ALUMINUM IN *Aircraft*

To
Richard & Pat Gillespie
"Good Luck" - Earhart '91
Neal Simpson

ALUMINUM COMPANY OF AMERICA

PITTSBURGH, PA.

1941a

FOREWORD

An increased demand for information about aluminum alloys has resulted from the expansion of aircraft production. This booklet was written to meet this demand and furnish the data needed to employ aluminum successfully. It is intended primarily for the newcomer who wants to obtain a general picture of the use of aluminum in aircraft, rather than for the veteran aircraft manufacturer.

Aluminum Company of America also publishes other booklets that cover in greater detail several of the subjects discussed in this manual. The following literature may be obtained on application to the nearest sales office:

- Alcoa Aluminum and Its Alloys
- The Working of Aluminum Alloys
- Shop Instructions for Heat Treatment of Alcoa Aluminum Alloys 17S and 24S
- Riveting Aluminum
- Welding Aluminum
- Machining Aluminum
- Forming Aluminum

CONTENTS

Many of the alloys included in this booklet, their processes of fabrication or casting, their heat treatment, or the products of one or more of these operations are covered by United States patents.

ALLOYS AND PRODUCTS

Commercially pure aluminum has a minimum aluminum content of 99 per cent, the balance being impurities normally present, mainly iron and silicon. In the wrought form, the commercially pure metal produced by Aluminum Company of America is known as Alcoa 2S,* which has a high degree of resistance to corrosion and ability to be easily formed into intricate shapes. It is relatively low in strength, however, having a tensile strength of about 12,000 pounds per square inch in its soft or annealed state. The pure metal is therefore not suitable for structural airplane parts.

Higher strengths may be obtained by the process of alloying; that is, by combining small amounts of one or more other metals with the aluminum. The resulting alloys are less easily formed and, with some exceptions, they have lower resistance to corrosion than the commercially pure metal.

Alloying is not the only way of increasing the strength of aluminum. Like copper, brass, steel and other metals, aluminum becomes stronger and harder as it is rolled, formed or otherwise cold-worked. Since the hardness depends on the amount of cold work done, some of the wrought aluminum alloys are available in several work-hardened tempers. As the strengths are increased, there is some sacrifice in the metal's

*The alloy designations given in this booklet are for Alcoa aluminum alloys produced by Aluminum Company of America.

ability to be worked easily and successfully into intricate commercial forms.

Heat treatment is still another way of increasing the strength of some of the aluminum alloys. With but minor exceptions, the aluminum alloys used for structural parts in aircraft are those which can be heat treated to obtain higher strengths. *When finally installed in the airplane, such materials must be in the heat-treated condition.* The first aluminum alloy that was successfully heat treated commercially was one containing four per cent copper and one-half per cent each of magnesium and manganese. This alloy became known under the trade name "Duralumin," later shortened to "Dural." These terms are sometimes applied to an entire class of alloys with similar compositions.

The principal aluminum alloy used in airplane structures is called Alcoa 24S by Aluminum Company of America. An improved alloy of the duralumin type, it contains the same alloying elements as the older 17S, but in different proportions, and possesses greater strength.

These alloys and others used in the airplane structure itself are the main subject of this booklet. However, some data are included on the aluminum alloys that are used in airplane engines and accessories.

CLASSIFICATION AND NOMENCLATURE

Aluminum alloys are obtainable in either cast or wrought forms. They may be further classed as nonheat-treatable and heat-treatable alloys.

The chemical composition of the alloys is indicated by the alloy number. Wrought alloys are distinguished from cast alloys by the letter "S" following this number.

