CHAPTER 6

Applications for Aluminum Alloys and Tempers

THERE ARE AT LEAST two approaches to overviewing important applications of aluminum alloys: by alloy class, as initiated in Chapter 3 and carried out in greater detail subsequently, and by type of application. Both approaches are considered in this chapter—a review first by alloy class and then by application.

Readers are referred to *Aluminum: Technology, Applications and Environment* (see Chapter 8) for more detailed information on many of the applications mentioned in this chapter.

All photographs are courtesy of the Aluminum Association unless otherwise indicated, many from the reference noted in the previous paragraph.

Applications by Alloy Class

Wrought Alloys

1*xxx*, Pure Aluminum. The major characteristics of the 1*xxx* series are:

- Strain hardenable
- Exceptionally high formability, corrosion resistance, and electrical conductivity
- Typical ultimate tensile strength range: 70 to 185 MPa (10–27 ksi)
- Readily joined by welding, brazing, and soldering

The 1*xxx* series represents the commercially pure (CP) 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). The 1*xxx* series of alloys are strain hardenable but would not be used where strength is a prime consideration.

The primary uses of the 1*xxx* series would be applications in which the combination of extremely high corrosion resistance and formability are required (e.g., foil and strip for packaging, chemical equipment, tank car or truck bodies, spun hollowware, and elaborate sheet metal work).

Electrical applications are one major use of the 1*xxx* series, primarily 1350, which has relatively tight controls on those impurities that might lower electrical conductivity. As a result, an electrical conductivity of 62% of the International Annealed Copper Standard (IACS) is guaranteed for this material, which, combined with the natural light weight of aluminum, means a significant weight and, therefore, cost advantage over copper in electrical applications.

Specific illustrations provided include an aluminum electrical bus bar installation (Fig. 1), food packaging trays of pure aluminum (Fig. 2), decorated foil pouches for food and drink (Fig. 3), aluminum foil of CP aluminum and pet food decorated wrap (Fig. 4), and a bright-polished telescopic mirror of a high-purity aluminum (Fig. 5).

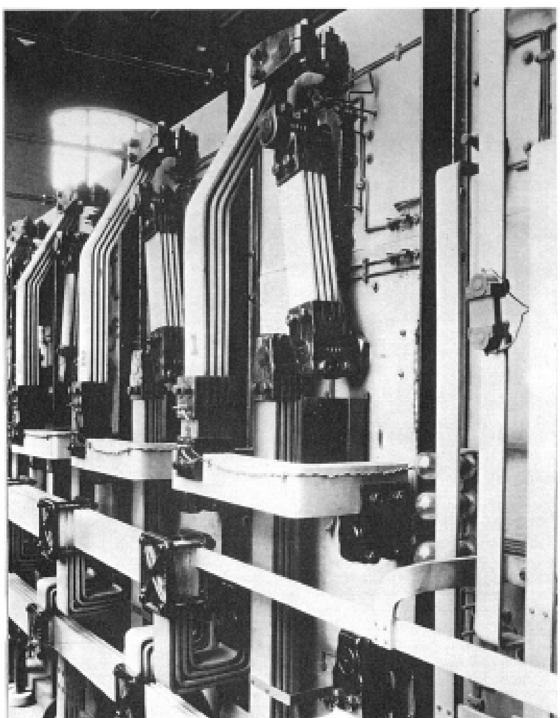


Fig. 1 Aluminum electrical bus bar installation with 1350 bus bar

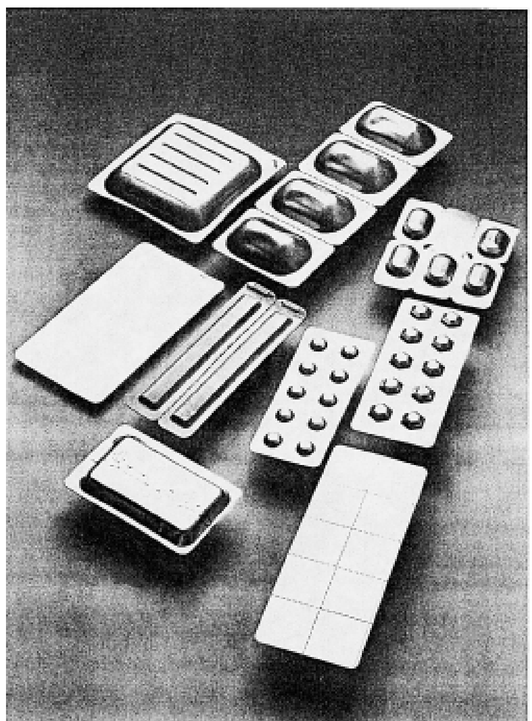


Fig. 2 Food packaging trays of pure aluminum (1100)

2*xxx*, Aluminum-Copper Alloys. The major characteristics of the 2*xxx* series are:

- Heat treatable
- High strength, at room and elevated temperatures
- Typical ultimate tensile strength range: 190 to 430 MPa (27–62 ksi)
- Usually joined mechanically, but some alloys are weldable

The 2*xxx* series of alloys 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 as resistant to atmospheric corrosion as several other series and so usually are painted or clad for added protection.

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

(a) (b)

Fig. 4 (a) Reynolds Wrap (Reynolds Metals Co., Richmond, VA) aluminum foil of commercially pure aluminum (1100 or similar) and (b) Reynolds pet food decorated wrap

Primary Uses. The higher-strength 2*xxx* alloys are widely used for aircraft (2024) and truck body (2014) applications, where they generally are used in bolted or riveted construction. Specific members of the series (e.g., 2219 and 2048) are readily joined by gas metal arc welding (GMAW) or gas tungsten arc welding (GTAW) and so are used for aerospace applications where that method is the preferred joining method.

Alloy 2195 is a new lithium-bearing aluminum alloy providing very high modulus of elasticity along with higher strength and comparable weldability to 2219 for space applications.

For applications requiring very high strength plus high fracture toughness, there are high-toughness versions of several of the alloys (e.g., 2124, 2324, and 2419) that 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 2*xxx* series alloys include aircraft internal and external structures (Fig. 6), structural beams of heavy dump and tank trucks and trailer trucks (Fig. 7), the fuel tanks and booster rockets of the Space Shuttle (Fig. 8), and internal railroad car structural members (Fig. 9).

3*xxx*, Aluminum-Manganese Alloys. The major characteristics of the 3*xxx* series are:

- High formability and corrosion resistance with medium strength
- Typical ultimate tensile strength range: 110 to 285 MPa (16–41 ksi)
- Readily joined by all commercial procedures

