TALAT Lecture 1101

Resources and Production of Aluminium

25 pages, 25 figures (also available as overheads)

Basic Level

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Objectives:

- to aquire sufficient basic knowledge to recognize the application benefits of aluminium and the forms in which it is available.

More specifically, the objectives are

- to illustrate the natural abundance of the element and the history of its extraction from the ore
- to show the properties of pure aluminium. To outline the importance of alloys to commercial development. To show the range of alloys available and their classification
- to describe the principal markets for aluminium
- to illustrate the basic processes used in the production of primary aluminium and the main fabricating routes used to provide the products needed by manufacturing industry
- to outline the structure of the European aluminium industry and the historical contexts which shaped its growth.

Date of Issue: 1999

1101 Resources and Production of Aluminium

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1101.01 History of exploitation and production

- Introduction
- History of discovery
- Development of industrial production

Introduction

It is only 160 years since the element aluminium was discovered and only 100 years since a viable production process was established, yet by volume more aluminium is produced each year than all other non-ferrous metals combined.

An astonishing achievement and a very good reason for engineers to appreciate the benefits and master the application technology.

Aluminium is the third most abundant element - comprising some 8 percent of the earth's crust. Therefore the natural abundance of aluminium is a key factor in a world of diminishing resources (see **Figure 1101.01.01**). Why was it not discovered sooner? The main reason is that it never occurs naturally in metallic form. Aluminium is found in most rocks, clay, soil and vegetation combined with oxygen and other elements.

.0001%	Copper
.006%	Sulphur
.009%	Manganese
.009%	Carbon
0.12%	Phosphorus
0.14%	Hydrogen
0.62%	Titanium
2.07%	Magnesium
2.58%	Potassium
2.83%	Sodium
3.64%	Calcium
5.06%	Iron
8.07%	Aluminium
27.61%	Silicon
46.46%	Oxygen

Source: Metals in the Service of Man. 9th Ed. 1989

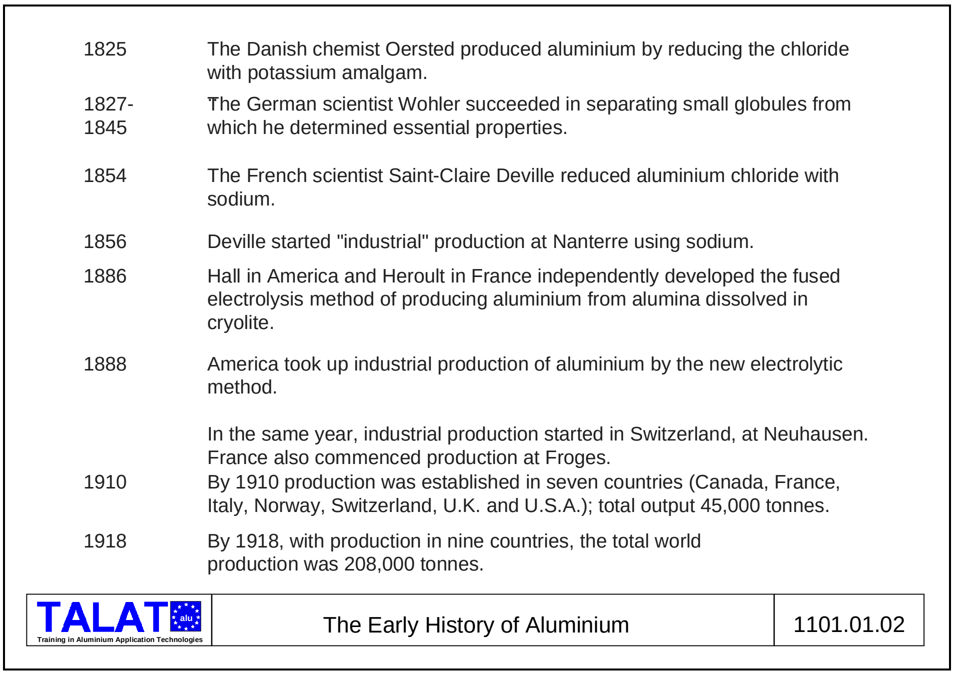
TALAT Training in Aluminium Application Technologies | Analysis of Earth's Crust | 1101.01.01

Aluminium bearing compounds have been used by man from the earliest times, pottery was made from clays rich in hydrated silicate of aluminium. Ancient Middle Eastern civilisations used aluminium salts for the preparation of dyes and medicines: they are used to this day in indigestion tablets and toothpaste. Alum, a double sulphate containing aluminium has been used for centuries for many useful purposes.

History of Discovery

In 1807, Sir Humphrey Davy, the British scientist, postulated the existence of the element arguing that alum was the salt of an unknown metal which he said should be called "Alumium". The name was respelt as the more euphonious aluminium by later scientists.

Following Davy's work, H.C. Oersted in Denmark isolated small nodules of aluminium by heating potassium amalgam with aluminium chloride (see also **Figure 1101.01.02**).. By 1845 Wöhler in Germany had established many of the metal's properties, including the remarkably low specific gravity. It was the determination of this property that paved the way for more generous development funding - its lightness!



1825	The Danish chemist Oersted produced aluminium by reducing the chloride with potassium amalgam.
1827- 1845	The German scientist Wohler succeeded in separating small globules from which he determined essential properties.
1854	The French scientist Saint-Claire Deville reduced aluminium chloride with sodium.
1856	Deville started "industrial" production at Nanterre using sodium.
1886	Hall in America and Heroult in France independently developed the fused electrolysis method of producing aluminium from alumina dissolved in cryolite.
1888	America took up industrial production of aluminium by the new electrolytic method.
	In the same year, industrial production started in Switzerland, at Neuhausen. France also commenced production at Froges.
1910	By 1910 production was established in seven countries (Canada, France, Italy, Norway, Switzerland, U.K. and U.S.A.); total output 45,000 tonnes.
1918	By 1918, with production in nine countries, the total world production was 208,000 tonnes.

TALAT Training in Aluminium Application Technologies

The Early History of Aluminium

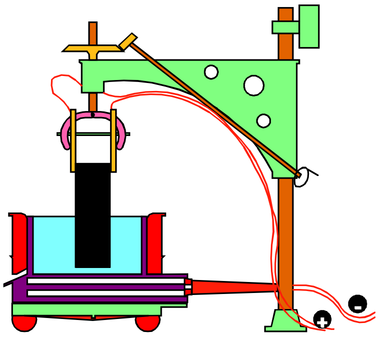
1101.01.02

During the third quarter of the 19th Century Henri Sainte-Claire Deville, a Frenchman, developed a reduction process using sodium which, with further refinement by others, allowed the production of high cost metal in limited quantities. Kilogrammes were a great advance on grammes.

These initial attempts to produce metallic aluminium in commercial quantities were of necessity based on chemical reduction of the oxide. The invention of the dynamo increased the options available to include electro-thermal and electrolytic processes.