An alloy in the fully heat-treated and aged temper (such as 24S-T) may be further cold-worked, such as by rolling, to obtain still greater strengths. It is then said to be in the "RT" temper. Although this further rolling reduces the elongation and workability, 24S and Alclad 24S in the "RT" temper are regularly corrugated and formed into other aircraft parts The various cold-worked and heat-treated tempers are

TEMPER DESIGNATION

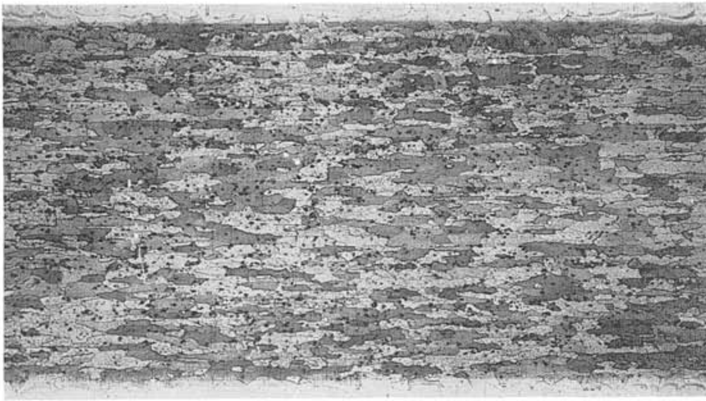
Heat-Treatable Alloys

Class	Description	Designation	Example
Wrought	Annealed condition	"O"	24S-O
	Fully heat treated	"T"	24S-T
	*Quenched, but not completely aged	"W"	61S-W
	Heat treated and cold worked	"RT"	24S-RT
Cast	Specific heat treatment indicated by number	"T4," "T6," etc.	195-T4 195-T6

Nonheat-Treatable Alloys

Class	Description	Designation	Example
Wrought	Annealed condition	"O"	3S-O
	Intermediate cold worked	"¼H" "½H" "¾H"	52S-¼H
	Maximum commercial degree of work hardening	"H"	2S-H
Cast	No temper designation	.....	43

*"W" Temper applies only to alloys requiring artificial aging to attain "T" condition.



Cross section of a piece of 0.040-inch Alclad 24S-T sheet. Note the integrally bonded layers of relatively high purity aluminum (known as the "coating") on each face of the high-strength 24S-T "core." This material is especially resistant to corrosion, primarily because of the electrolytic protection afforded the core by the coating.

also indicated by symbols as shown in the table on page 7.

The mechanical properties specifications for wrought alloys and products are given on pages 75 to 84 and for cast alloys on pages 70 and 71.

SHEET

A large percentage of the material in the modern airplane is aluminum alloy sheet, used for the outer covering or skin and for various other structural parts. Since most of this sheet is subject to high stresses under some flight conditions, high-strength alloy 24S-T is almost universally used, although some 17S-T is employed. Nonstructural parts are sometimes made from the alloys that are not heat treated or from one of the lower strength heat-treated alloys.

Whether the sheet is 24S or 17S, it is usually used in the form known as "Alclad"* sheet. This material has a high-

*Registered trademark, Aluminum Company of America. Since the mechanical properties and working characteristics of 24S and 17S are quite similar to the corresponding Alclad 24S and Alclad 17S sheet, reference to 24S and 17S in many places in this text also implies reference to Alclad 24S and Alclad 17S.

strength "core" covered on each side with a coating of relatively high-purity aluminum which has a high resistance to corrosion. This coating protects the core in two ways. It not only covers most of the core and prevents contact with corrosive agents, but also protects the core electrolytically. This electrolytic protection is given to the cut edges, to areas where the coating is abraded away and even to rivetheads. Alclad materials have been in use for over twelve years, and have an enviable service record in seaplanes and landplanes operating in every part of the world.*

Standard sizes of 24S and Alclad 24S sheet in both the annealed and the heat-treated condition are listed in Table 26, page 92. This material is normally carried in stock, and can be delivered in less time than nonstandard sizes. Eighteen of the items, as indicated in Table 26, are in much greater use than the others. In ordering these sizes the user can gain a price advantage by agreeing to accept up to 20 per cent of the order in random smaller standard sizes. The sheet in this stock has been inspected for chemical composition and mechanical properties by the U.S. Navy Department Inspector, and its use on both Navy and Army contracts has been approved.

