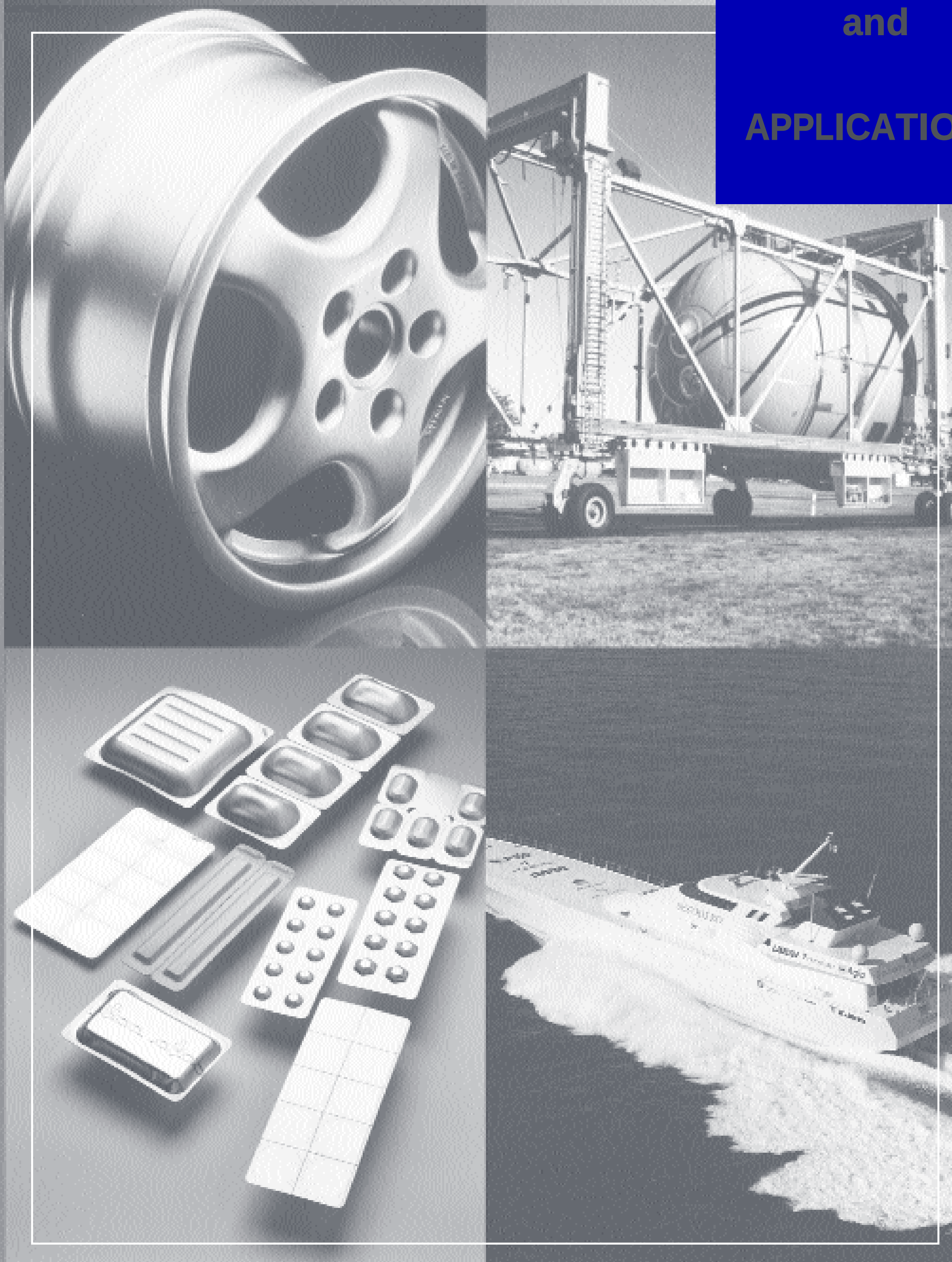
ALUMINUM ALLOY

SELECTION

and

APPLICATIONS



The Aluminum Association, Inc.

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Aluminum Alloy Selection and Applications

This monograph contains an outstanding introductory description of the properties of wrought and cast aluminum alloys and the enormous variety of their applications. From transportation and packing to construction, infrastructure and aerospace, the versatility of aluminum as a practical material is amply documented.The text is richly illustrated with numerous applications which demonstrate the enormous flexibility and the wide range of applications for aluminum alloys.

This publication will be invaluable to engineers,designers and students unfamiliar with the variety of aluminum alloys and to those faced with an alloy selection decision. It outlines many of the issues to consider in selecting an alloy for a specific application and environment. Starting with a description of the aluminum alloy designation system,the text describes the major alloy series, outlines their primary chemical constituents, mechanical properties and major characteristics,and provides numerous examples of specific alloys in use.

In summary, this monograph provides a lot of clarity to the process of selecting alloys for various applications.