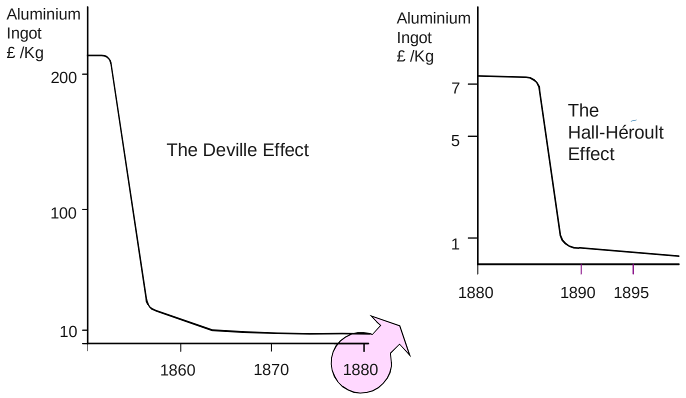
Development of Industrial Production

In 1886, Charles Martin Hall and Paul L.T. Héroult each perfected a similar method for producing aluminium electrolytically from aluminium oxide (alumina) dissolved in cryolite (**Figure 1101.01.03**). Hall filed patents in the USA and Héroult in France, a fact that was to have great influence on the future structure of the industry.



TALAT Training in Aluminium Application Technologies | Heroult's Crucible - 1888 | 1101.01.03

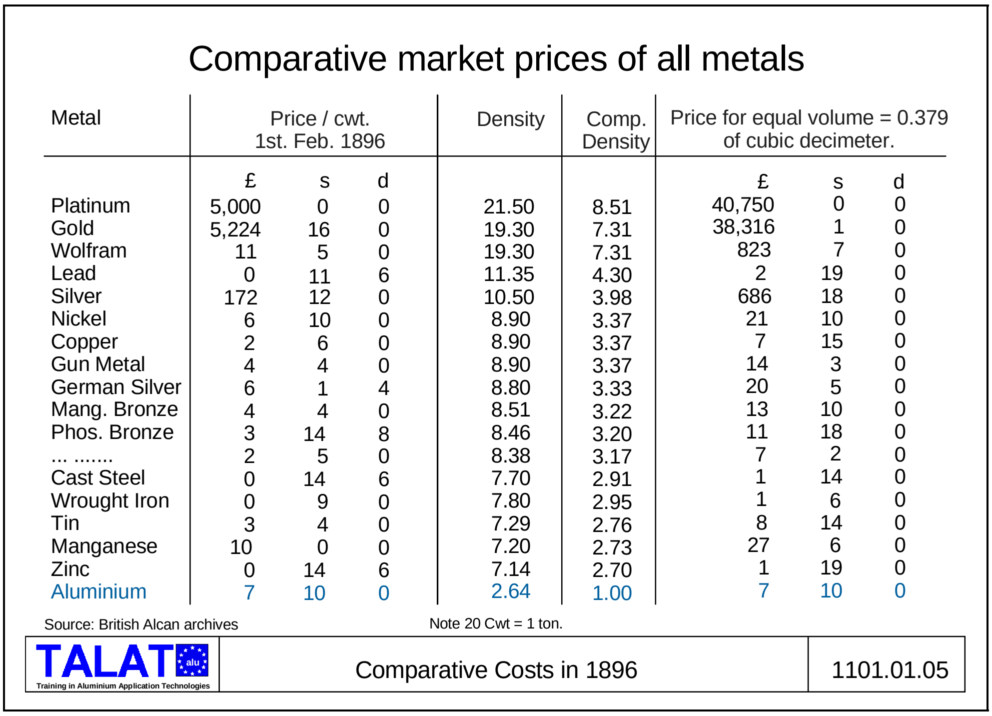
The success of the Hall/Héroult process was compounded in 1888 when Karl Bayer, an Austrian, developed a viable process for producing alumina from bauxite ore. While the Deville production cost savings were the more dramatic in magnitude, the final figure (price) was still uncompetitive with alternative materials. The Hall/Héroult invention closed the critical gap. By 1890 the cost of aluminium had tumbled some 80 percent from Deville's prices (see **Figure 1101.01.04**). The metal was now a commercial proposition, how would it be used?



Source: Light Metals Industry. Temple Press. 1949

TALAT Training in Aluminium Application Technologies | Early Cost Changes | 1101.01.04

Figure 1101.01.05 shows that differences in density make a price per unit of weight largely irrelevant. Price/volume is the key. In most lightly stressed applications it is area that matters most for practical purposes. Thus, in 1896 tin, bronze, gunmetal, German silver, copper and nickel were obvious targets. Substitution of ″cheaper″ materials would be possible only where aluminium could provide a key benefit commanding a premium price.



Comparative market prices of all metals

Metal	Price / cwt. 1st. Feb. 1896			Density	Comp. Density	Price for equal volume = 0.379 of cubic decimeter.		
	£	s	d			£	s	d
Platinum	5,000	0	0	21.50	8.51	40,750	0	0
Gold	5,224	16	0	19.30	7.31	38,316	1	0
Wolfram	11	5	0	19.30	7.31	823	7	0
Lead	0	11	6	11.35	4.30	2	19	0
Silver	172	12	0	10.50	3.98	686	18	0
Nickel	6	10	0	8.90	3.37	21	10	0
Copper	2	6	0	8.90	3.37	7	15	0
Gun Metal	4	4	0	8.90	3.37	14	3	0
German Silver	6	1	4	8.80	3.33	20	5	0
Mang. Bronze	4	4	0	8.51	3.22	13	10	0
Phos. Bronze	3	14	8	8.46	3.20	11	18	0
... .	2	5	0	8.38	3.17	7	2	0
Cast Steel	0	14	6	7.70	2.91	1	14	0
Wrought Iron	0	9	0	7.80	2.95	1	6	0
Tin	3	4	0	7.29	2.76	8	14	0
Manganese	10	0	0	7.20	2.73	27	6	0
Zinc	0	14	6	7.14	2.70	1	19	0
Aluminium	7	10	0	2.64	1.00	7	10	0

Source: British Alcan archives

Note 20 Cwt = 1 ton.

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Comparative Costs in 1896

1101.01.05

The discovery, successful extraction and the first commercial applications of aluminium all took place in the 19th Century. That period's enthusiasm for new materials and their possible use was immense. Not only metals were involved, the first organic plastics were made in the 1870's. The rubber and plywood industries were also established during the same period.

The public in general were also intrigued. Charles Dickens (Household Words, Dec. 13th 1856) commenting on Deville's initial success wrote: "*Aluminium may probably send tin to the right about face, drive copper saucepans into penal servitude, and blow up German-silver sky-high into nothing*".

Some 25 years later J.W. Richards wrote in his standard work "Aluminium" that: "*It has been well said that if the problem of aerial flight is ever to be solved, aluminium will be the chief agent in its solution*".

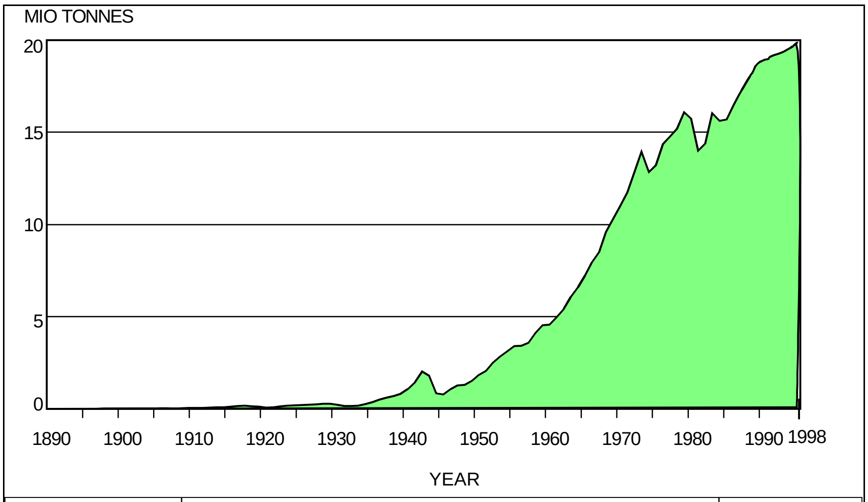
It is important to visualise the technical and economic context of the pioneer efforts.