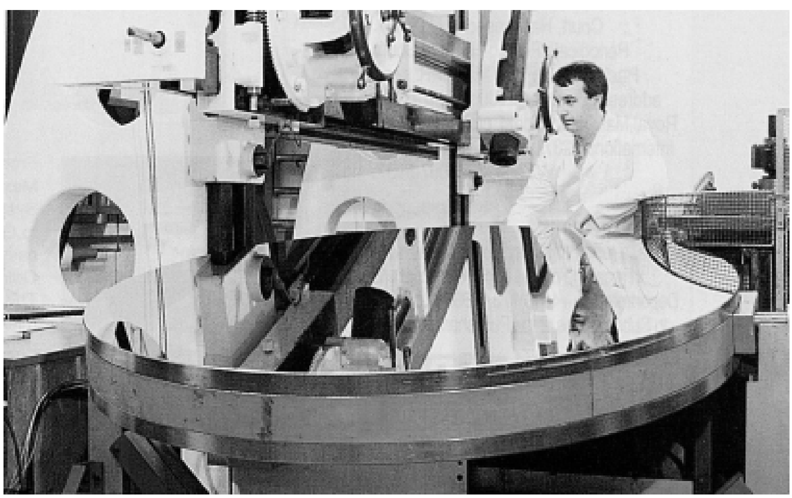


Fig. 5 Bright-polished telescopic mirror of a high-purity aluminum

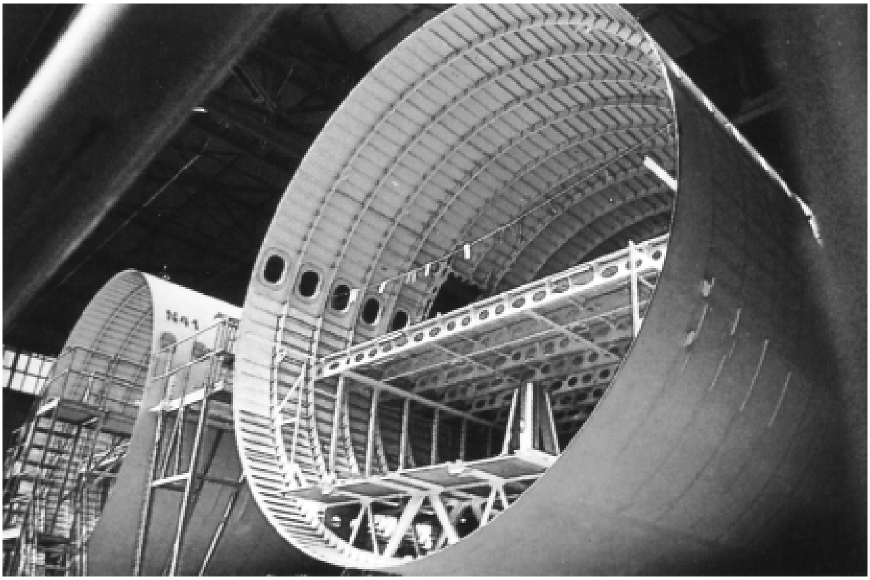
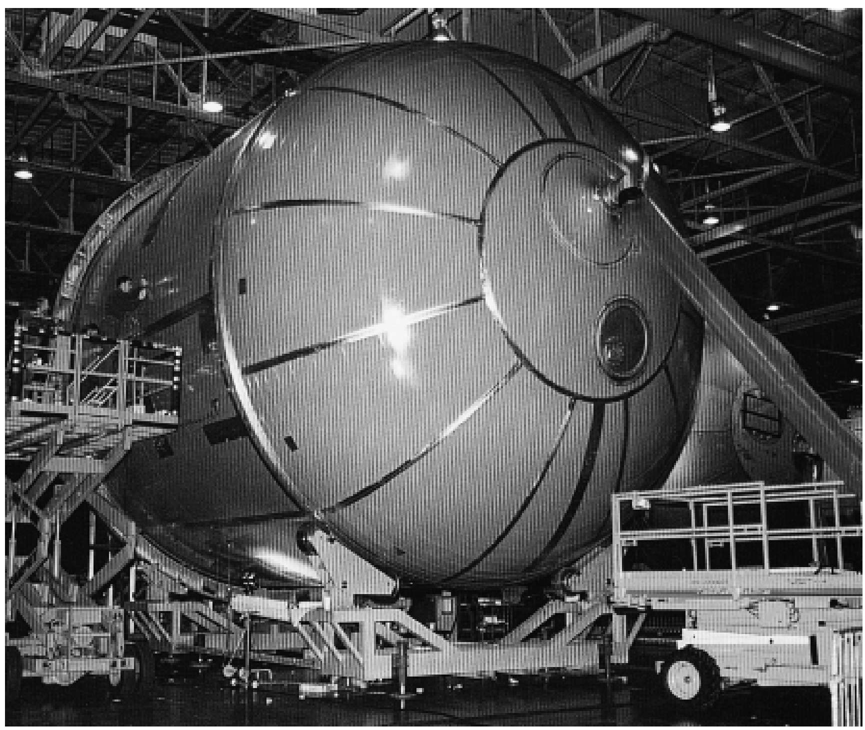


Fig. 6 Aircraft internal structure includes extrusions and plate of 2*xxx* alloys such as 2024, 2124, and 2618. External sheet skin may be alclad 2024 or 2618; the higher-purity cladding provides corrosion protection to the aluminum-copper alloys that otherwise will darken with age.

Fig. 7 Heavy dump and tank trucks and trailer trucks may employ 2*xxx* extrusions for their structural members.

(a)



(b)

Fig. 8 (a) The booster rockets and (b) fuel tanks of the Space Shuttle are 2*xxx* alloys, originally 2219 and 2419; now sometimes aluminum-lithium "Weldalite" alloy 2195

The 3*xxx* series of alloys are strain hardenable, have excellent corrosion resistance, and are readily welded, brazed, and soldered.

Primary Uses. 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 because of its superior corrosion resistance. Alloy 3105 is a principal for roofing and siding.

Because of the ease and flexibility of joining, 3003 and other members of the 3*xxx* series are widely used in sheet and tubular form for heat exchangers in vehicles and power plants.

Alloy 3004 and its modification 3104 are the principals for the bodies of drawn and ironed can bodies for beverage cans for beer and soft drinks. As a result, they are among the most used individual alloys in the aluminum system, in excess of 1.6 billion kg (3.5 billion lb) per year.

Typical applications of the 3*xxx* alloy series include automotive radiator heat exchangers (Fig. 10) and tubing in commercial power plant heat exchangers (Fig. 11). In addition, the bodies of beverage cans (Fig. 12) are alloys 3004 or 3104, making it the largest volume alloy combination in the industry.

4*xxx*, Aluminum-Silicon Alloys. The major characteristics of the 4*xxx* series are:

- Heat treatable
- Good flow characteristics, medium strength
- Typical ultimate tensile strength range: 175 to 380 MPa (25–55 ksi)
- Easily joined, especially by brazing and soldering

Primary Uses. There are two major uses of the 4*xxx* series, both generated by the excellent flow characteristics provided by relatively high

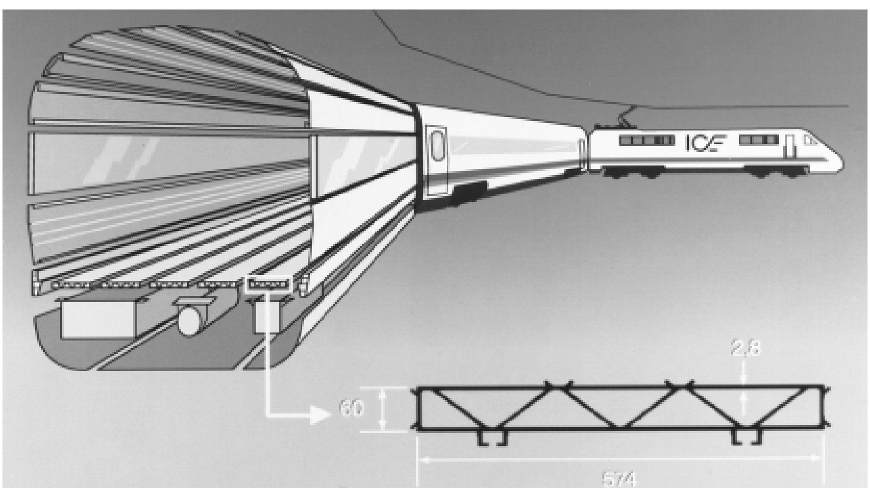


Fig. 9 Internal railroad car structural members are sometimes 2*xxx* alloys (also sometimes 6*xxx* alloys).