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Introduction & Scope

1

Aluminum and its alloys offer an extremely wide range of capability and applicability, with a unique combination of advantages that make it the material of choice for numerous products and markets. It is the purpose of this presentation to (a) provide an overview of the various types of aluminum alloys that are available to engineers,designers,and others considering aluminum for new products or applications, and (b) to describe the properties and characteristics that make aluminum alloys so useful.

The breadth of individual alloys and of applications is so broad that it will be necessary to hit only the highlights and provide representative examples. For more detail on the alloys,their properties,and the applications,I refer you to the new textbook on the subject, ***"Aluminum: Technology, Applications, and Environment"***, by Dr. Dietrich G. Altenpohl.

In what follows, we will look first at the Aluminum Association Alloy and Temper Designation Systems,as these are the systems that make the tracking and recognition of the alloys and their characteristics relatively straightforward.Then we will begin an overview by alloy type, first for wrought alloys and then for cast alloys,covering the characteristics and most important applications of those alloys. By way of background,wrought alloys are those which are cast as ingot or billet and then mechanically worked by some process such as rolling, extrusion,or forgings to final form;cast alloys are those which are cast to final or near final form with out any mechanical working.The wrought and cast alloys,their properties and their applications are somewhat different and so we will discuss them separately.

2

The Aluminum Association Alloy and Temper Designation System

The Aluminum Association Alloy and Temper Designation System is recognized by the American National Standards Institute (ANSI) as the United States national standard,and as such is incorporated into ANSI Standards H35.1.and H35.2. The maintenance of the system is managed by the Aluminum Association, Inc.,under ANSI's charter. In addition, there is an International Accord recognizing the Aluminum Association Wrought Alloy Designation System as the de facto international standard;this Accord has been ratified by almost all of the world's aluminum producing countries.

The alloy designation system is briefly described below, first for wrought alloys and then for cast alloys,and these are followed by a brief description of the temper designation system. More detailed information on The Aluminum Association Alloy & Temper Designation System may be gained from study of section 1.0 of Aluminum Association publication "Aluminum Standards & Data."

2.1 Alloy Designation System – Wrought Alloys

— First digit - Principal alloying constituent(s)

— Second digit - Variations of initial alloy

— Third and fourth digits - Individual alloy variations (number has no significance but is unique)

- 1xxx - Pure Al (99. 00% or greater)
- 2xxx - Al-Cu Alloys
- 3xxx - Al-Mn Alloys
- 4xxx - Al-Si Alloys
- 5xxx - Al-Mg Alloys
- 6xxx - Al-Mg-Si Alloys
- 7xxx - Al-Zn Alloys
- 8xxx - Al+Other Elements
- 9xxx - Unused series

2.2 Alloy Designation System — Casting Alloys

— First digit -Principal alloying constituent(s)

— Second and third digits - Specific alloy designation (number has no significance but is unique)

— Fourth digit - Casting (0) or ingot (1,2) designation

— Variations indicated by preceding letter (A,B, C)

- lxx.x - Pure Al (99.00% or greater)
- 2xx.x - Al-Cu Alloys
- 3xx.x - Al-Si + Cu and/or Mg
- 4xx.x - Al-Si
- 5xx.x - Al-Mg
- 7xx.x - Al-Zn
- 8xx.x - Al-Sn
- 9xx.x - Al+Other Elements
- 6xx.x - Unused Series

2.3 Tempers Designation System

F - As-fabricated

0 - Annealed

H - Strain-hardened (wrought products only)

W- Solution heat-treated

T - Thermally treated to produce tempers other than F,O,H (usually solution heat-treated,quenched and precipitation hardened)

Numeric additions indicate specific variations

e.g.,T6 = solution heat treated and artificially aged

3

A Review of Aluminum Alloy Series, Their Principal Characteristics and Applications

3.1 Wrought Alloys

1xxx - Pure Al

- Strain hardenable
- High formability, corrosion resistance and electrical conductivity
- Electrical, chemical applications
- Representative designations: 1100,1350
- Typical ultimate tensile strength range:10-27 ksi

The 1xxx series represents the commercially pure aluminum, ranging from the baseline 1100 (99.00% min. Al) to relatively purer 1050/1350 (99.50% min. Al) and 1175 (99.75 % min. Al).Some,like 1350 which is used especially for electrical applications,have relatively tight controls on those impurities that might lower electrical conductivity.

The 1xxx series are strain-hardenable,but would not be used where strength is a prime consideration. Rather the emphasis would be on those applications where extremely high corrosion resistance, formability and/or electrical conductivity are required,e.g., foil and strip for packaging, chemical equipment,tank car or truck bodies,spun hollowware,and elaborate sheet metal work.