With hindsight we can say that the Hall/Héroult process was the winner, but at the time is was by no means so obvious. High risk choices had to be made.

During the period between 1855 and 1900 many aluminium manufacturing businesses were established, most briefly prospered and rapidly waned. A select few survived into the 20th Century.

All the pioneers found that once viable production was established that selling the output was very difficult indeed. Markets did not exist, they had to be developed. Above all manufacturing industry, the users of more traditional metals, needed to acquire specific skills to successfully fabricate aluminium end products.

The first target markets involved the substitution of copper, brass and bronze. Despite the problems world production of aluminium soared from less than 200 tonnes in 1885 to something approaching 18 million tonnes in 1990 - plus some 4 million tonnes of recycled aluminium (**Figure 1101.01.06,** also see **Figure 1101.05.01)**. The prophecies of Dickens and Richards have come true!



TALAT Training in Aluminium Application Technologies | World Primary Production | 1101.01.06

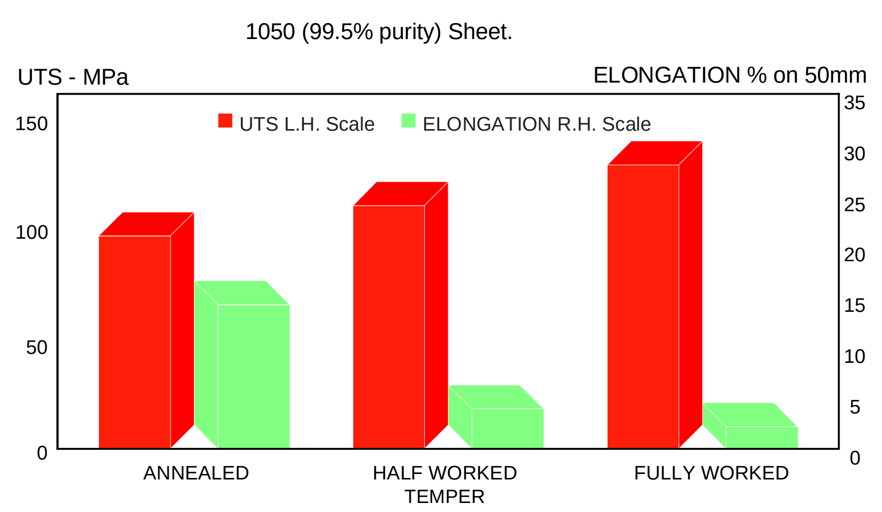
1101.02. Developing Useful Properties and Markets

- Properties of unalloyed aluminium
- Aluminium alloys

Properties of Pure Aluminium

The properties of pure aluminium are remarkable (see **Figure 1101.02.01**). It is comparatively soft metal of limited strength. The properties of 99.5% purity aluminium are such that the obvious first applications were where modest strength was acceptable, e.g. domestic utensils, electrical conductor, decorative uses, etc. Aluminium conducts both heat and electricity well; better than copper on a weight for weight basis. It has high ductility.

Thanks to a natural and tenacious oxide film it has excellent corrosion resistance and in most applications is extremely durable. It is a good reflector of light and heat. It has low emissivity of heat .



Mechanical Properties of Pure Aluminium 1101.02.01

Aluminium has only one third the density of steel.

The pure metal is malleable and easily worked by the main manufacturing processes. Cold working, e.g. rolling, induces higher strength and hardness.

It has poor foundry characteristics.

Wrought aluminium products such as sheet, rod and wire in unalloyed form were the infant industry's first commercial offerings.

If it was the inventive genius of Hall and Héroult that made aluminium commercially available, it was the subsequent development of alloys, enhancing the properties of pure metal, that brought about aluminium's dominance amongst non-ferrous metals.

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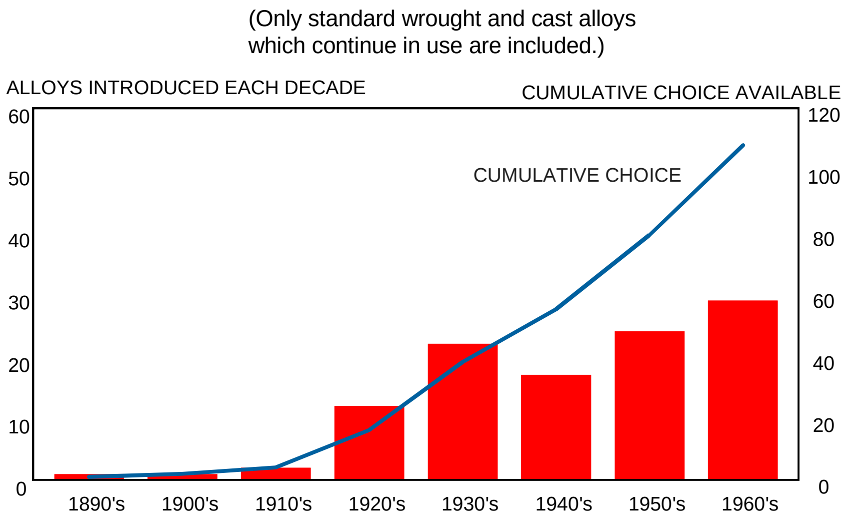
Aluminium Alloys

Even earlier than 1886 aluminium had been employed as an alloying constituent in bronze and as a de-oxidant in steel making.

The first official alloy designation that denotes commercially pure aluminium dates back to 1888. Since then the introduction of new wrought and casting alloys, each developed for specific qualities, has continued steadily until the present day (**Figure 1101.02.02**). The range of alloy choice is important. The number of widely used commercial alloys is of course much smaller. Designers should try to avoid a fixation on the familiar specification, it may not be a logical choice for a new product or application.


(Only standard wrought and cast alloys
which continue in use are included.)