The aircraft industry is making increased use of 24S and 17S coiled strip because of its economic and other advantages. Available gauges and widths are shown in Table 30, page 94. Heat-treated coiled strip is generally used in the fabrication of rolled sections, where the long lengths are very useful. Annealed coiled strip is used for blanking out small parts which are subsequently heat treated.

EXTRUDED SHAPES

An extruded shape is produced by forcing hot metal through a die in which there is an opening corresponding in shape to the desired cross section. This process frequently provides more efficient utilization of metal than rolled shapes, and it permits production of many shapes that cannot be

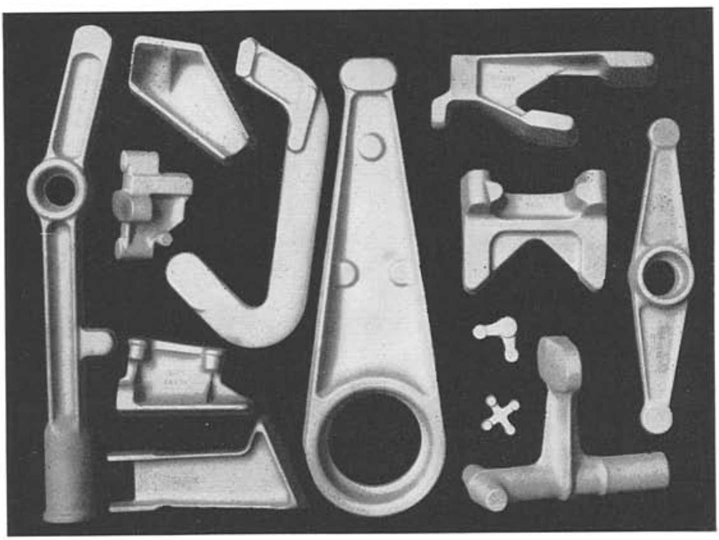
*See "Ten Years' Service Experience with Alclad Materials in Aircraft," S.A.E. Journal, Vol. 44, No. 5, May, 1939.

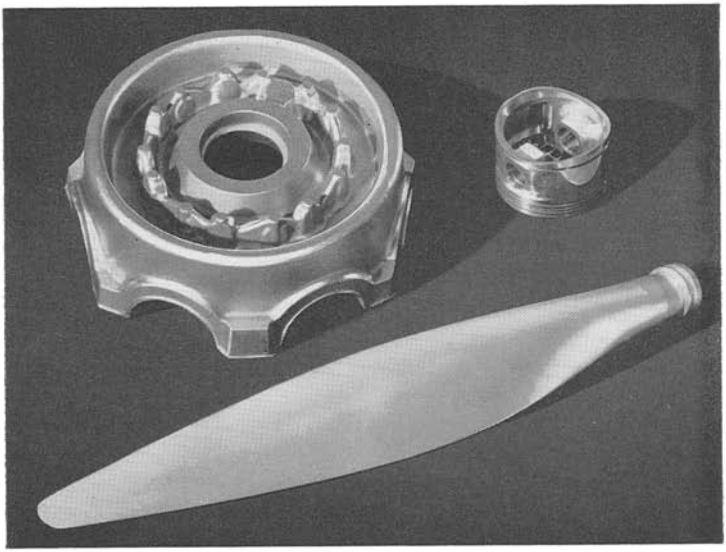
rolled. Extruded shapes are used as stringers and other important structural parts of the airframe, and provide easy assembly as well as maximum structural usefulness. Since high strength is desired for most aircraft applications of extrusions, 24S-T is the alloy generally used. Extruded shapes not requiring high strength are sometimes made from 53S or 61S in a suitable temper, or from 2S or 3S. These last two alloys are used in the "as-extruded" condition which is very slightly work-hardened, and not in a specific temper. Sales offices of Aluminum Company of America should be consulted for information regarding available sections and design limitations for new sections.