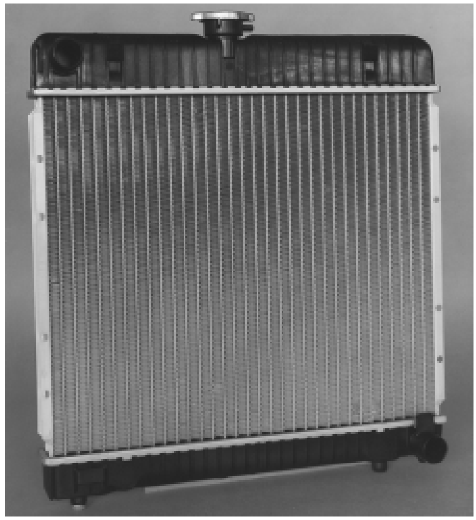


Fig. 10 Automotive radiator heat exchangers are of alloys such as 3002.

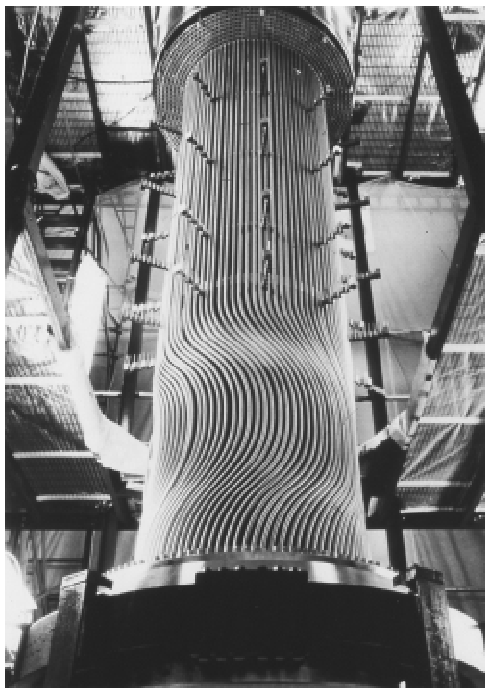


Fig. 11 Alloy 3003 tubing in commercial power plant heat exchanger

silicon contents. The first is for forgings: the workhorse alloy is 4032, a medium high-strength, heat treatable alloy used principally in applications such as forged aircraft pistons. The second major application is a weld filler alloy; here the workhorse is 4043, used for GMAW and GTAW 6*xxx* alloys for structural and automotive applications.

Fig. 12 The bodies of beverage cans are alloys 3004 or 3104, making it the largest volume alloy combination in the industry.

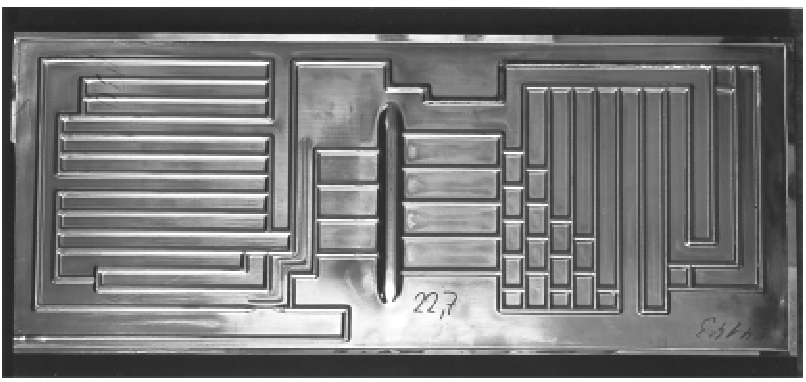


Fig. 13 Refrigerator coolant circulation system in brazed unit of high-silicon brazing alloy sheet

As noted, the same characteristic—good flow provided by the high silicon content—leads to both types of application. In the case of forgings, this good flow ensures the complete and precise filling of complex dies; in the case of welding, it ensures complete filling of grooves in the members to be joined. For the same reason, other variations of the 4*xxx* alloys are used for the cladding on brazing sheet, the component that flows to complete the bond.

Figure 13 illustrates a refrigerator coolant circulation system in a brazed unit of a high-silicon brazing alloy sheet. Alloy 4043 is one of the most widely used weld wires used in applications such as the automated welding of an auto body structure illustrated in Fig. 14.

5*xxx*, Aluminum-Magnesium Alloys. The major characteristics of the 6*xxx* series are:

- Strain hardenable
- Excellent corrosion resistance, toughness, weldability; moderate strength
- Building and construction, automotive, cryogenic, and marine applications
- Representative alloys: 5052, 5083, and 5754
- Typical ultimate tensile strength range: 125 to 350 MPa (18–51 ksi)

Aluminum-magnesium alloys of the 5*xxx* 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 (8 in.).

Primary Use. As a result, 5*xxx* alloys find wide application in building and construction; highway structures, including bridges, storage tanks, and pressure vessels; cryogenic tankage and systems for temperatures as low as –270 °C (−455 °F) or near absolute zero, and marine applications.

Alloys 5052, 5086, and 5083 are the workhorses from the structural standpoint, with increasingly higher strength associated with the increasingly higher magnesium 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.

Care must be taken to avoid use of 5*xxx* 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 SCC. For this reason, alloys such as 5454 and 5754 are recommended for applications where high temperature exposure is likely.

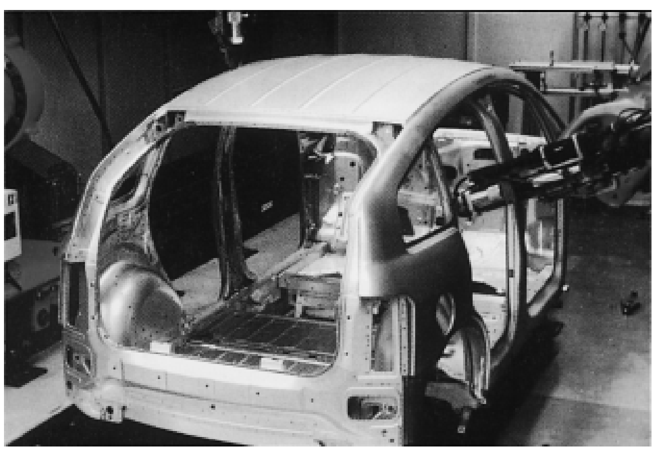


Fig. 14 Alloy 4043 is one of the most widely used weld wires used in applications such as this automated welding of an auto body structure.

High-speed, single-hull ships such as the Destriero, shown in Fig. 15, employ 5083-H113/H321machined plate for hulls, hull stiffeners, decking, and superstructure. Figure 16 shows the internal hull stiffener structure of a high-speed yacht. Single- or multiple-hull high-speed ferries employ several aluminum-magnesium alloys, 5083, 5383, and 5454, as sheet and plate (Fig. 17) (along with 6*xxx* extruded shapes, described next) with all-welded construction. Other applications for the broadly used 5*xxx* series of alloys can be seen in Fig. 18 to 26.

6*xxx*, Aluminum-Magnesium-Silicon Alloys. The major characteristics of the 6*xxx* series are:

- Heat treatable
- High corrosion resistance, excellent extrudibility; moderate strength

Fig. 15 High-speed, single-hull ships such as the Destriero, employ 5083-H113/H321 machined plate for hulls, hull stiffeners, decking, and superstructure.

Fig. 16 The internal hull stiffener structure of a high-speed yacht (see Fig. 15)

- Typical ultimate tensile strength range: 125 to 400 MPa (18–58 ksi)
- Readily welded by GMAW and GTAW methods

The 6*xxx* alloys are heat treatable and have moderately high strength coupled with excellent corrosion resistance. A unique feature is their great extrudability, making it possible to produce in single shapes relatively complex architectural forms, as well as to design shapes that put the majority of the metal where it will most efficiently carry the highest tensile and compressive stresses. This feature is a particularly important advantage for architectural and structural members where stiffness-criticality is important.

Primary Use. Alloy 6063 is perhaps the most widely used because of its extrudability; it is not only the first choice for many architectural and structural members, but it has been the choice for the Audi automotive space frame members. A good example of its structural use was the all-aluminum bridge structure in Foresmo, Norway (Fig. 26); it was prefabricated in a shop and erected on the site in only a few days.