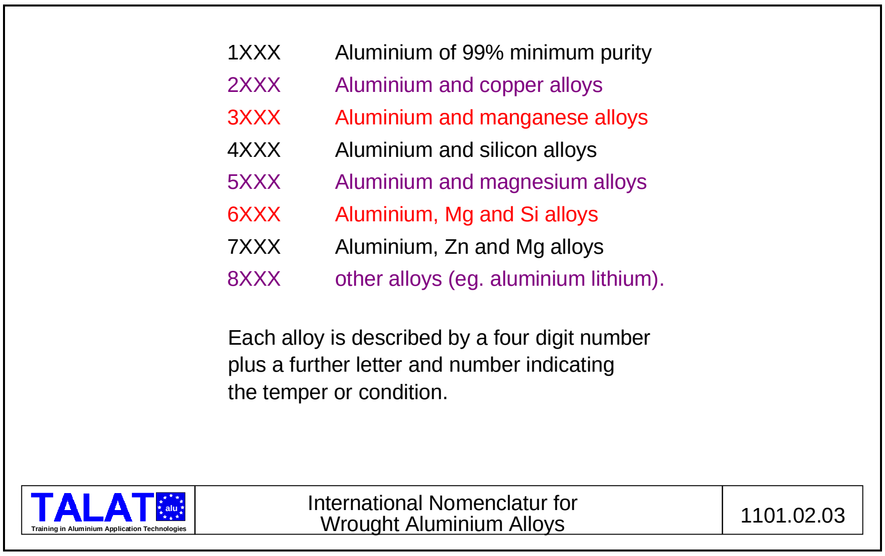
Source: Aluminum Association

TALAT Training in Aluminium Application Technologies | More Alloy Choice - More Decisions | 1101.02.02

There is an impressive array of commercially available alloys the composition and logic being regulated by agreed international nomenclature. For wrought alloys each is described by a four digit number plus further letter and number indicating the temper or condition of the alloy (see **Figure 1101.02.03**).

The classification provides for :

1xxx aluminium of 99% min. purity
2xxx aluminium and copper alloys
3xxx aluminium and manganese alloys
4xxx aluminium and silicon alloys
5xxx aluminium and magnesium alloys
6xxx aluminium, Mg and Si alloys
7xxx aluminium, Zn and Mg alloys
8xxx other alloys (e.g. aluminium lithium)

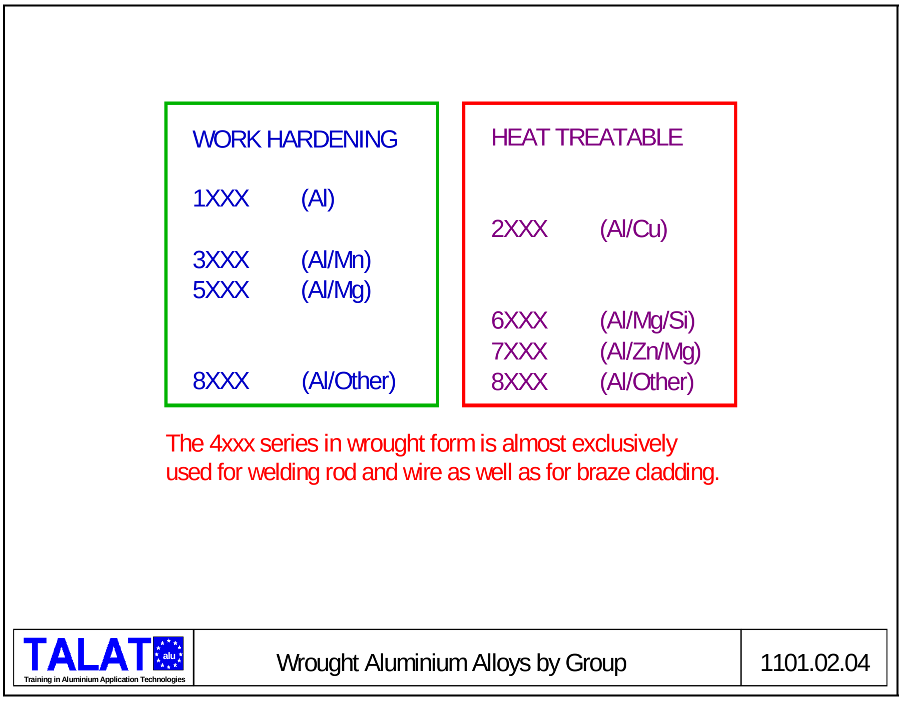


1XXX	Aluminium of 99% minimum purity
2XXX	Aluminium and copper alloys
3XXX	Aluminium and manganese alloys
4XXX	Aluminium and silicon alloys
5XXX	Aluminium and magnesium alloys
6XXX	Aluminium, Mg and Si alloys
7XXX	Aluminium, Zn and Mg alloys
8XXX	other alloys (eg. aluminium lithium).

Each alloy is described by a four digit number plus a further letter and number indicating the temper or condition.

TALAT Training in Aluminium Application Technologies | International Nomenclatur for Wrought Aluminium Alloys | 1101.02.03

These alloys fall into two main groups (**Figure 1101.02.04**). The work hardening alloys, where strength is related to the amount of 'cold work' applied, by rolling or forming, and heat treatable or precipitation hardening alloys. With the latter strength and other properties are enhanced by heat treatment of various kinds.



WORK HARDENING		HEAT TREATABLE	
1XXX	(Al)	2XXX	(Al/Cu)
3XXX	(Al/Mn)	6XXX	(Al/Mg/Si)
5XXX	(Al/Mg)	7XXX	(Al/Zn/Mg)
8XXX	(Al/Other)	8XXX	(Al/Other)

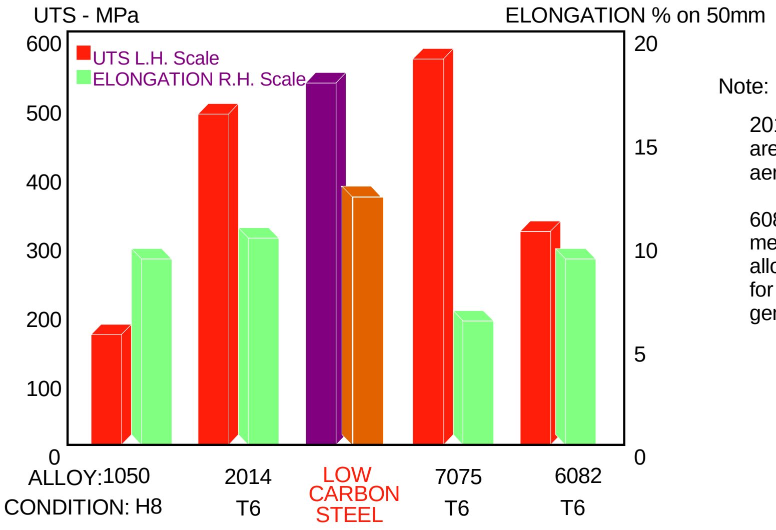
The 4xxx series in wrought form is almost exclusively used for welding rod and wire as well as for braze cladding.

TALAT Training in Aluminium Application Technologies | Wrought Aluminium Alloys by Group | 1101.02.04

In 1906, Alfred Wilm, a metallurgist working at Düren in Germany, quenched an experimental AlCu-alloy after annealing it and left the specimen on the bench over the weekend. Testing it a few days later he found that both hardness and strength had increased simply by having been left at room temperature. Wilm gave the name 'Duralumin' to his alloys after the place where they were first made.

This discovery of hardening during natural ageing was a vital turning point. It became possible eventually to endow aluminium with strengths comparable with steel, so providing structural alloys for aircraft and many other markets. Indeed, by 1912 aluminium alloy properties were equated to those of ash - then the principal structural material for aircraft (**Figure 1101.02.05**). Alloys 2014 and 7075 are virtually unweldable, as are most copper containing alloys. 6082 is weldable, hence its usefulness in many commercial applications. The limits on the solution of alloy constituents are set by the speed of solidification possible with conventionally manufactured aluminium alloy ingots. This restriction can be overcome by less conventional production routes, e.g. powder metallurgy (see also TALAT lectures 1400).