Among the specific illustrations provided:

Fig.1.1 - Aluminum electrical bus bar installation with 1350 bus bar

Fig.1. 2 - Food packaging trays of pure aluminum (1100)

Fig.1. 3 - Decorated foil pouches for food and drink (1060 or 1100)

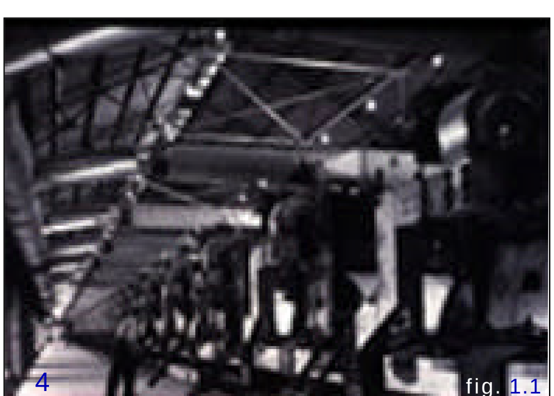
fig. 1.1


fig. 1.2

fig. 1.3

2xxx - Al-Cu Alloys

- Heat treatable
- High strength,at room & elevated temperatures
- Aircraft, transportation applications
- Representative alloys:2014,2017, 2024,2219,2195
- Typical ultimate tensile strength range:27-62 ksi

The 2xxx series are heat-treatable,and possess in individual alloys good combinations of high strength (especially at elevated temperatures),toughness, and,in specific cases, weldability;they are not resistant to atmospheric corrosion, and so are usually painted or clad in such exposures.The higher strength 2xxx alloys are primarily used for aircraft (2024) and truck body (2014) applications; these are usually used in bolted or riveted construction.Specific members of the series (e.g.,2219 and 2048) are readily welded,and so are used for aerospace applications where that is the preferred joining method.

Alloy 2195 is a new Li-bearing alloy for space applications providing very high modulus of elasticity along with high strength and weldability.There are also high-toughness versions of several of the alloys (e.g.,2124, 2324,2419), which have tighter control on the impurities that may diminish resistance to unstable fracture,all developed specifically for the aircraft industry. Alloys 2011,2017, and 2117 are widely used for fasteners and screw-machine stock.

Illustrations of applications for the 2xxxx series alloys include:

Fig. 2.1 - Aircraft internal structure includes extrusions and plate of 2xxx and 7xxx alloys like 2024,2124 and 2618. External sheet skin may be alclad 2024 or 2618;the higher purity cladding provides corrosion protection to the Al-Cu alloys that will darken with age otherwise.

Fig. 2.2 - Heavy dump and tank trucks and trailer trucks employ 2xxx extrusions for their structural members.

Fig.2.3 - The fuel tanks and
Fig. 2.4 - booster rockets of the Space Shuttle are 2xxx alloys, originally 2219 and 2419,now sometimes Al-Li “Weldalite”alloy 2195.

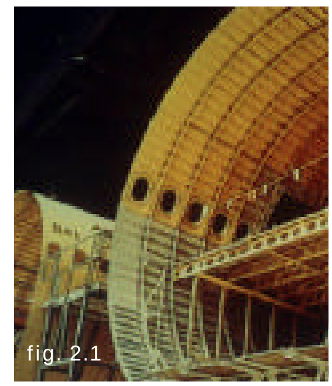
fig. 2.1

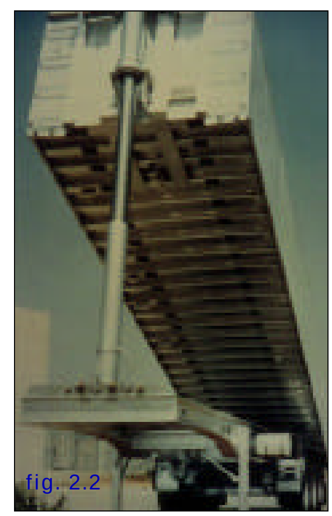
fig. 2.2


fig. 2.4


fig. 2.3

3xxx - Al-Mn Alloys

- High formability, corrosion resistance,and joinability;medium strength
- Heat transfer, packaging, roofing-siding applications
- Representative alloys:3003,3004,3005
- Typical ultimate tensile strength range:16-41 ksi

The 3xxx series are strain-hardenable, have excellent corrosion resistance,and are readily welded,brazed and soldered. Alloy 3003 is widely used in cooking utensils and chemical equipment because of its superiority in handling many foods and chemicals,and in builders'hardware. Alloy 3105 is a principal for roofing and siding. Variations of the 3xxx series are used in sheet and tubular form for heat exchangers in vehicles and power plants.

Alloy 3004 and its modification 3104 are among the most widely used aluminum alloys because they are drawn and ironed into the bodies of beverage cans.

Typical applications include:

Fig.3.1 - Automotive radiator heat exchangers are of alloys like 3002.

Fig. 3.2 - Alloy 3003 tubing in commercial power plant heat exchanger.

Fig.3.3 - The bodies of beverage cans are alloys 3004 or 3104,making it the largest volume alloy combination in the industry.