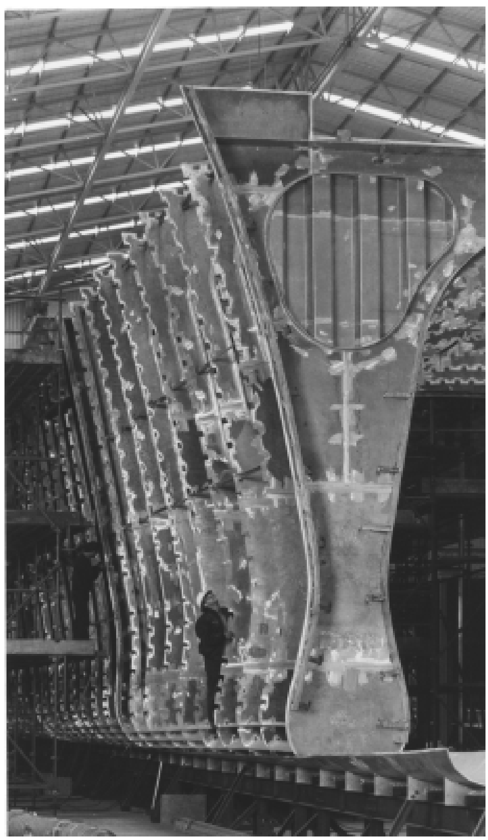


Fig. 17 Single- or multiple-hull high-speed ferries employ several aluminum-magnesium alloys—5083, 5383, and 5454—as sheet and plate (along with 6*xxx* extruded shapes) with all-welded construction.

Higher-strength alloy 6061 extrusions and plate find 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; 6070 for the highest strength available in 6*xxx* extrusions; and 6101and 6201 for high-strength electrical bus and electrical conductor wire, respectively.

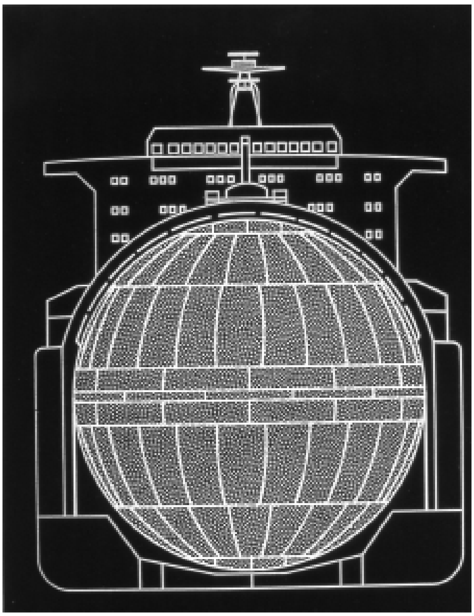


Fig. 18 Alloy 5083 was the workhorse for the 32 m (125 ft) diam spheres for shipboard transport of liquefied natural gas; the all-welded construction was 200 mm (8 in.) thick at the horizontal diam.

Fig. 19 The superstructure of many ocean liners, ferries, and most naval ships is of welded 5*xxx* alloy construction, providing lightweight and excellent corrosion resistance.

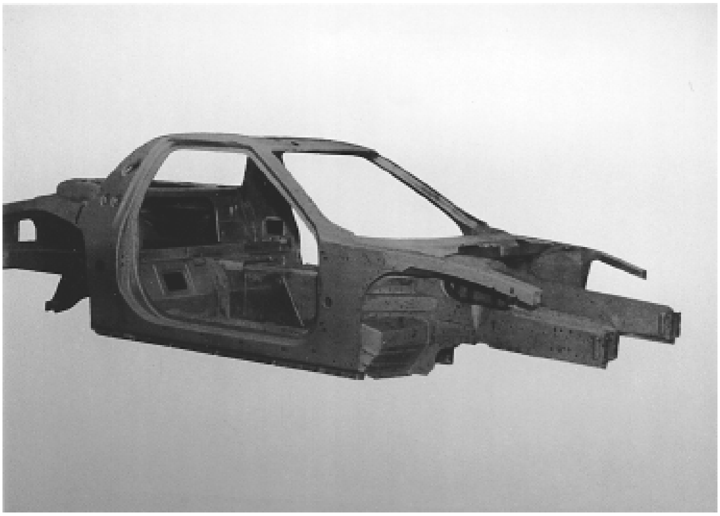
Figure 27 shows that the power of extruded aluminum-magnesium-silicon alloys is the "put-the-metal-where-you need-it" flexibility these alloys and the extrusion process provide.

Some of the other most important applications for aluminum-magnesium-silicon are in the structural members of wide-span roof structures for arenas and gymnasiums shown in Fig. 28; geodesic domes, such as the one made originally to house the *Spruce Goose,* the famous Hughes wooden flying boat, in Long Beach, CA, the largest geodesic dome ever constructed, at 250 m (1000 ft) across, 100 m (400 ft) high (Fig. 29); an integrally stiffened bridge deck shape, used to produce replacement bridge decks, readily put in the roadway in hours (Fig. 30, 31); and a magnetic levitation (Mag-Lev) train in development in Europe and Japan

Fig. 20 Rugged coal cars are provided by welded 5454 alloy plate construction.

Fig. 21 The demands of the superstructures of offshore oil rigs in high humidity and water exposure are met with 5454, 5086, and 5083 aluminum-magnesium alloy welded construction.

(Fig. 32). In addition, aluminum light poles are widely used around the world for their corrosion resistance and crash protection systems providing safety for auto drivers and passengers, as shown in Fig. 33. Representative important applications of the 6*xxx* alloy series in automobile structures are shown in Fig. 34 to 36.



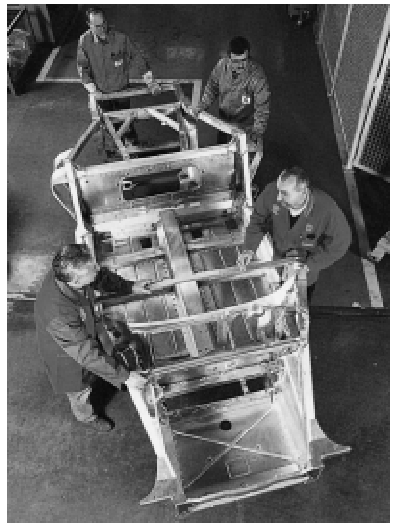


Fig. 22 Automotive structures are likely to employ increasing amounts of 5754-O formed sheet for parts such as internal door stiffeners or the entire body-in-white.

Fig. 23 Aluminum cans have ends of alloy 5182, making that one of the largest volume alloys in production.

***7xxx,* Aluminum-Zinc Alloys.** The major characteristics of the 7*xxx* series are:

- Heat treatable
- Very high strength; special high-toughness versions
- Typical ultimate tensile strength range: 220 to 610 MPa (32–88 ksi)
- Mechanically joined

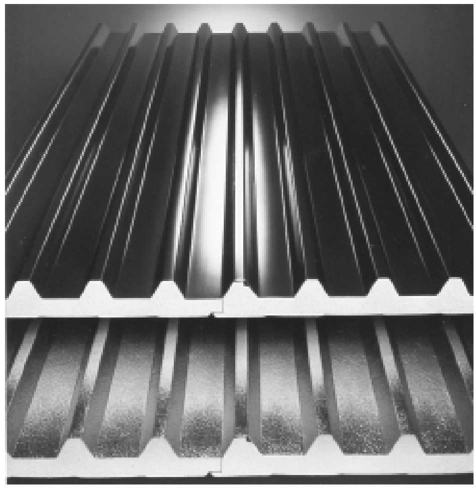


Fig. 24 5*xxx* alloys are commonly used as external facing sheets of composite aluminum-plastic structural panels, as in this Alusuisse Alucoban example.