All the wrought alloys are amenable to commonly used metal working processes such as rolling, extrusion and forging. Casting alloys with four-figure or other designation provide specific combinations of properties allied to acceptable foundry characteristics. All have been devised to meet particular requirements and offer different combinations of properties.



Note:

2014 and 7075 are typical aerospace alloys.

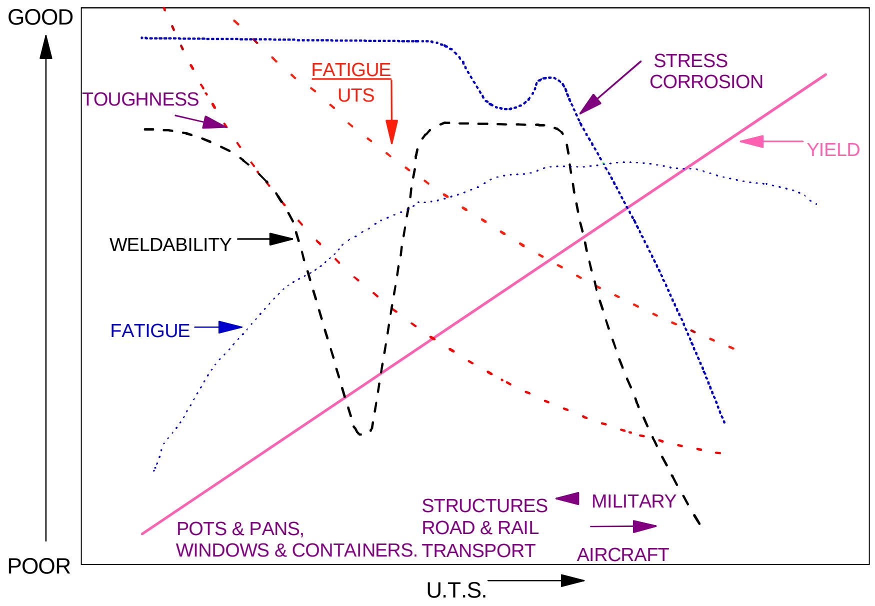
6082 is a medium strength alloy widely used for transport and general structures.

TALAT alu Training in Aluminium Application Technologies

1050-H8 (99.5% Al) Compared with Heat Treatable Alloys and Work Hardening Alloys

1101.02.05

Particular properties vary for different reasons, heat treatment or chemical composition for example (**Figure 1101.02.06**). This unscaled purely indicative diagram is intended to stress the importance of selecting alloys on the basis of several properties. The vertical axis rises from ″poor″ to ″good″, the central zone of medium strength weldable alloys involve AlMg compositions with AlZnMg at the right-hand or higher strength margin. The selection available is thus more in the nature of a full restaurant menu rather than ″today's special″. The end product designer needs to know his or her way around the menu if the full benefits of the metal are to be exploited.



Source: A.R. Woodward

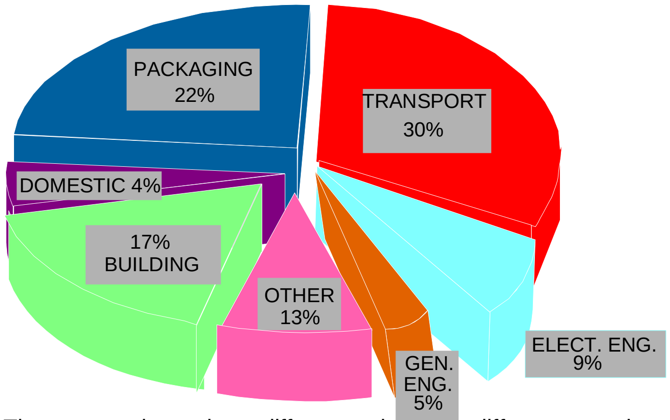
TALAT Training in Aluminium Application Technologies | Properties Vary | 1101.02.06

1101.03 Principal Markets

- Building and Construction
- Transportation
- Electrical engineering
- Packaging
- Other applications

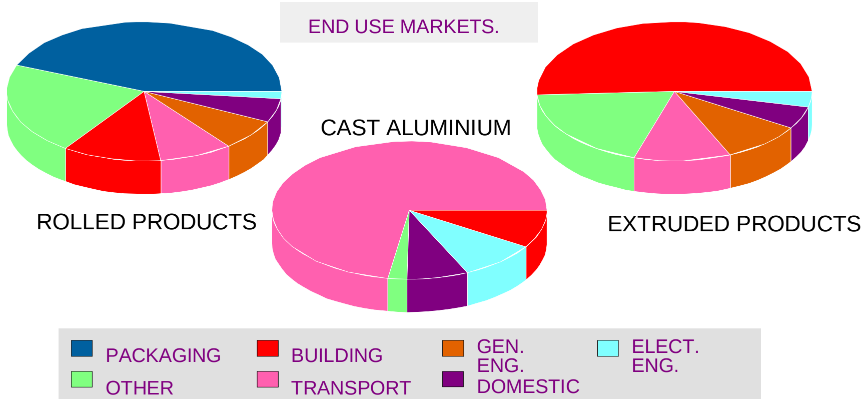
The principal markets for aluminium are represented in **Figures 1101.03.01** and **1101.03.02.**

END USE MARKETS 1997



Note: There are major end use differences between different wrought products, and equally wide variations between national markets.

TALAT Training in Aluminium Application Technologies | Aluminium Semis in Europe | 1101.03.01



Source: European Aluminium Association 1991

TALAT Training in Aluminium Application Technologies | Aluminium Semis in Europe | 1101.03.02

Building and Construction

In buildings aluminium was initially used for decorative purposes. Today it is used in wall panels, roofing, partitions, windows, doors, awnings and canopies. All aluminium structures and sub-structures are growing in popularity. Durability and finish ability are the key benefits closely followed by extrudability - complex architectural sections can be produced (see **Figure 1101.03.03**).

Much construction equipment, e.g. scaffolding, staging and ladders employ the metal. A major sector of the market is in home improvements; glass houses, conservatories etc. Competitive materials include: steel, brick, concrete, timber, plastic, copper and lead.

TALAT Training in Aluminium Application Technologies | Building Applications | 1101.03.03

TALAT Training in Aluminium Application Technologies | Transport Applications | 1101.03.04

Transportation

(see **Figure 1101.03.04**)

Strength to weight plus durability are the main reasons for aluminium being specified. The overwhelming tonnage goes into road transport, aircraft represent no more than 5% of the industry's shipments. In aerospace aluminium usage has long dominated all other constructional materials. The metal constitutes about 80% of a civil airliner's structural weight. Competing materials include: titanium, magnesium and carbon fibre composites.

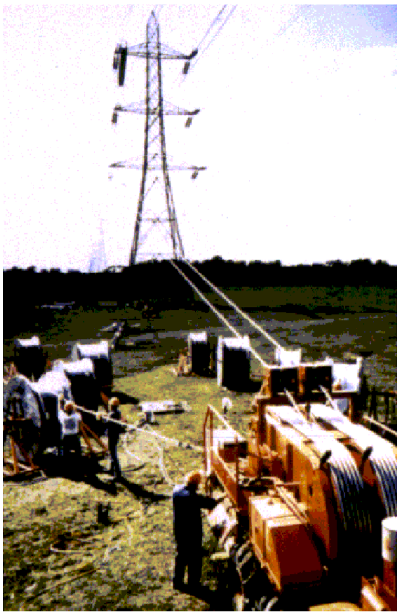
Aluminium trains and rolling stock are in widespread use as railroads seek for operational economics.

