The Manufacture and Uses of Aluminum and its Alloys

T. A. MOORMAN, A. B.

Cincinnati University, 1916—Grad. Student Ohio State University

THE aluminium industry is frequently cited as one of the expansions of industries that have marked the last three decades as an epoch in commercial exploits, and rightly so, for in this time the manufacture of the metal and its alloys has grown to the extent of supplying many of our daily needs. At the present time, aluminum in the form of alloys is finding ever wider application, and in the newer alloys or in improvements of some that are well known will find a field of usefulness that can not be definitely limited.

Historical

In 1886, Hall in America and Heroult in France applied for patent processes very similar in principle for the electrolytic manufacture of aluminum; so successful was the commercial exploitation of these processes that the old method introduced largely by DeVille in 1854, of preparation by reduction from aluminum chloride with metallic sodium became quite obsolete. The cost of manufacture also dropped and made possible the competition that aluminum offered to many other previously used metals.

Process of Manufacture

The Hall electrolytic process consists in the electrolysis of aluminum oxide dissolved in a molten bath of Cryolite, the double fluoride of sodium and aluminum. The negative electrode upon which the aluminum is precipitated electrically consists of a carbon lining in a large rectangular steel box, in which the fused bath containing the dissolved oxide is melted. The negative electrodes consist of solid carbon cylinders or blocks, suspended from a current carrying support and immersed partly in the bath. The passage of a heavy current for the electrolysis is sufficient to maintain the bath in a molten state, the addition at correct intervals of an amount of aluminum oxide to replace that used in the precipitation of the metal being all that is required to make the process continuous. The molten metal that collects on the carbon lining is tapped into ladles and after freeing from any adhering bath, is poured into ingot molds or made directly into alloys. During electrolysis the carbon cylinders of the anode are slowly burnt away by the oxygen, which is set free on their surface and are accordingly slowly moved downward or entirely replaced by new ones.

It appears remarkable that, aside from minor alterations and mechanical improvements in the larger and more efficient installations, the Hall process of aluminum manufacture has not been greatly improved since its introduction. Efforts to render more efficiency from the standpoint of power consumption are, however, being made today as in the past, following, however, the indications of a research laboratory.

The economies that might be effected in power consumption can be obtained from a consideration of the power theoretically needed and that which is actually consumed. The average potential used at present in successful manufacture is near 7 volts; theoretically only 2.8 volts should suffice for decomposition. It is seen that if operation were possible at, say, 3.5 volts the power used would furnish twice as much metal or the power efficiency would be doubled. The current consumption and aluminum oxide consumption are very good, and in good practice the electrode consumption and wastage are near to the practical limit of operations.

The most expensive ingredient used in aluminum manufacture is the oxide, which must be very pure if the metal to be made should be pure. Aluminum oxide is prepared from Bauxite, the only mineral containing aluminum in a state of combination that allows of a cheap enough chemical treatment for its separation from iron oxide, titanium oxide and silica. Bauxite is found in various places in the United States, the deposits of Arkansas furnishing the bulk of the ore. In the chemical treatment the aluminum oxide must be brought into solution, freed from all insoluble and soluble impurities and again be precipitated and calcined at a high temperature to free it from any combined water. The expense of this elaborate treatment is offset only by an installation of considerable size, which must be operated at full capacity to be of any usefulness; obviously the solution to this problem will be of influence in lowering the cost of the metal.

Properties and Uses of Aluminum and Its Alloys

In the commercially pure state, aluminum possesses several properties which have warranted its use on a large scale, chief among which may be mentioned its low density, its high electrical conductivity, its fair tensile strength, its ductility and, under normal conditions, its resistance to corrosion. To a greater or less extent these properties are found to enter into consideration in the use of the metal for any specific purpose. In alloys of high aluminum content, the property of lightness is most frequently the desired property and alloys of high strength, ductility, casting ability and rigidity have been developed and fill a long-felt need.