Fig. 25 Sheet of 5*xxx* alloys often forms the surface of geodesic dome structures, as in this example of a water treatment plant.

The 7*xxx* alloys are heat treatable and, among the aluminum-zinc-magnesium-copper versions in particular, provide the highest strengths of all aluminum alloys. These alloys are not considered weldable by commercial processes and are regularly used with riveted construction.

Primary Use. The widest application of the 7*xxx* alloys historically has been in the aircraft industry, where fracture-critical design concepts have

Fig. 26 The Foresmo Bridge in northern Norway is an excellent example of the use of aluminum-magnesium alloys for built-up girders systems; this photograph illustrates a major advantage of replacement aluminum bridges—the ability to prefabricate the spans and move them in place quickly, minimizing the disruption to traffic.

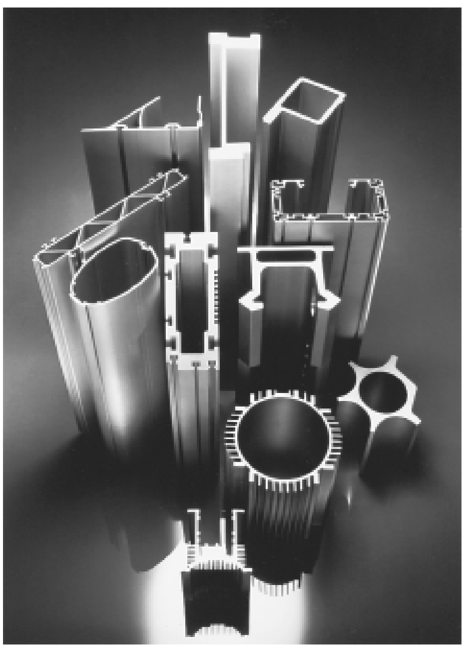


Fig. 27 The power of extruded aluminum-magnesium-silicon alloys is the "put-in-the metal-where-you-need-it" flexibility these alloys and the extrusion process provide.

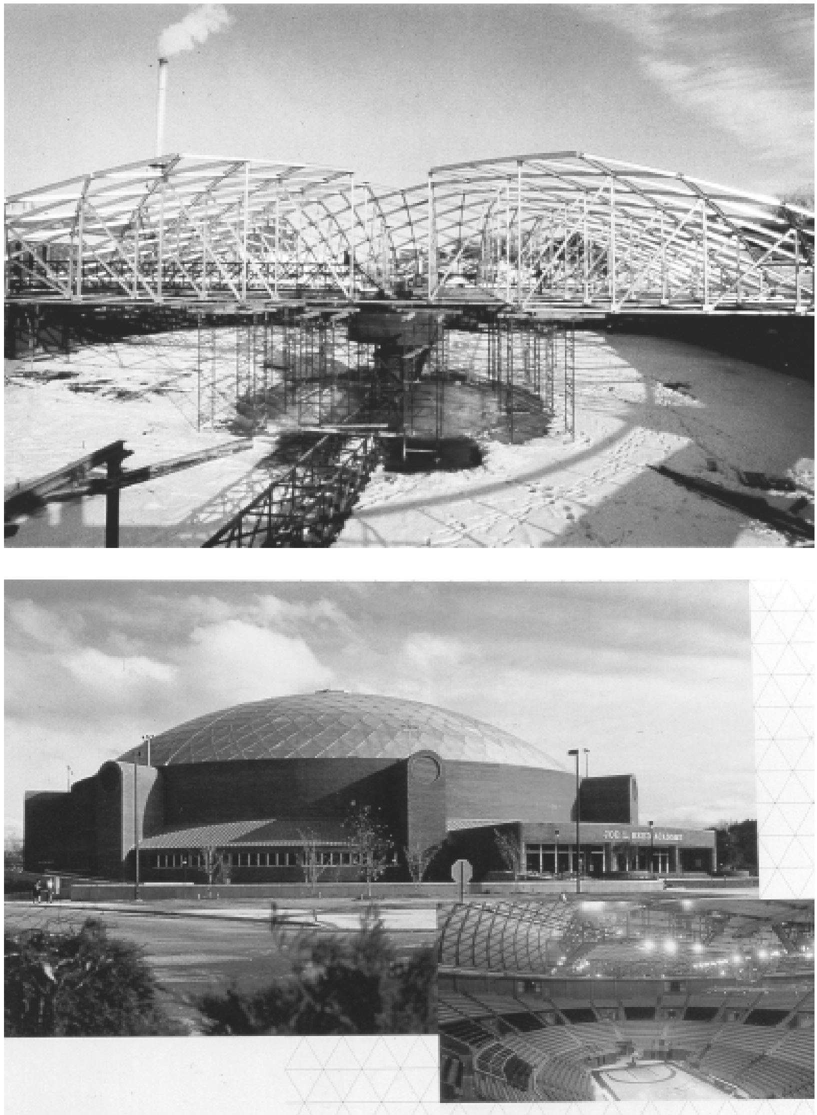


Fig. 28 The structural members of wide-span roof structures for arenas and gymnasiums are usually 6063 or 6061 extruded tube or beams, covered with 5*xxx* alloy sheet.

provided the impetus for the high-toughness alloy development. There are several alloys in the series that are produced especially for their high toughness, notably 7150, 7175, and 7475; for these alloys, controlled impurity levels, particularly of iron and silicon, maximize the combination of strength and fracture toughness.

The atmospheric corrosion resistance of the 7*xxx* alloys is not as high as that of the 5*xxx* and 6*xxx* alloys, thus, in such service, they usually are coated or, for sheet and plate, used in an alclad version. Also, special tempers have been developed to improve their resistance to exfoliation

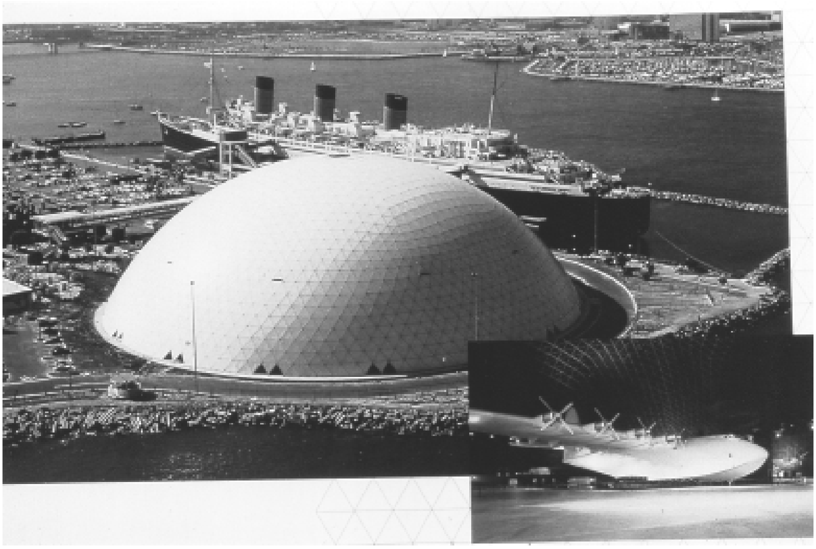


Fig. 29 This geodesic dome in Long Beach, CA, made originally to house the "Spruce Goose," is the largest geodesic dome ever constructed—250 m (1000 ft) across, 100 m (400 ft) high.

Fig. 30 Integrally stiffened bridge deck shape, which is usually produced in 6063

and SCC, the T76 and T73 types, respectively. These tempers are especially recommended in situations where there may be high short transverse (through the thickness) stresses present during exposure to atmospheric or more severe environments.

Applications of 7*xxx* alloys include critical aircraft wing structures of integrally stiffened aluminum extrusions (Fig. 37), long-length drill pipe (Fig. 38), and the premium forged aircraft part of alloy 7175-T736 (T74) shown in Fig. 39.