Automobile designers have turned to aluminium for the same reason. Bodies, bumpers, radiators, wheels and engine components can be made in aluminium - and frequently are.
Commercial and public service vehicles, where payload is at a premium, incorporate substantial quantities of the metal. In both rail and road transport the competing material include iron, steel, timber and plastic (incl. glass reinforced plastic).

On the water aluminium masts and spars are now more common than wood for small craft. Aluminium hulls are not a rarity. Larger vessels have been built with aluminium superstructures, the Queen Elizabeth 2 has some 1500 tonnes on board. The competition is primarily steel, timber and GRP in small craft.

Electric Engineering

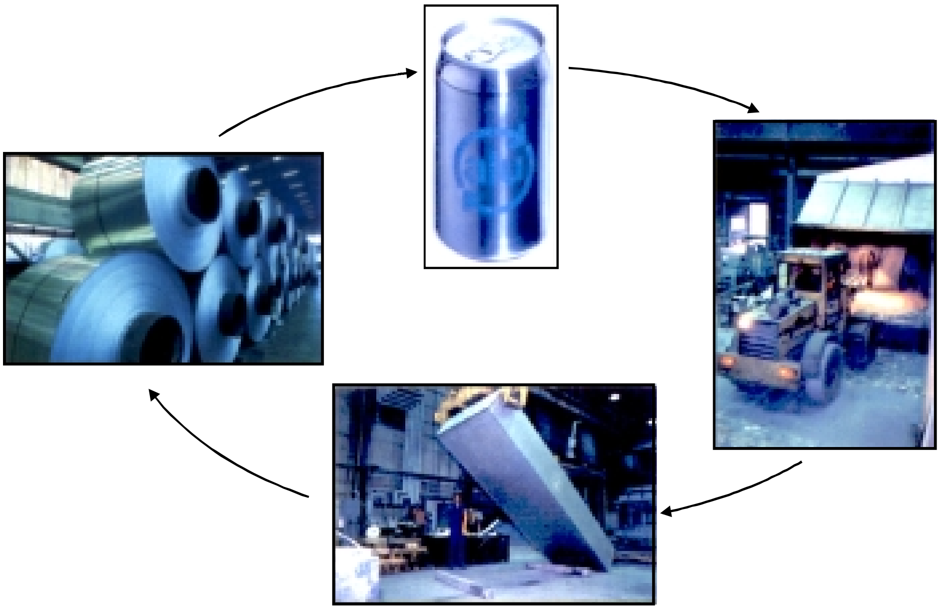
In the electrical field aluminium is widely used for long distance high voltage transmission lines (see **Figure 1101.03.05**). Virtually all high voltage transmission lines use aluminium conductor. Although larger in cross section than the equivalent copper cable, the aluminium conductor is only half the weight allowing larger pylon spacing and easier stringing. The electrical industry as a whole employs the metal for many purposes including busbars, condenser windings, heat exchangers, equipment housings and electrical hardware. The competitor is principally copper.



TALAT Training in Aluminium Application Technologies | Electricity Transmission | 1101.03.05

Packaging

The recyclable beverage can, made from aluminium, is now an integral part of modern living competing on equal terms with tin plated steel (**Figure 1101.03.06**). It is one of the few products that as ″used″ scrap can be recycled back into can stock and thus new cans. It therefore commands a premium scrap price and, once the collecting infrastructure is in place, achieves high levels of recycling.

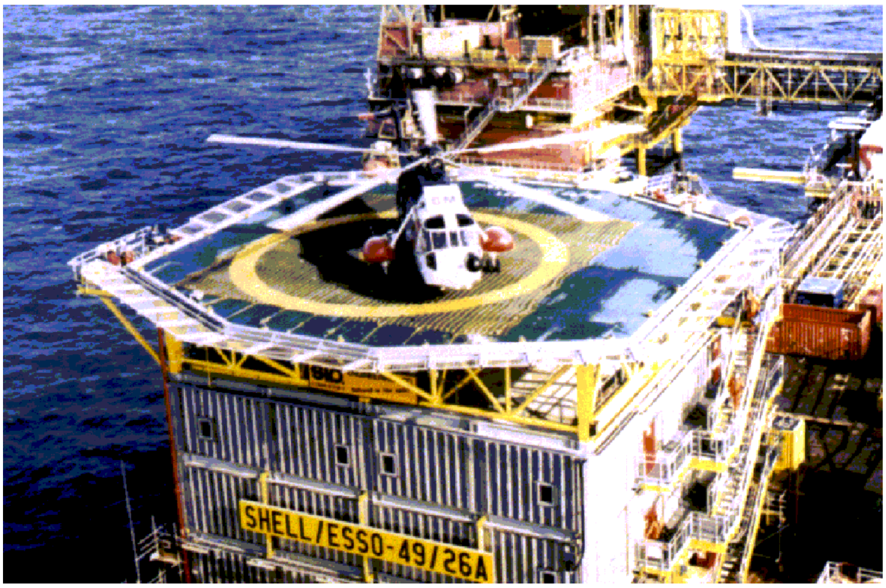


TALAT Training in Aluminium Application Technologies | Recyclable Beverage Cans | 1101.03.06

The metal is also used for many other types of containers, caps and closures. Aluminium foil, on its own or laminated to paper or plastic, is excellent for preserving foodstuffs - and making the package attractive.

Other Applications

There are a myriad other uses, some that use significant quantities of aluminium are: Lithographic sheets (for printing), storage silos, TV aerials and dishes, domestic appliances, office equipment and offshore structures for oil industry. Weight saving and freedom from maintenance are the key benefits. Weight saved on the superstructure of an oil rig can result in massive savings in structural cost below sea level (**Figure 1101.03.07**).



TALAT Training in Aluminium Application Technologies | Off-Shore Structures | 1101.03.07

The consumption of aluminium varies widely in different parts of the world. Many uses considered commonplace in North America and Europe are not yet widespread elsewhere. **Figure 1101.03.08** shows an Indian bullock cart: at a cost premium of 10/15% the aluminium cart offers twice the useful life and an extra payload of 200/400kg. It also saves three scarce trees from being felled.

Much remains to be done to fully exploit proven uses and their associated aluminium application technologies.

TALAT Training in Aluminium Application Technologies | National Variety: Indian Bullock Cart | 1101.03.08

1101.04 Production of Primary Aluminium and Semi-finished Production

- Primary aluminium
- Semi-fabricating
  - Rolling
  - Forging
  - Casting
  - Extrusion

Primary Aluminium

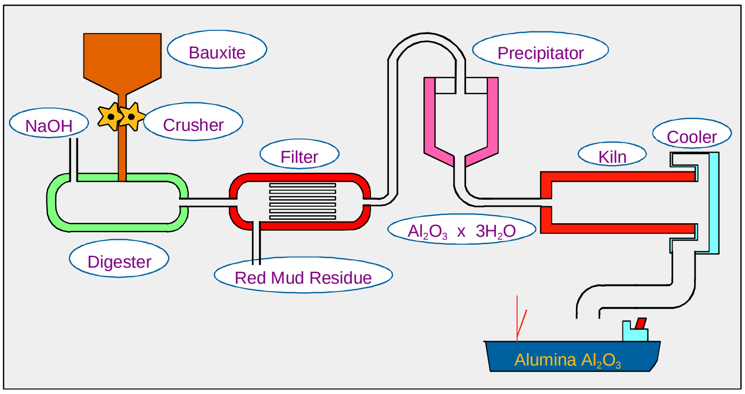
Aluminium produced from ore via the alumina stage is termed primary metal to distinguish it from secondary or recycled aluminium.