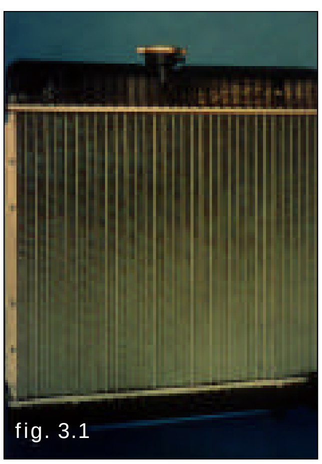
fig. 3.1

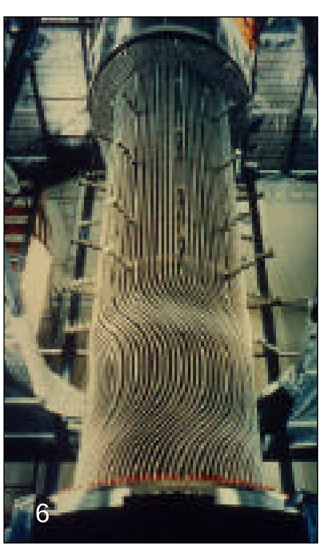
fig. 3.2


fig. 3.3

4xxx - Al-Si Alloys

- Heat treatable
- Good flow characteristics, medium strength
- Pistons,complex-shaped forgings;
- Representative alloys:4032 and filler alloy 4043
- Typical ultimate tensile strength range:25-55 ksi

Of the two most widely used 4xxx alloys, 4032 is a medium high-strength,heat-treatable alloy used principally for forgings in applications such as aircraft pistons. Alloy 4043 on the other hand is one of the most widely used filler alloys for gas-metal arc (GMA) and gas-tungsten arc (GTA) welding 6xxx alloys for structural and automotive applications.

The same characteristic leads to both applications: good flow characteristic provided by the high silicon content, which in the case of forgings ensures the filling of complex dies and in the case of welding ensures complete filling of crevices and grooves in the members to be joined. For the same reason,other variations of the 4xxx alloys are used for the cladding on brazing sheet, the component that flows to complete the bond.

The several classes of 4xxx alloys in widest use are represented by the following applications:

Fig. 4.1 - Refrigerator coolant circulation system in brazed unit of high-Si brazing alloy sheet.

Fig. 4.2 - Alloy 4043 is one of the most widely used weld wires

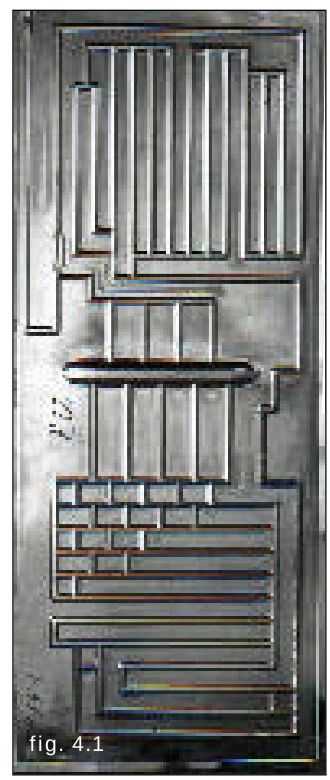

fig. 4.1

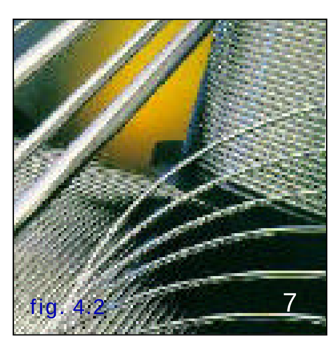

fig. 4.2

5xxx - Al-Mg Alloys

- Strain hardenable
- Excellent corrosion resistance,toughness, weldability; moderate strength
- Building & construction,automotive,cryogenic, marine applications
- Representative alloys:5052,5083,5754
- Typical ultimate tensile strength range:18-51 ksi

Al-Mg alloys of the 5xxx series are strain hardenable,and have moderately high strength, excellent corrosion resistance even in salt water, and very high toughness even at cryogenic temperatures to near absolute zero.They are readily welded by a variety of techniques, even at thicknesses up to 20 cm. As a result, 5xxx alloys find wide application in building and construction,highways structures including bridges, storage tanks and pressure vessels,cryogenic tankage and systems for temperatures as low as -270°C (near absolute zero),and marine applications.

Alloys 5052, 5086,and 5083 are the work horses from the structural standpoint, with increasingly higher strength associated with the increasingly higher Mg content.Specialty alloys in the group include 5182,the beverage can end alloy, and thus among the largest in tonnage;5754 for automotive body panel and frame applications;and 5252,5457,and 5657 for bright trim applications, including automotive trim.


fig. 5.1

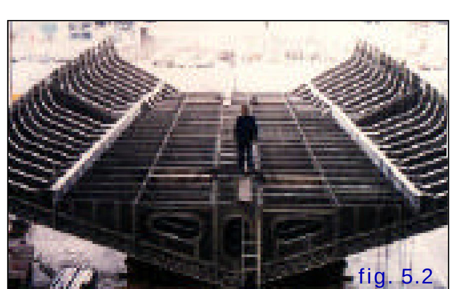
fig. 5.2

fig. 5.3

Care must be taken to avoid use of 5xxx alloys with more than 3% Mg content in applications where they receive continuous exposure to temperatures above 100°C (212°F). Such alloys may become sensitized and susceptible to stress corrosion cracking. For this reason, alloys such as 5454 and 5754 are recommended for applications where high temperature exposure is likely.