8*xxx*, Alloys with Aluminum Plus Other Elements (Not Covered by Other Series). The major characteristics of the 8*xxx* series are:

- Heat treatable
- High conductivity, strength, and hardness
- Typical ultimate tensile strength range: 120 to 240 (17–35 ksi)

The 8*xxx* series is used for those alloys with lesser-used alloying elements such as iron, nickel, and lithium. Each is used for the particular characteristics it provides the alloys.

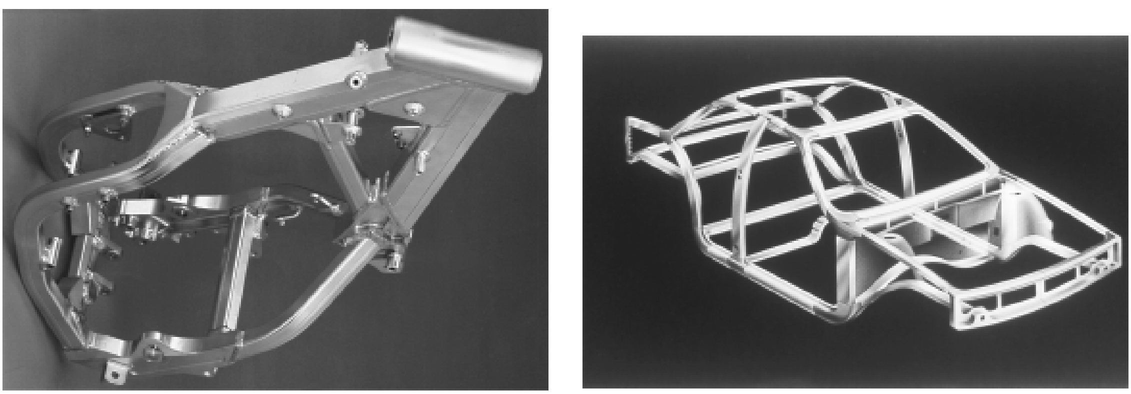
Fig. 31 Replacement bridge decks, usually produced in 6063, are readily put into the roadway in hours.

Fig. 32 Experimental magnetic levitation (Mag-Lev) train in development in Europe and Japan, employ bodies with 6061 and 6063 structural members.

Primary Use. Iron and nickel provide strength with little loss in electrical conductivity and so are used in a series of alloys represented by 8017 for conductors.

Lithium in alloy 8090 provides exceptionally high strength and modulus, and so this alloy is used for aerospace applications in which increases in stiffness combined with high strength reduces component weight. A forged helicopter component of aluminum-lithium alloy 8090-T852 can be seen in Fig. 40.

Fig. 33 Aluminum light poles are widely used around the world for their corrosion resistance, and their breakaway-base crash protection systems that provide safety for car drivers and passengers.



(a) **(b)**

Fig. 34 Extruded aluminum-magnesium-silicon alloys make up (a) a complete Verlicchi Nino & Fugli motorcycle chassis and (b) the entire body frame of the Audi A-8.

Cast Alloys

In comparison with wrought alloys, casting alloys contain larger proportions of alloying elements such as silicon and copper, which 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 is shown later, good metallurgical and foundry practices 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 such as squeeze

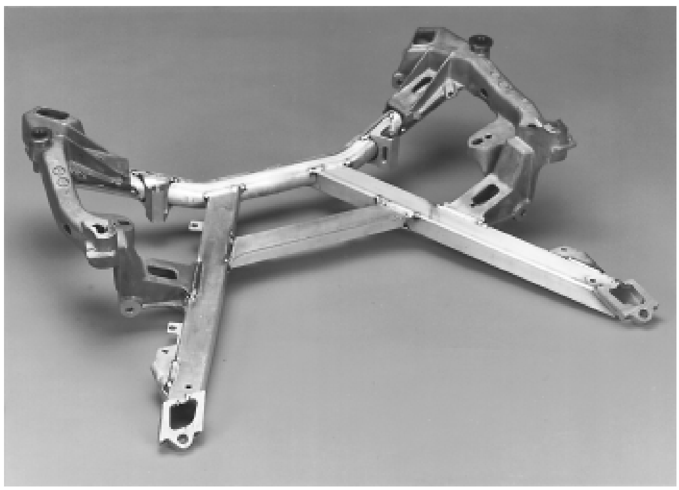


Fig. 35 Welded 6063 extrusions combined with 5083 tube and 357 casting make up the axle body assembly for the BMW Model 5.

Fig. 36 The General Motors Aurora, like many other production automobiles, has aluminum closure panels of alloy 6111-T4.

casting have brought about some significant improvements in the consistency and level of properties of castings, and these should be taken into account in selecting casting processes for critical applications.

2*xx.x*, Aluminum-Copper Alloys. The major characteristics of the 2*xx.x* series are:

- Heat treatable sand and permanent mold castings
- High strength at room and elevated temperatures; some high-toughness alloys

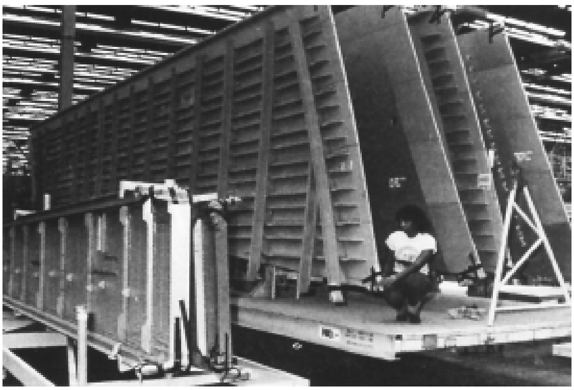


Fig. 37 Critical aircraft wing structures are often of 7*xxx* alloy sheet or integrally stiffened extrusion construction; alloy 7075-T73 or high-toughness alloys such as 7050 or 7475 are among the principal choices.

Fig. 38 Long-length drill pipe often is made of 7*xxx* (as well as 2*xxx*) aluminum alloy extruded tube.

- Approximate ultimate tensile strength range: 130 to 450 MPa (20–65 ksi)

Primary Use. The strongest of the common casting alloys is heat treated 201.0, which has found important application in the aerospace industry. The castability of the alloy 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 castings), and in aircraft construction.

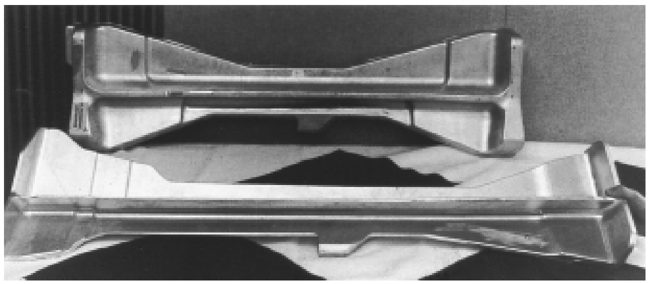


Fig. 39 An example of a premium forged aircraft part of alloy 7175-T736 (T74)

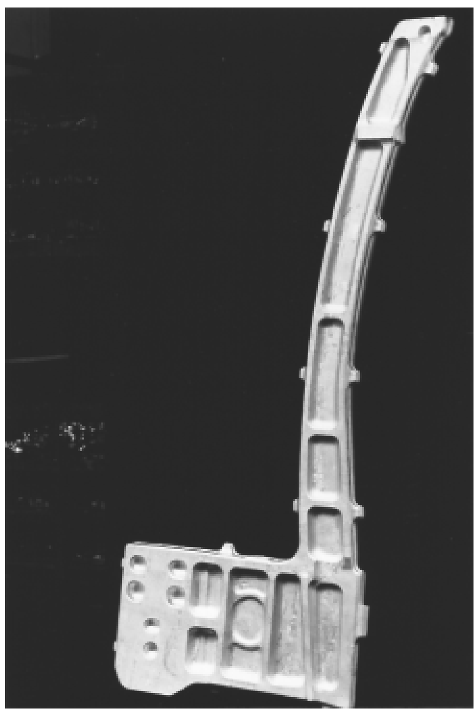


Fig. 40 A forged helicopter component of aluminum-lithium alloy 8090-T852

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, which to date is the aluminum casting alloy with the highest strength at approximately 200 °C (400 °F). An example of an application for 2*xx.x* alloys is an aircraft component that is made in alloys of high-strength alloy 201.0-T6 (Fig. 41).