FORGINGS

Forgings make up a relatively small percentage of the total weight of an airframe, but they serve a most important func-

Typical airframe forgings. These parts serve various functions, ranging from structural fittings to levers and bell cranks for operating the controls. Forgings provide high-strength fittings of great reliability which, under large-scale production conditions, are very economical.





Typical power-plant forgings. Because they have high strength and homogeneity of structure, forgings find extensive use in the manufacture of parts for engines and propellers.

tion as structural and other fittings, in addition to their well-known uses for making engine parts and propeller blades. Most forgings are made in dies on hammers, but some are pressed rather than struck, and these are called press forgings. The latter require less "draft" than hammer forgings and permit somewhat closer tolerances. Many forgings are made from alloy A51S-T, while 14S-T is usually used for highly stressed forged fittings. Various aluminum forging alloys are listed in Table 14, page 76.

CASTINGS

Aluminum castings are more extensively used in the airplane engine and for accessories than in the airframe itself. Depending on the quantities and properties required, such castings are produced by one of three basic methods: sand, permanent mold and die. Sand castings are adaptable to a wide range of products from the smallest to the largest. Permanent-mold castings are used in order to obtain higher mechanical properties, better surfaces or more accurate dimensions. Die castings find application in cases where relatively large production of a given part is involved, since this will distribute the die costs over a large number of units, at the same time reducing machining costs because of closer tolerances and better finish.

Any shape which can be forged can also be produced as a casting. While forgings are sometimes preferred because of their greater strength and homogeneity, it may be necessary to produce complicated shapes as castings. Many castings are furnished "as-cast," but some alloys are heat treated to obtain increased strength.

WIRE, ROD AND BAR

The products in the group known as "Wire, Rod and Bar" find their application in aircraft principally in the form of structural fittings machined from rod or bar, usually 24S-T or 17S-T. Other uses include screw-machine products. Rivets are made from special rivet wire. Table 31, page 95, covers the sizes of wire, rod and bar which are considered standard for aircraft use. These sizes should be specified in order to insure relatively prompt shipment.

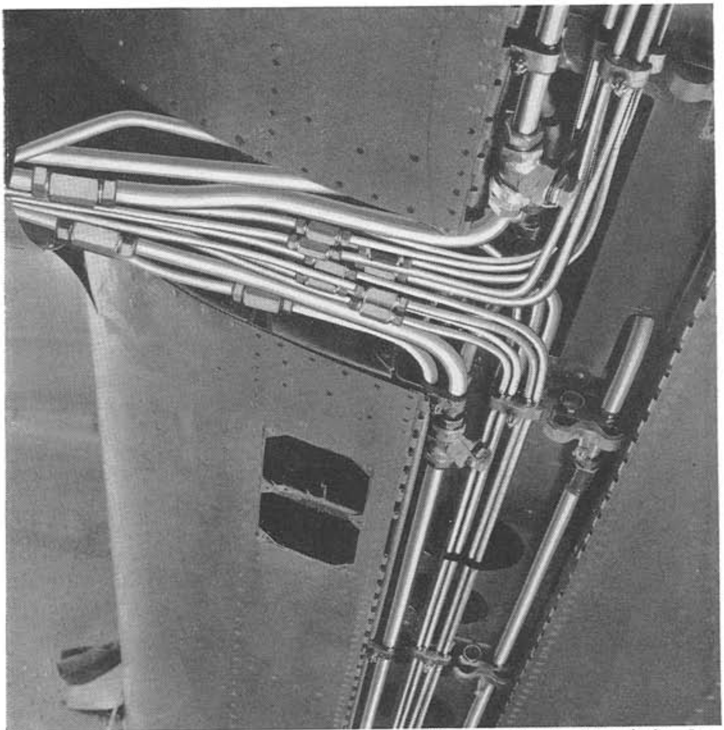
RIVETS AND SCREW-MACHINE PRODUCTS

In addition to supplying wire, rod and bar for rivets and screw-machine products, Aluminum Company of America also manufactures these items. The most widely used rivet alloy is A17S-T. Joints requiring higher strength are made with 17S-T or 24S-T rivets. Standard sizes of rivets with shank ends chamfered are shown in Table 34, page 104.