Examples of applications for the broadly used 5xxx series of alloys include:

- Fig.5. 1 - High speed single-hull ships like the Proserio employ 5083-H113/H321 machined plate for hulls,hull stiffeners,decking and superstructure.
- Fig.5.2 - The internal hull stiffener structure of the high-speed yacht Proserio,from the previous figure.
- Fig.5.3 - Single or multiple hull high-speed ferries, employ several Al-Mg alloys,5083,and 5454 as sheet and plate (along with 6xxx extruded shapes,to be described next) with all-welded construction.
- Fig. 5.4 - Alloy 5083 was the work horse for the 125-ft.diameter spheres for shipboard transport of liquefied natural gas;the all-welded construction was 8-in.thick at the horizontal diameter.
- Fig.5.5 - The Foresmo bridge in northern Norway is an excellent example of the use of Al-Mg alloys for built up girders systems; this photo illustrates a major advantage of replacement aluminum bridges: the ability to pre-fabricate the spans and move them in place quickly, minimizing the disruption to traffic.
- Fig.5.6 - Rugged coal cars are provided by welded 5454 alloy plate construction.

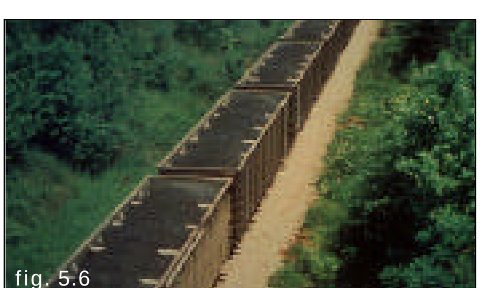

fig. 5.6

fig. 5.5

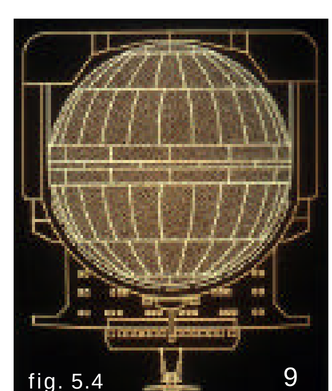

fig. 5.4

Fig.5.7 - The demands of high-humidity and water exposure in offshore oil rigs are met with 5454, 5086,and 5083 Al-Mg alloy welded construction.

Fig.5.8 and 5.9 - Automotive structures are likely to employ increasing amounts of 5754-0 formed sheet for parts such as internal door stiffeners or the entire body-in-white.

Fig.5.10 - Aluminum can ends of 5182 make that one of the largest volume alloys in production.

fig. 5.7

fig. 5.8

fig. 5.9

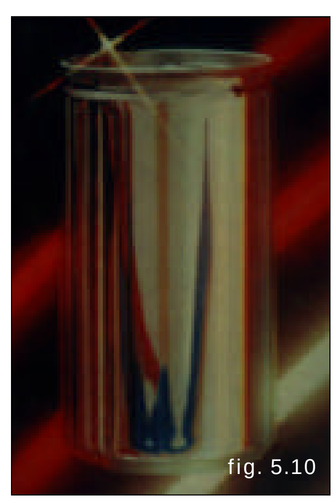

fig. 5.10

6xxx - Al-Mg-Si Alloys

- Heat treatable
- High corrosion resistance, excellent extrudibility;moderate strength
- Building & construction,highway, automotive,marine applications
- Representative alloys: 6061,6063, 6111
- Typical ultimate tensile strength range:18-58 ksi

The 6xxx alloys are heat treatable,and have moderately high strength coupled with excellent corrosion resistance.They are readily welded. A unique feature is their extrudability, making them the first choice for architectural and structural members where unusual or particularly strength- or stiffness-criticality is important.

Alloy 6063 is perhaps the most widely used because of its extrudability;it was a key in the recent all-aluminum bridge structure erected in only a few days in Foresmo,Norway, and is the choice for the Audi automotive space frame members.

Higher strength 6061 alloy finds broad use in welded structural members such as truck and marine frames, railroad cars,and pipelines. Among specialty alloys in the series:6066-T6, with high strength for forgings;6111 for automotive body panels with high dent resistance; and 6101and 6201 for high strength electrical bus and electrical conductor wire, respectively.

Among the most important applications for Al-Mg-Si alloys are:

Fig.6.1 - The power of extruded Al-Mg-Si alloys is the “put-the-metal-where-you need-it” flexibility that these alloys and the extrusion process provide.

Fig.6.2 - Roof structures for arenas and gymnasiums are usually 6063 or 6061 extruded tube, covered with 5xxx alloy sheet

Fig. 6.3 - Geodesic domes,such as this one made originally to house the “spruce Goose”in Long Beach,CA, the largest geodesic dome ever constructed,at 1000 ft across, 400 ft. high.