3*xx.x*, Aluminum-Silicon Plus Copper or Magnesium Alloys. The major characteristics of the 3*xx.x* series are:

- Heat treatable sand, permanent mold, and die castings
- Excellent fluidity, high-strength, and some high-toughness alloys
- Approximate ultimate tensile strength range: 130 to 275 MPa (20–40 ksi)
- Readily welded

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

Primary Use. 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 types of casting, including, especially, the relatively newly commercialized squeeze/forge cast technologies. Alloy 332.0 also is one of the most frequently used aluminum

Fig. 41 Aircraft components are made from high-strength cast aluminum alloys, such as alloy 201.0.

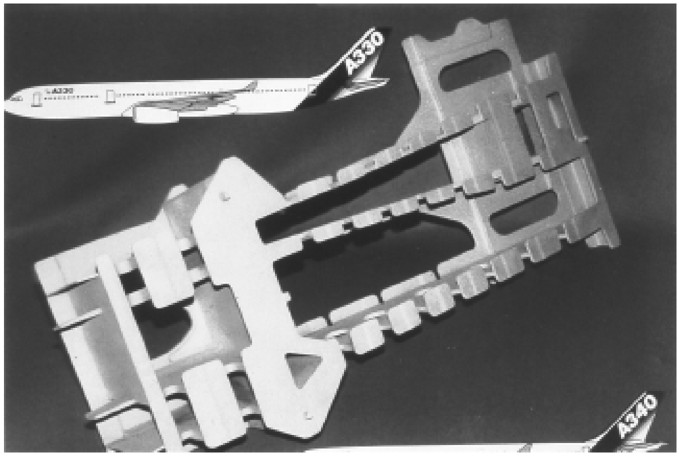


Fig. 42 Thixoformed A356.0-T6 inner turbo frame for the Airbus family of aircraft

casting alloys because it can be made almost exclusively from recycled scrap.

Among the illustrative applications are the thixoformed A356.0-T6 inner turbo frame for the Airbus family of aircraft (Fig. 42); the gearbox casing for a passenger car in alloy pressure die cast 380.0 shown in Fig. 43; rear axle housing (Fig. 44); complex 3*xx.x* castings made by the investment casting processes, providing the ability to obtain exceptionally intricate detail and fine quality (Fig. 45); and A356.0 cast wheels, which are widely used in the U.S. automotive industry (Fig. 46).

4*xx.x,* Aluminum-Silicon Alloys. The major characteristics of the 4*xx.x* series are:

- Non-heat-treatable sand, permanent mold, and die castings
- Excellent fluidity, good for intricate castings
- Approximate ultimate tensile strength range: 120 to 175 MPa (17–25 ksi)

Alloy B413.0 is notable for its very good castability and excellent weldability, which are due to its eutectic composition and low melting point of 700 °C (1292 °F). 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.

Primary Use. These alloys have found applications in relatively complex cast parts for typewriter and computer housings and dental equipment, and also for fairly critical components in marine and architectural applications.

5*xx.x,* Aluminum-Magnesium Alloys. The major characteristics of the 5*xx.x* series are:

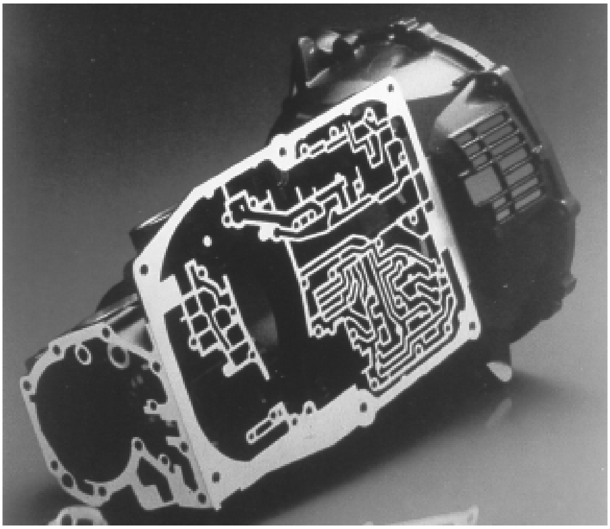


Fig. 43 Gearbox casting for a passenger car, in alloy pressure die cast 380.0

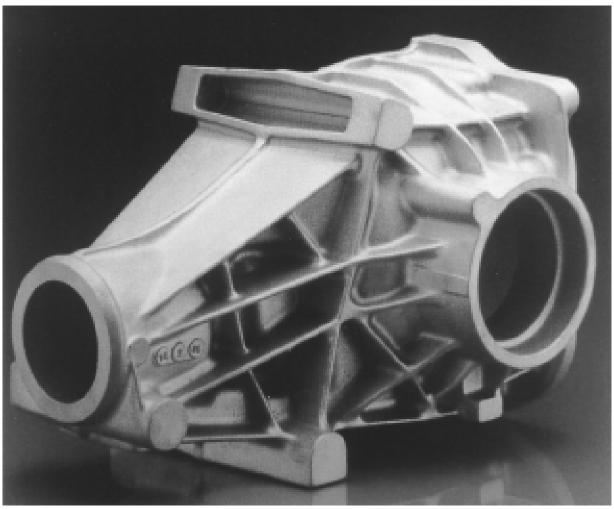


Fig. 44 Rear axle housing of 380.0 sand casting

- Non-heat-treatable sand, permanent mold, and die castings
- Tougher to cast; provides good finishing characteristics
- Excellent corrosion resistance, machinability, and surface appearance
- Approximate ultimate tensile strength range: 120 to 175 MPa (17–25 ksi)

The common feature of this group of alloys is good resistance to corrosion.

Primary Use. Alloys 512.0 and 514.0 have medium strength and good elongation and are suitable for components exposed to seawater or to other similar corrosive environments. These alloys often are used for door and window fittings, which can be decoratively anodized to give a metallic finish or provide a wide range of colors. Their castability is inferior to that of the aluminum-silicon alloys because of its magnesium

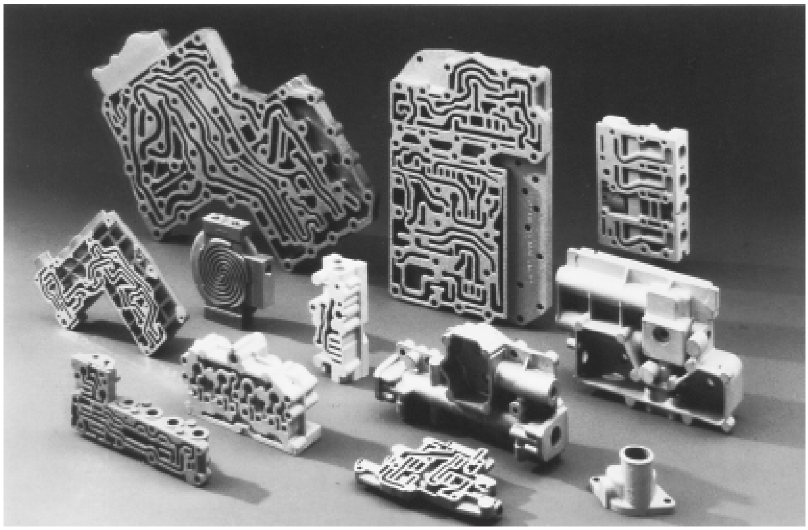


Fig. 45 Complex 3*xx.x* castings made by the investment casting processes, providing the ability to obtain exceptionally intricate detail and fine quality

Fig. 46 A356.0 cast wheels are widely used in the U.S. automotive industry.

content and, consequently, long freezing range. For this reason, it tends to be replaced by 355.0, which has long been used for similar applications.