The ore most commonly used for the extraction process is bauxite - named after Les Baux in France where it was first identified. Bauxite is rich in aluminium oxide, typically 40 to 60%, the remainder being mainly iron and silicon compounds. Aluvial deposits near the surface, and thus amenable to opencast working, are normally used.

Today the greatest proportion of bauxite is mined in Australia, West Africa, Brazil and Jamaica. Crushed, and if necessary dried, bauxite is shipped to the alumina plant. This may be adjacent to the deposits or half way round the world nearer to the smelter.

The economic size of modern alumina plants is large, capacities of 800,000 to 1,000,000 tonnes per annum being the norm when producing metallurgical grades. A substantial, though smaller, quantity of alumina hydrates are used for non-metallurgical end uses. This activity constitutes a chemical industry in its own right. The extraction process, devised by Karl Josef Bayer in the late 1880's depends on the fact that aluminium trihydrate dissolves in heated caustic soda but the impurities do not; this enables practically pure aluminium oxide (alumina) to be separated. **Figure 1101.04.01** is a much simplified schematic diagram. A full sized plant is a large complex with perhaps a quarter of a million tonnes of steel pipework and tanks. The kiln can be rotary (like a cement works) or, in more modern plants a fluid bed furnace.

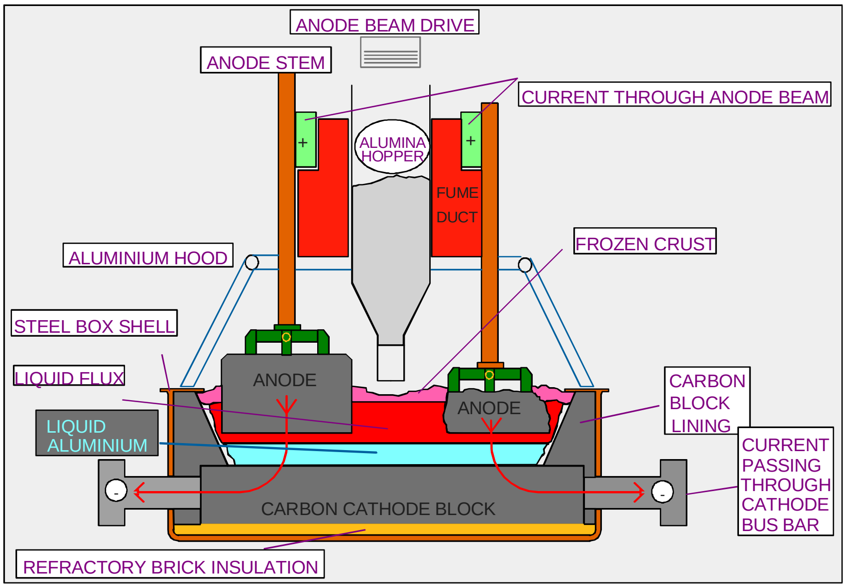
The bauxite is crushed and ground to powder, then mixed at high temperature with a solution of caustic soda (NaOH) in digesters, under pressure. The aluminium trihydrate dissolves in the caustic soda, forming sodium aluminate which, being soluble, can be passed through filters, leaving the insoluble impurities behind. The aluminate solution is pumped into precipitator tanks 25 metres high, in which very fine and pure particles of aluminium trihydrate are added as "seed". Under agitation by compressed air with gradual cooling, pure aluminium trihydrate precipitates on the "seed" and is then separated from the caustic soda solution by settling and filtration. Heating to 1000-1100 degrees C, drives off the chemically combined water, leaving the alumina as a fine white powder suitable for the electrolytic smelting process. The caustic soda is recovered and returned to the start of the process, to be used over again to treat fresh bauxite.



The Chemical Process: Bayer Process 1101.04.01

Four tonnes of bauxite are required to produce two tonnes of alumina, which in turn produce one tonne of aluminium at the primary smelter. The logistical implications are clear, for each million tonnes of primary metal produced four million tonnes of bauxite and two million tonnes of alumina have to be transported.

At the smelter the alumina is mixed with cryolite (sodium aluminium fluoride), which at a temperature of about 950 degrees C, forms the electrolyte of the large "cells" or "pots". Each pot is a steel shell up to 10m in length, some 4m wide and 1.5m deep, lined with pure carbon, baked hard. The lining acts as the cathode of the electrolytic cell. Suspended in the middle of the pot are the consumable carbon anode blocks through which the electric current enters the cell. Pots run on very low voltage but high amperage, 180,000 amps or more being typical values for a modern smelter (see **Figure 1101.04.02).** The alumina hopper has a built-in crust breaking prong to allow computer controlled injections of alumina into the fused electrolyte. Anode adjustment is computer controlled, anode replacement is mechanically assisted.

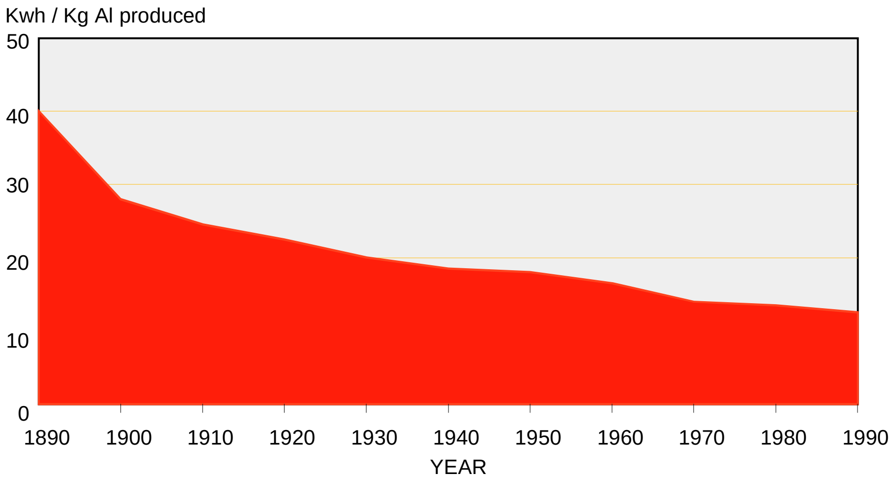


TALAT Training in Aluminium Application Technologies | Cross Section of an Electrolytic Cell | 1101.04.02

Each cell in a primary smelter produces over 1 tonne of molten aluminium each 24 hours. The operation is continuous for the life of the pot which may well be between 5 and 10 years. With a modern smelter having an annual capacity of 150 to 250 thousand tonnes there will be several hundred pots. The molten metal is syphoned out of the pots and taken to a cast house for further processing.