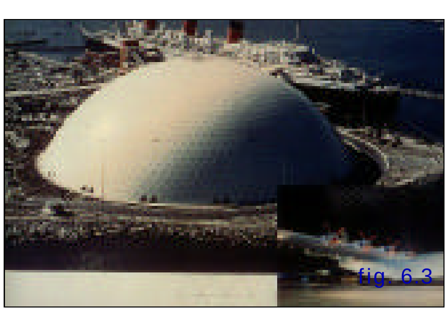
fig. 6.3


fig. 6.2


fig. 6.1

Fig.6.4 and 6.5 - An integrally stiffened bridge deck shape usually produced in 6063,used to produce replacement bridge decks, readily put in the roadway in hours.

Fig. 6.6 and 6.7 - The new Mag-Lev trains in development in Europe and Japan employ bodies with 6061 and 6063 structural members.

Fig.6.8 and 6.9 - Extruded Al-Mg-Si alloys may make up the entire frame of motorcycles or cars (illustration is of the Audi A-8 body)

Fig.6. 10 - Welded 6063 extrusions combined with 5083 tube make up the front and rear axle bodies for the BMW Model 5.


fig. 6.4

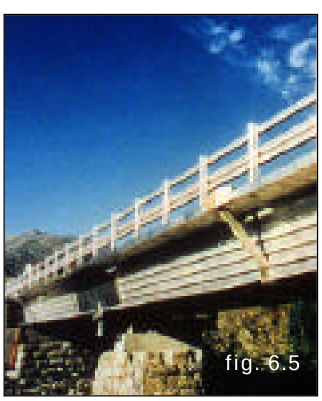
fig. 6.5


fig. 6.6

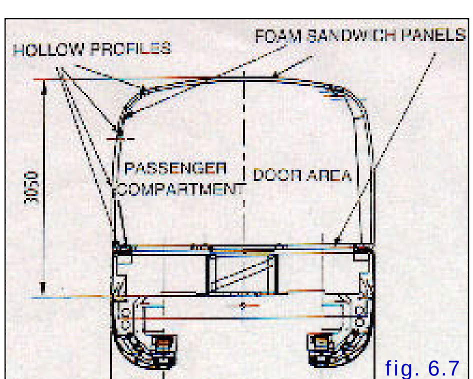

fig. 6.7

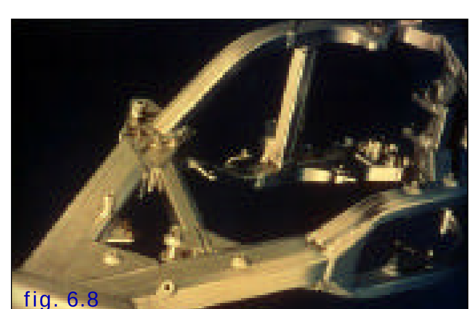
fig. 6.8

7xxx - Al-Zn Alloys

- Heat treatable
- Very high strength;special high toughness versions
- Aerospace,automotive applications
- Representative alloys: 7005,7075, 7475, 7150
- Typical ultimate tensile strength range:32-88 ksi

The 7xxx alloys are heat treatable and among the Al-Zn-Mg-Cu versions provide the highest strengths of all aluminum alloys.There are several alloys in the series that are produced especially for their high toughness,notably 7150 and 7475, both with controlled impurity level to maximize the combination of strength and fracture toughness.

The widest application of the 7xxx alloys has historically been in the aircraft industry, where fracture-critical design concepts have provided the impetus for the high-toughness alloy development.These alloys are not considered weldable by routine commercial processes,and are regularly used in riveted construction.

The atmospheric corrosion resistance of the 7xxx alloys is not as high as that of the 5xxx and 6xxx alloys,so in such service they are usually coated or, for sheet and plate,used in an alclad version.The use of special tempers such as the T73-type are required in place of T6-type tempers whenever stress corrosion cracking may be a problem.

Applications of 7xxx alloys include;

Fig. 7.1 - Aircraft structures are of 7xxx alloy sheet or extrusion construction; alloys like 7075-T73 or high-toughness alloys like 7050 or 7475 are among the principal choices.

Fig. 7.2 - Lightweight 7029 or 7129 bumper structures help improve our gas mileage.


fig. 7.1

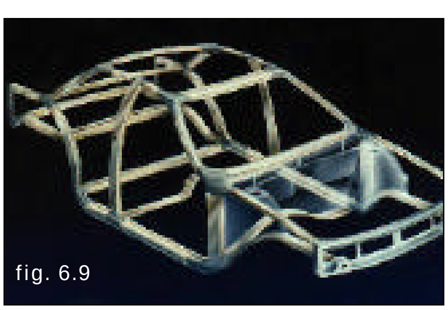
fig. 6.9

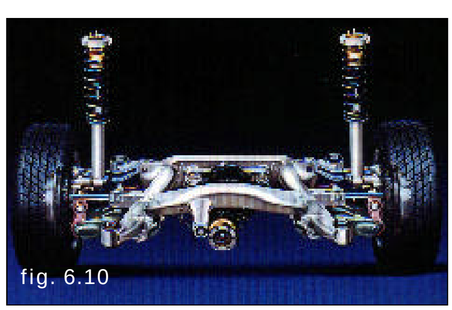
fig. 6.10


fig. 7.2

8xxx - Alloys with Al+Other Elements (not covered by other series)

