a space
- Symbol of the major alloying element usually followed by the percentage of mass
- Other alloying elements (max. 4 elements) in descending order; if the mass fractions are the same, in alphabetical order
- In case of similar composition, the difference is made by:
  - Stating the nominal contents
    Example: EN AC-Al Si7Mg0.3, EN AC-Al Si7Mg0.6
    or
  - Stating the impurities in brackets
    Example: EN AC-Al Si10Mg(Cu)

Casting process:

The first letter after the 5 alloy numerals or chemical symbols characterises the casting process. The following symbols are used:

D: Pressure die casting
K: Chill or permanent mould casting
L: Investment casting
S: Sand casting

Example: EN AC-42000K

3.3.3 Temper designation system for castings – EN 1706

Temper designations for castings

The conditions of thermal treatment of castings as defined by EN 1706 are as follows:

F:	As-cast
O:	Annealed
T1:	Controlled cooling from casting and naturally aged
T4:	Solution heat treated and naturally aged
T5:	Controlled cooling from casting and artificially aged or over-aged
T6:	Solution heat treated and fully artificially aged
T64:	Solution heat treated and artificially under-aged
T7	Solution heat treated and artificially over-aged (stabilised)

Product designation on drawings

Following is an example for a complete designation of a permanent mould casting of casting alloy 42100, solution annealed and artificially aged, according to EN 1706:

Example: EN 1706 AC-42100KT6

All details about the European designation refer to the publications: EN 1780: 1999-12 and EN 1706: 1998-06, respectively.

3.3.4 Designation system for alloy castings according to American Standard

Cast Aluminium and Aluminium Alloy Designation System (ANSI H35.1(M)-1997) uses a 4 digit numerical designation.
The 1st digit identifies the alloy group. The 2nd two digits determine the alloy or indicate the aluminium purity. The last digit - separated by a decimal point - indicates the product form, i.e. castings (0) or ingot (1, 2).
A modification of the original alloy or impurity limits is indicated by a serial letter before the numerical designation.

Example: A356.0 (AlSi7Mg0.3)

Numerical Designation System according to ANSI and AA

Definition of Casting Alloy Groups	
Aluminium, 99.00 percent minimu and greater	1xx.x
Aluminium alloys grouped by major alloying elements	
Copper (Cu)	2xx.x
Silicon (Si), with added copper and/or magnesium	3xx.x
Silicon (Si)	4xx.x
Magnesium (Mg)	5xx.x
Zinc (Zn)	7xx.x
Tin (Sn)	8xx.x
Other elements	9xx.x
Unused series	6xx.x

Alloys are registered with Aluminium Association Registration Record (AA). The designation system is identical to the specification J452 and J453 of the SAE (Society of Automotive Engineers).