Nuts, bolts, screws and various special screw-machine products for aircraft use are made almost exclusively from 24S-T and 17S-T.

TUBING

Tubing is used in aircraft construction for fuel, oil and other liquid lines; instrument lines; and structural parts, either in the airframe itself or in places such as the control



Courtesy Douglas Aircraft Co., Inc.

Plumbing in the underside of the wing of a modern transport airplane. The aluminum alloy tubing, which serves as fuel, oil, instrument and other lines, is readily bent into the desired forms.

system or power plant. Standard sizes and alloys for various uses are indicated in Table 32, page 98, and Table 33, page 99.

U.S. GOVERNMENT SPECIFICATIONS

Table 1, page 57, provides a list of Aluminum Company of America's alloys and products, together with references to applicable U.S. Government Specifications. For each product, the nominal composition and the available tempers covered by the specifications are listed. Material ordered on the basis of Aluminum Company of America specifications will comply with corresponding Government specifications.

INSPECTION OF MATERIALS

Material for U.S. Naval and Army aircraft is usually Government-inspected at its source by the resident U.S. Navy Department inspectors of naval materials. When there is no resident inspector at the plant producing the material, the government inspection is carried out at destination.

Quantitative inspection items include chemical composition, mechanical properties, dimensional requirements (which sometimes include straightness), and packing and shipping requirements. The limits to which these factors must conform are set forth in detail in government specifications.

Qualitative inspection items include general surface appearance, specific surface abrasions and blemishes, flatness and straightness. Government specifications discuss these items under "workmanship." The following, among others, are *not* normally considered grounds for rejection:

1. *Surface discoloration of heat-treated materials.* Alclad sheet is less susceptible than other heat-treated sheet.
2. *A few small surface blisters on heat-treated Alclad sheet.*
3. *Shallow scratches on Alclad sheet.* The surface of Alclad sheet is relatively soft, and is therefore somewhat susceptible to handling scratches. Extensive investigations have shown that these scratches do not detract from the resistance to corrosion and do not have a measurable effect on the tensile strength, yield strength or elongation.
4. *Light die scratches and minor surface abrasions on extrusions, tubing, rods, bars and rolled shapes.*
5. *Small residual heat-treating buckles and lack of perfect flatness, particularly on thin gauge (under 0.040 inch thick) heat-treated alloy sheet.*
6. *Lack of perfect flatness on annealed sheets of any gauge.*

Those not familiar with accepted standards for these qualitative items of inspection are urged to consult with our local representatives. Special inspection requirements are sometimes included in contracts for material to be used for special purposes for which commercial grades are not applicable.

AIRFRAME FABRICATION

Aluminum alloys are fabricated on the machinery and equipment normally employed for other metals. The details of methods, tools and dies depend on the particular alloy and temper, the quantity of identical parts involved, and the nature of the parts themselves.

Many of the manufacturing methods developed by the aircraft industry have been the result of conditions peculiar to the industry itself, not the materials used. For example, aluminum alloys can be successfully formed on the large mechanical presses which are so common in the automotive field. However, the smaller quantities generally involved in the aircraft industry have not warranted investment in the tools and dies required by these presses.

CUTTING AND BLANKING

One of the first fabricating operations involves the cutting of rectangular sheets of metal into the sizes and shapes required for the individual parts of the airframe. The methods used can be classified as shearing or cutting.

Equipment for shearing includes guillotine shears (either power- or foot-operated) for making straight cuts; roll shears

Courtesy Onsrud Machine Works, Inc.