- Heat treatable
- High conductivity, strength,hardness
- Electrical,aerospace,bearing applications
- Representative alloys: 8017,8176, 8081,8280,8090
- Typical ultimate tensile strength range:17-35 ksi

The 8xxx series is used for those alloys with lesser used alloying elements such as Fe,Ni and Li.Each is used for the particular characteristics it provides the alloys: Fe and Ni provide strength with little loss in electrical conductivity and so are used in a series of alloys represented by 8017 for conductors.Li in alloy 8090 provides exceptionally high strength and modulus, and so this alloy is used for aerospace applications where increases in stiffness combined with high strength reduces component weight.

3.2 - Cast Alloys

In comparison with wrought alloys,casting alloys contain larger proportions of alloying elements such as silicon and copper.This results in a largely heterogeneous cast structure,i.e. one having a substantial volume of second phases.This second phase material warrants careful study, since any coarse,sharp and brittle constituent can create harmful internal notches and nucleate cracks when the component is later put under load.The fatigue properties are very sensitive to large heterogeneities. As will be shown later, good metallurgical and foundry practice can largely prevent such defects.

The elongation and strength,especially in fatigue,of most cast products are relatively lower than those of wrought products.This is because current casting practice is as yet unable to reliably prevent casting defects. In recent years however, innovations in casting processes have brought about considerable improvements,which should be taken into account in any new edition of the relevant standards.

2xx.x - Al-Cu Alloys

- Heat treatable/sand and permanent mold castings
- High strength at room and elevated temperatures; some high toughness alloys
- Aircraft, automotive applications/engines
- Representative alloys: 201.0,203.0
- Approximate ultimate tensile strength range:19-65 ksi

The strongest of the common casting alloys is heat-treated 201.0/AlCu4Ti. Its castability is somewhat limited by a tendency to microporosity and hot tearing,so that it is best suited to investment casting.Its high toughness makes it particularly suitable for highly stressed components in machine tool construction,in electrical engineering (pressurized switchgear casings), and in aircraft construction.

Besides the standard aluminum casting alloys,there are special alloys for particular components, for instance, for engine piston heads,integral engine blocks,or bearings. For these applications the chosen alloy needs good wear resistance and a low friction coefficient, as well as adequate strength at elevated service temperatures. A good example is the alloy 203.0/AlCu5NiCo,which to date is the aluminum casting alloy with the highest strength at around 200°C.

Fig. 21C - Landing flap mountings and other aircraft components are made in alloys of the 201.0 or in A356.0 types.

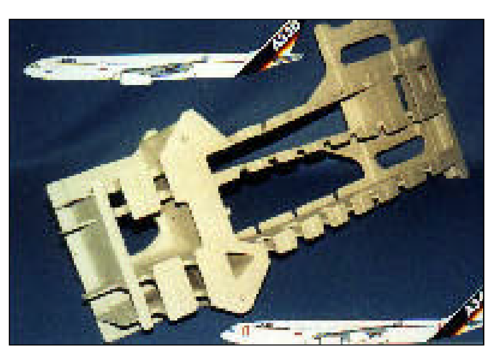

fig. 21C

3xx.x - Al-Si+Cu or Mg Alloys

- Heat treatable/sand,permanent mold,and die castings
- Excellent fluidity/high strength/some high-toughness alloys
- Automotive and applications/pistons/pumps/electricAl
- Representative alloys:356.0, A356.0,359.0, A360.0
- Approximate ultimate tensile strength range:19-40 ksi

The 3xx.x series of castings are one of the most widely used because of the flexibility provided by the high silicon contents and its contribution to fluidity plus their response to heat treatment which provides a variety of high-strength options.Further the 3xx.x series may be cast by a variety of techniques ranging from relatively simple sand or die casting to very intricate permanent mold,lost foam/lost wax type castings,and the newer thixocasting and squeeze casting technologies.

Among the workhorse alloys are 319.0 and 356.0/A356.0 for sand and permanent mold casting,360.0, 380.0/A380.0 and 390.0 for die casting, and 357.0/A357.0 for many type of casting including especially the squeeze/forge cast technologies. Alloy 332.0 is also one of the most frequently used aluminum casting alloys because it can be made almost exclusively from recycled scrap.