Among the best known uses of the pure metal is that of its fabrication into cooking and other utensils, where its light weight makes it convenient to work with, and its high thermal conductivity increases the efficiency of heat transfer while lessening the danger of overheating the contents of the utensil. It has been found that the purest metal, known commercially as No. 1, which contains 99% aluminum or more,

(Continued on page 28)

(Continued from page 11)

is best suited for this purpose, because of its high resistance to corrosion. Lower grades are subject to pitting, which lowers their durability. There exist today utensils made from the purer metal, which have given service for more than twenty years, and are still as useful as when first made, showing only mechanical wear.

As a conductor for electricity, in transmission lines and all wiring in general, the high conductivity of aluminum, coupled with its low specific gravity, has led to its extensive application as a metallic conductor. In this case it is displacing copper, which weighs more than three times as much and has only about one-third greater conductivity. For cross sections of equal conductivity the ratio of copper to aluminum is 1:1.59, and in weight per unit length for equal conductivities, the aluminum conductor is less than 50% of the weight of the copper conductor (commercially 48.33%).

This advantage in favor of aluminum is offset by its greater cost per pound; indeed, the cost of aluminum in cable is largely determined by this factor, the cost of aluminum being such that it can compete with copper on an equal footing, and with the new designs in cable construction at an advantage. Aluminum has a high coefficient of expansion, which causes considerable sagging of cables in warm weather, and its tensile strength in the hard drawn condition as used in cables is such that a greater cross section than that necessary for obtaining equal conduction with copper is required. To meet these conditions aluminum cables are now made with a steel wire core, which has given the aluminum cable properties far in advance of any other commercial cable. Because of the increased strength much greater spans are possible, eliminating towers and reducing in addition thereto the hazards from insulator supports. Large spans are becoming more common, the largest to date is probably that erected by the Knoxville Power Company, which the writer had the opportunity of seeing some time ago. This high tension transmission line has a span of over 5000 feet at the point where it crosses the gorge of Little Tennessee River, and is a part of the line running from the Cheoch power house to Alcoa, Tennessee.

The largest use for pure aluminum is in the manufacture of alloys to be used for certain purposes. The addition of other metals only partly affects the density, while the mechanical properties can be altered at will and made to approach those of mild steel. Aluminum forms the basis of the common "light alloys," which in recent years have come into prominence in their application to automobile and aeronautic industries. For casting purposes the main alloys are those containing copper, and zinc with small amounts of copper. Many special alloys to meet particular casting requirements have been developed, literature for which is quite voluminous. For general forging purposes the alloy "Duralumin," presents the maximum attained to date for lightness combined with strength and ductility. It contains generally from 3 to 5 per cent copper with 0.2 to 1.0 per cent magnesium in addition to the commercial impurities of iron and silicon in the metal as made. The properties can be altered by further additions of other metals, such as manganese, nickel, iron, even excess silicon finding some value in this respect. A newly published Duralumin having a tensile strength of over 90,000 pounds per square inch and an elongation of 9 per cent contains, in addition to the magnesium and copper, 20 per cent zinc. The castings and forgings of Duralumin are capable of being heat treated in a manner similar to steel, thus they can be worked in an annealed condition, then by heat treatment be brought into the condition of greatest strength. Uses of these light alloys, which are still somewhat expensive, are restricted to those parts that are subject to repeated stress, which these alloys seem to withstand to a large degree, for example in connecting rods, forged pistons and as heat treated castings for very light motors such as the "Liberty Twelve" and other automobile parts. The use of Duralumin in construction of airships and to replace the customary fabric of aeroplanes is well known.

For equal volumes aluminum alloys are cheaper than brass or bronze, and its machining ability being far in excess of as regards speed to that of cast iron, has led to its wide use for the purpose of sheer econcmy.

The heat of combustion of aluminum is relatively high in comparison to that of the other metals. Advantage is taken of this fact in the alumino-thermic process used for preparing carbon free metals and alloys of purity by direct reduction of the oxides with aluminum. This process is also used in welding, in raising the temperature of melts of metals and in the deoxidation of steel for the production of sound ingots.