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

7*xx.x*, Aluminum-Zinc Alloys. The major characteristics of the 7*xx.x* series are:

- Heat treatable sand and permanent mold castings (harder to cast)
- Excellent machinability and appearance
- Approximate ultimate tensile strength range: 210 to 380 MPa (30–55 ksi)

Primary Use. Because of the increased difficulty in casting 7*xx.x* alloys, they tend to be used only where the excellent finishing characteristics and machinability are important. Representative applications include furniture, garden tools, office machines, and farming and mining equipment.

8*xx.x*, Aluminum-Tin Alloys. The major characteristics of the 8*xx.x* series are:

- Heat treatable sand and permanent mold castings (harder to cast)
- Excellent machinability
- Bearings and bushings of all types
- Approximate ultimate tensile strength range: 105 to 210 MPa (15–30 ksi)

Primary Use. As with the 7*xx.x* alloys, 8*xx.x* alloys are relatively hard to cast and tend to be used only where their combination of superior surface finish and relative hardness are important. The prime example is for parts requiring extensive machining and for bushings and bearings.

Applications by Market Area

In the paragraphs that follow, a review is provided of the alloys often selected for products in a number of the major markets in which aluminum is used.

Electrical Markets

The major products for which aluminum is used in electrical applications are electric cable and bus conductors, where the high electrical conductivity (60% IACS) makes aluminum a cost-effective replacement for copper products:

- *Electrical conductor wire:* 1350 where no special strength requirements exist; 6201 where a combination of high strength and high conductivity are needed
- *Bus conductor:* 6101
- *Electrical cable towers:* 6061 or 6063 extruded shapes

Building and Construction Markets

Building and construction encompasses those markets in which architectural and/or structural requirements come together. Such applications include residential housing, commercial storefronts and structures, conference centers and areas (i.e., long roof bay requirements), highway bridges and roadside structures, and a variety of holding tanks and chemical structures (also considered under "Chemical and Petroleum Markets"). Among the choices are:

- *Bridges and other highway structures:* 6061 and 6063 extrusions (Fig. 30); 5083, 5086, and 5454 plate (Fig. 26, 30, 31, 33)
- *Storefronts, curtain wall:* 6063 extrusions
- *Building sheet, siding:* 3005, 3105, and 5005 sheet
- *Arena and convention center roofs:* 6061 extrusions with 5*xxx* alloy sheet panels (Fig. 29)
- *Residential housing structures:* 6063 extrusions
- *Architectural trim:* 5257, 5657, 6463
- *Composite wall panels:* 5*xxx* alloy sheet plus expanded polymers (Fig. 24)

Transportation Applications

The transportation market has several major subsections, as discussed subsequently.

Automobile, Van, Sport Utility Vehicle (SUV), Bus, and Truck Applications. Automotive structures require a combination of aluminum castings, sheet, and extrusions to cover all good opportunities to increase gasoline mileage and reduce pollutants. Among examples are the following:

- *Frame:* 5182 or 5754 sheet (Fig. 14, 22) or, for space frame designs, 6063 or 6061 extrusions (Fig. 34a and b)
- *External body sheet panels where dent resistance is important:* 2008, 6111 (Fig. 36)
- *Inner body panels:* 5083, 5754
- *Bumpers:* 7029, 7129
- *Air conditioner tubes, heat exchangers:* 3003 (Fig. 10, 14)
- *Auto trim:* 5257, 5657, 5757
- *Door beams, seat tracks, racks, rails, and so on:* 6061, 6063
- *Hood, deck lids:* 2036, 6016, 6111 (Fig. 36)

- *Truck beams:* 2014, 6070 (Fig. 7)
- *Truck trailer bodies:* 5456 (Fig. 7)
- *Wheels:* A356.0 (Fig. 46) or formed 5*xxx* sheet
- *Housings, gear boxes:* 357.0, A357.0 (Fig. 43, 44)

Aircraft and Aerospace Applications. Aircraft and aerospace applications require high strength combined with, depending on the specific component, high fracture toughness, high corrosion resistance, and/or high modulus (sometimes all three). The result has been a great number of alloys and tempers developed specifically for this market, as illustrated by the examples below:

- *Space mirror:* High-purity aluminum (Fig. 5)
- *Wing and fuselage skin:* 2024, alclad 2024, 7050 and 7475 sheet and plate or extrusions (Fig. 6)
- *Wing structures:* 2024, 2124, 2314, 7050 stiffened extrusions (Fig. 37)
- *Bulkhead:* 2197, 7049, 7050, 7175
- *Rocket tankage:* 2195, 2219, 2419 (Fig. 8a, b)
- *Engine components:* 2618
- *Propellers:* 2025
- *Rivets:* 2117, 6053
- *If high modulus is critical:* Lithium-bearing alloys 2090, 2091, 2195, 8090
- *If high fracture toughness is critical:* 2124, 2224, 2324, 7050, 7175, 7475
- *For maximum fracture toughness:* 7475
- *If stress-corrosion resistance is important:* 7*X*50 or 7*X*75 in the T73-type temper
- *If resistance to exfoliation attack is vital:* 7*xxx* alloys in the T76-type temper
- *For welded construction, as for shuttle tanks:* 2219, 2195, 5456

Marine Transportation

Many aluminum alloys readily withstand the corrosive attack of marine salt water and so find applications in boats, ships, offshore stations, and other components that are immersed in saltwater:

- *Hull material:* 5083, 5383, 6061, 6063 (Fig. 15–17)
- *Superstructure:* 5083, 5456 (Fig. 15)
- *Structural beams:* 6061, 6063 (Fig. 16, 17)
- *Offshore stations, tanks:* 5083, 5456 (Fig. 21)

Rail Transportation

Much as for automobile and truck bodies, aluminum lends itself to railcar structural and exterior panel applications:

- *Beams:* 2014, 6061, 6070 (Fig. 9)
- *Exterior panels:* 5456, 6111 (Fig. 9, 32)
- *Tank cars:* 5083, 5454
- *Coal cars:* 5083, 5454 (Fig. 20)
- *Cars for hot cargo:* 5454 (Fig. 20)

Packaging Applications

Packaging applications require either great ductility and corrosion resistance for foil and wrapping applications or great strength and workability for rigid container sheet applications (i.e., cans). Alloy choices include:

- *Aluminum foil for foods:* 1175 (Fig. 2–4)
- *Rigid container (can) bodies:* 3004 (Fig. 12)
- *Rigid container (can) ends:* 5182 (Fig. 23)

Petroleum and Chemical Industry Components

The excellent combination of high strength combined with superior corrosion resistance plus weldability makes a number of aluminum alloys ideal for chemical industry applications, even some involving very corrosive fluids:

- *Chemical piping:* 1060, 5254, 6063
- *Pressure vessels (ASME Code):* 5083, 5086, 6061, 6063
- *Pipelines:* 6061, 6063, 6070
- *Cryogenic tankage:* 5052, 5083, 5454, 6061, 6063 (Fig. 18)
- *Containers for hydrogen peroxide:* 5254, 5652

Other Markets

While not major markets in themselves, a variety of specialty products find great advantage in aluminum alloys:

- *Screw machine products:* 2011, 6262
- *Appliances:* 5005, 5052
- *Tread plate:* 6061
- *Weld wire:* 4043 (for welding 6*xxx* alloys), 5356, 5183, 5556 (for welding 5*xxx* alloys) (Fig. 14)