High-speed routing machine for cutting a number of aluminum sheets at one time. The cutter is moved by hand and guided by templates which are shown bolted through the stack of aluminum sheets to the fixed table.

for curves; male and female blanking dies; and a variety of modifications of the foregoing. To obtain sheared edges with a minimum of burr, the cutting edges must be smooth and sharp, and set with a clearance equal to about seven per cent to ten per cent of the thickness of the metal being cut. The use of metal dies and rubber pads for blanking sheet metal has been very popular in the aircraft industry because the tool cost is low, and the small quantities have not justified the cost of male and female blanking dies.

Two types of cutting are used on sheet stock: sawing and milling (or routing). Band saws are sometimes used for cutting stacks of sheet-metal blanks and, of course, both band and circular saws are used for miscellaneous work on sheet and extruded sections. High blade speeds (5,000 feet per minute for band saws and 10,000 feet per minute for circular saws) are desirable for best results, and saw teeth should be fairly coarse with a slight set and front rake.* A more recent

*See "Machining Aluminum," published by Aluminum Company of America.

method for cutting stacks of sheet-metal blanks involves the use of routers. The cutter is a small diameter milling tool which turns at high speed on a vertical axis. It is guided by a template clamped to the work and cuts a path all around the blanks equal in width to the diameter of the cutter. This method leaves the edges of the blanks in a smoother condition than when the metal is sawed.

FORMING*

Most of the forming work in the aircraft industry is done on sheet. In general, the equipment consists of basic machines, which are fitted with special tools or dies for each part they are to process. Thus a double-action mechanical press (of which there are but few in the aircraft industry) would be equipped with a number of sets of punches, dies and blankholders. The cost of such tools for large parts has led the industry to seek other methods.

Single-action presses, usually hydraulic when large in size, are used extensively. The large hydraulic presses are usually fitted with a rubber pad on the ram, both for blanking and forming. Because there is no tendency to "iron" or draw out wrinkles when metal is formed over a die (metal, wood or synthetic material) with a rubber pad, it is common practice to notch the flange and also to provide flutes or scallops in the flange to use up the excess metal. Parts formed by this method usually have a more or less flat surface surrounded by a flange, as for example a curved channel, a wing rib or a flanged bulkhead. Mechanical presses equipped with metal dies are used for a number of forming operations and simple draws, usually on small parts.

Drop hammers, using zinc or zinc alloy dies and lead punches cast in the die cavity, are very extensively used. Many of the parts produced in this manner could be drawn