Among the illustrative applications are:

Fig.31C - 356.0 inner turbo frame for a Mercedes truck

Fig. 32C - Gearbox casing for a passenger car in alloy pressure die cast 380.0

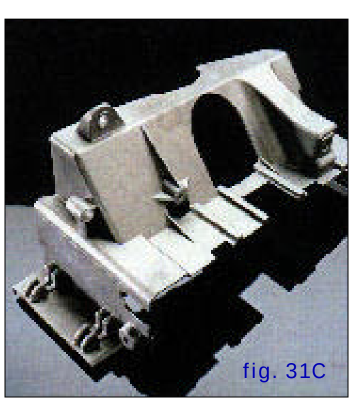

fig. 31C

fig. 32C

fig. 33C

Fig. 33C - Rear axle housing of 380.0 sand casting

Fig.34C - Automotive components of 357.0 and A357.0 sand and permanent mold castings

Fig.35C - 3xxx.x castings made by the lost-foam process,providing exceptional detail and complexity.

Fig. 36C - A356.0 cast wheels are now widely used in the US industry

fig. 36C

fig. 35C

fig. 34C

4xx.x - Al-Si Alloys

- Non-heat treatable/sand,permanent mold,and die castings
- Excellent fluidity/good for intricate castings
- Typewriter frames/dental equipment/marine/architectural
- Representative alloys:413.0,443.0
- Approximate ultimate tensile strength range:17-25 ksi

Alloy B413.0/AlSi12 is notable for its very good castability and excellent weldability, which are due to its eutectic composition and low melting point of 570°C.It combines moderate strength with high elongation before rupture and good corrosion resistance.The alloy is particularly suitable for intricate,thin walled,leak-proof, fatigue resistant castings.

5xx.x - Al-Mg Alloys

- Non-heat treatable/sand,permanent mold,and die
- Tougher to cast/provides good finishing characteristics
- Excellent corrosion resistance/machinability/surface appearance
- Cooking utensils/food handling/aircraft/highway fittings
- Representative alloys:512.0,514.0,518.0, 535.0
- Approximate ultimate tensile strength range:17-25 ksi

The common feature which the third group of alloys have is good resistance to corrosion. Alloys 512.0 and 514.0 have medium strength and good elongation, and are suitable for components exposed to sea water or to other similar corrosive environments.These alloys are often used for door and window fittings, which can be decoratively anodized to give a metallic finish or in a wide range of colors.Their castability is inferior to that of the Al-Si alloys because of its magnesium content and consequently long freezing range. For this reason it tends to be replaced by 355.0/AlSi5Mg,which has long been used for similar applications.

For die castings where decorative anodizing is particularly important,the alloy 520.0 is the most suitable.

7xx.x - Al-Zn Alloys

- Heat treatable/sand and permanent mold cast (harder to cast)
- Excellent machinability/appearance
- Furniture/garden tools/office machines/farm/mining equipment
- Representative alloys: 705.0,712.0
- Approximate ultimate tensile strength range:30-55 ksi

Because of the increased difficulty in casting 7xx.x alloys,they tend to be used only where the excellent finishing characteristics and machinability are important.

8xx.x - Al-Sn Alloys

- Heat treatable/sand and permanent mold castings (harder to cast)
- Excellent machinability
- Bearings and bushings of all types
- Representative alloys:850.0,851.0
- Approximate ultimate tensile strength range:15-30 ksi

Like the 7xx.x alloys, 8xx.x alloys are relatively hard to cast and are used only where their unique machining and bushing characteristics are essential.

In concluding this section on casting,it is worth noting that conventional die casting tends to yield parts with relatively low elongation values, which are therefore unsuitable for safety-critical components.In recent years,higher pressure types of casting (e.g., squeeze casting and thixocasting) have been developed to a commercial level. As a result, elongation values of well over 10% are now attainable,together with higher strengths.This considerably widens the range of application of aluminum alloy castings.

4.0 Summary - An Aluminum Alloy for Every Application

It seems apparent from the foregoing overview that aluminum alloys possess a number of very attractive characteristics which,together with their very light weight,make then extremely attractive for many applications.Further, their versatility with respect to options of how to shape them and strengthen them provide an amazing variety of choices when you are looking for an ideal material for a special application.

Ease of extrudibility is one characteristic that justifies some special emphasis in wrapping up this summary because the extrusion process,most uniquely suitable to aluminum alloys,allows the designer to create special shapes that place the metal where it can carry the required load most efficiently.There is no need,as with steel or most titanium alloys,to be limited to "standard"shapes.The economics and metallurgy of the extrusion process permit you to economically create unique shapes, even multi-hollow shapes, for unique applications,perhaps combining what would otherwise be several separate parts that would have to be joined,into one specially shaped piece.Extrusion is one of aluminum's "aces in the hole", as the expression goes.

We hope this over view has illustrated for you that aluminum alloys are up to the task,and that no matter what your needs may be there is probably a ready-made aluminum alloy to do the job.

For additional information on standards for aluminum alloys and on their applications,please refer to the following:

— *Aluminum:Technology, Applications, and Environment,*
by Dr. Dietrich G. Altenpohl,
The Aluminum Association and TMS,1998.

— *Aluminum Standards & Data,*
The Aluminum Association,1997.

— *The Aluminum Design Manual,*
The Aluminum Association,1994.

The Aluminum Association, Inc.

900 19th Street, N.W.
Washington, D.C. 20006
(202) 862-5100

www.aluminum.org