Clearly, large amounts of electrical energy are required and the cost of power is critical to successful operation. Over 60 percent of primary aluminium production uses renewable hydro-electric power and smelters tend to be located near suitable watersheds. Such a large element of basic cost has been subjected to continuous study during the 100 years production experience of the Hall/Héroult process. Early plants needed 40 to 50 KWh to produce 1kg of metal, modern smelters only use 12 to 14 **(Figure 1101.04.03).**

At the primary smelter the metal can be cast into ingots (pig) or larger blocks (sows) for subsequent remelting. More usually the metal is alloyed at the smelter and then cast into extrusion billet (cylindrical) or rolling ingot (rectangular slabs). A semi-continuous process known as direct chill casting (DC) is employed.



Source: Aluminiumteknik 1991

TALAT Training in Aluminium Application Technologies	Development of Electricity Consumption in the Electrolytic Process	1101.04.03

The primary smelter products are shipped to factories that make what are known as semi-fabricated products. These are the types of material required by end product manufacturers.

Semi-fabricating

Semi-fabricating involves mainly the following processes:

Rolling.

Rolling ingot is hot rolled down to plate or slab. The slab is subsequently cold rolled to sheet or foil thicknesses, with intermediate annealing where necessary.

Forging.

The metal is hammered or pressed into required shapes which have been cut into facing dies. The starting stock can be either cast blocks or extruded bar.

Casting.

This is the oldest and simplest (in theory if not in practice!) means of manufacturing shaped components. The metal is melted and poured into moulds of the required shape. Moulding in sand is one of the oldest industrial arts and still practised extensively. Other processes include gravity (or permanent mould) die casting in which the aluminium flows by gravity into a metal mould and pressure die casting in which molten metal is forced under pressure into a steel die.

Extrusion.

This process entails forcing heated metal through a die cut to the cross section of the required shape, in much the same way as toothpaste is squeezed from its tube. This is the principal method of making structural shapes, tubes and an endless variety of sections both large and small.

Although other processes are used, particularly for specialist products and purposes, these four semi-fabricating routes account for the overwhelming proportion of aluminium used by manufacturing industry.

The production of both alumina and primary aluminium are highly capital intensive and the volume production of semi-fabricated products requires substantial investment. The aluminium industry tends therefore to be vertically integrated from alumina to semi-fabs.
The further fabrication of semi-fabs into finished products is ideally suited to light manufacturing facilities needing more modest capital investment.

1101.05 Development of the European Industry

As previously mentioned the industry in 1890 was divided by the Hall patent in the USA and Héroult patent in France. At the interface between the two there were some stormy incidents with litigation about patent rights in various parts of the world. The colonies - remember them? - were a particular bone of contention. Eventually an uneasy but generally peaceful relationship was established.

When the two patents finally lapsed the differences became less disruptive. Since 1945 many more aluminium companies have become truly international with their operations spread over several continents.

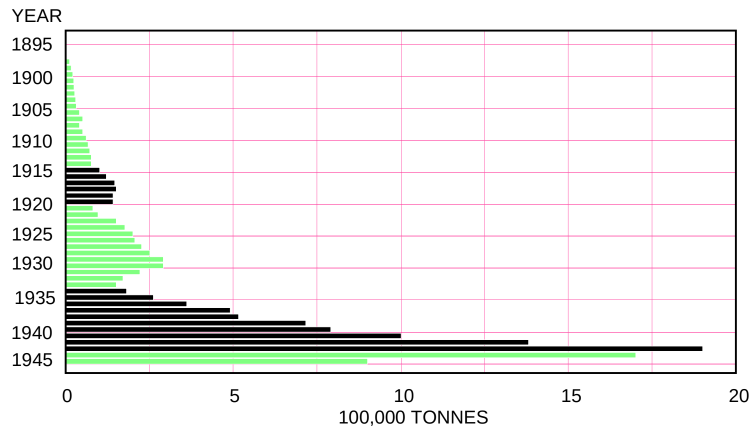
Because of the difficulty initially in selling aluminium in ingot form, the first companies rapidly started to integrate forward so that they could offer a full range of semi-fabricated products and in some cases consumer products.

The classic example of this trend was Hall's own company in the USA, The Pittsburgh Reduction Company, soon renamed the Aluminum Company of America, which found itself becoming a major manufacturer of domestic holloware. It could find no established company in that business willing to manufacture in aluminium.

In Europe many companies were formed to provide a wide range of semi-fabs in modest quantities to national markets. As consumption grew the economies of larger scale production became attainable, a process that naturally led to mergers, acquisitions and eventually joint ventures.

In the first half of the 20th Century the development of the motorcar and the aeroplane, coupled with the massive demands of two major wars in under twenty years, produced phenomenal growth.

The First World War more than doubled capacity in three years, the second was even more spectacular providing 600% growth in under ten years from a much higher base. In both cases peacetime demand caught up with the available capacity within five or six years (**Figure 1101.05.01**).



Source: Light Metals Industry. 1949

TALAT Training in Aluminium Application Technologies | 50 Year's Production of Aluminium | 1101.05.01

From 1950 onward aluminium consumption grew at a relatively steady 8% compound for another 25 to 30 years - with packaging and building applications amongst the leaders.

Clearly production efficiencies had to be massively improved to meet this demand, and the availability of secondary (recycled) metal and its economic attractions increased (see also **Figure 1101.05.02**).

In alumina production the size of plant increased to present day levels of 1 million t.p.a. or more. Not surprisingly many new alumina plants are joint ventures. The cost of bulk shipment has fallen in real terms for both bauxite and alumina as bulk carrier vessels have increased in size.

In smelting the individual pots grew in size and the operating amperage increased. For obvious reasons a large pot is thermally more efficient than a smaller one. Anode technology and detailed cell design has steadily improved. The service life of the pot has been extended by several years.

Despite these improvements the total power requirement for a smelter has increased as the economic size grew. This has led to new smelters - being concentrated even more in favourable power cost regions.

In the European aluminium industry today:

- 13 alumina plants produce 6.6 million tonnes
- 40 primary smelters produce 3.8 million tonnes
- 60 rolling mills, 200 extrusion plants produce 4.8 million tonnes of semi-fabricated products
- 2500 foundries produce 1.4 million tonnes of castings
- 200 secondary refiners produce 1.7 million tonnes, which represent 31 % of the metal supply
- The industry directly employs over 200,000 people
- In 1991 the total turnover was 25 billion ECU and investment in plant was 2.5 billion ECU

European Aluminium Industry Today (1991) 1101.05.02

Semi-fabricated product manufacture has seen the greatest productivity improvement within the entire industry. Sheet mills within a 25 year period have increased rolling speeds from 150m/minute to over 600m, strip width has doubled and coil sizes have grown from 1 to 2 tonnes to 15 to 20 tonnes or more.

The average extrusion press a quarter of a century ago produced perhaps 1/2 tonne of section per hour with a crew of 6 or more people; a modern press has three times the output with half the crew.

All these changes involve much greater specialisation and lead to plants requiring markets far beyond their national boundaries, especially for rolled products. The speed of change has also varied from country to country; the adjustment by many of the former controlled economies in Eastern Europe still has to take place.

Reference to a trade directory will show that the most commonly required semi-fabs are still manufactured in many European countries. Such references do not indicate the scale of manufacture or the corporate links that bind many of these plants across international borders.

1101.06 Literature

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1101.07 List of Figures