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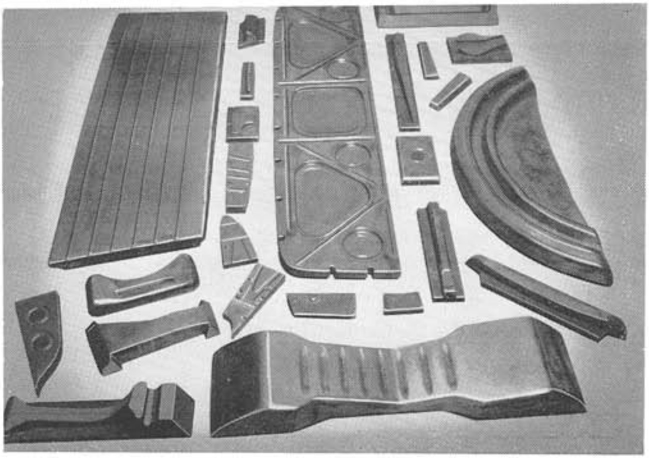
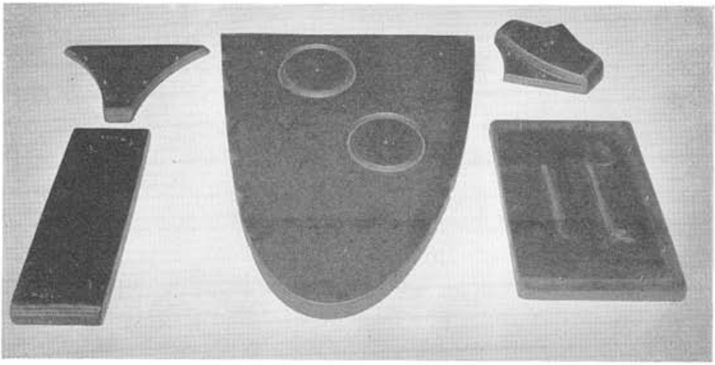
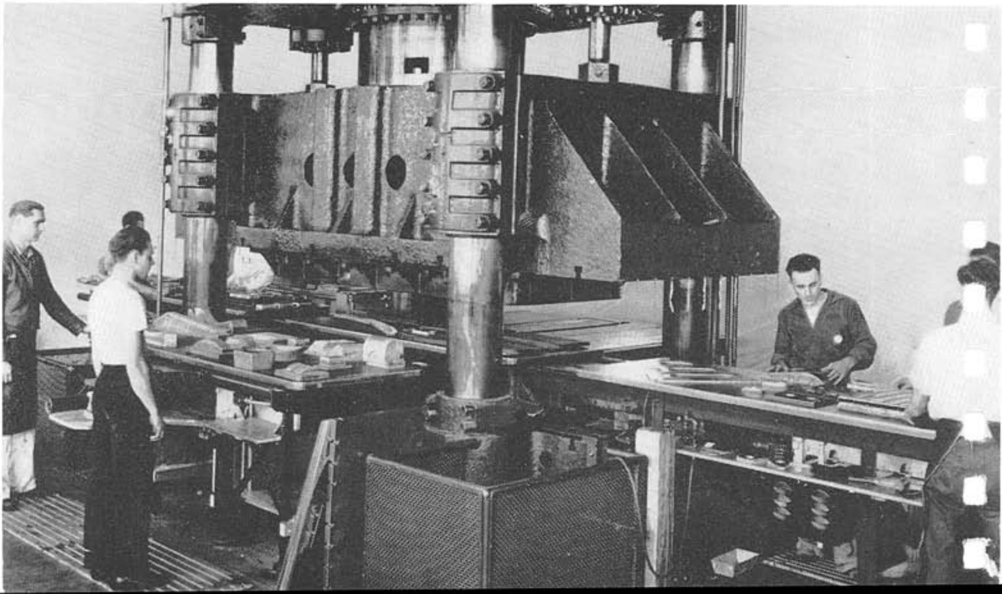
*See "Job-Lot Aircraft Stampings," The Iron Age, Oct. 19 and 26, 1939, and "Forming Aluminum," published by Aluminum Company of America.

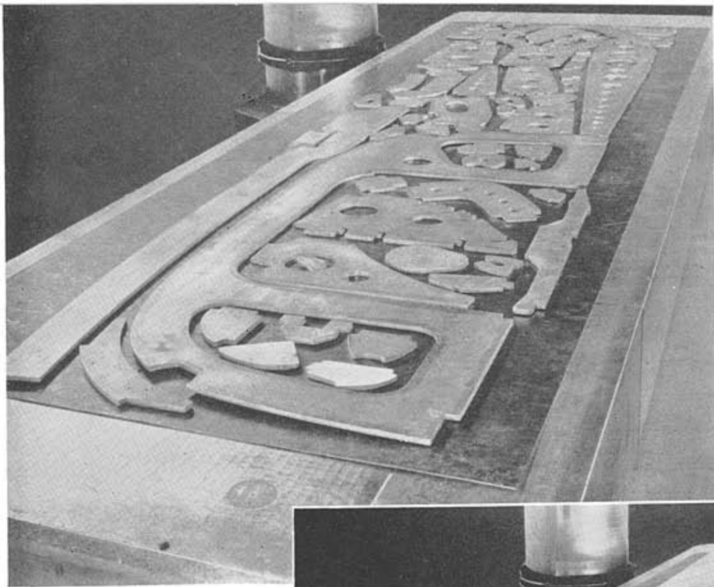


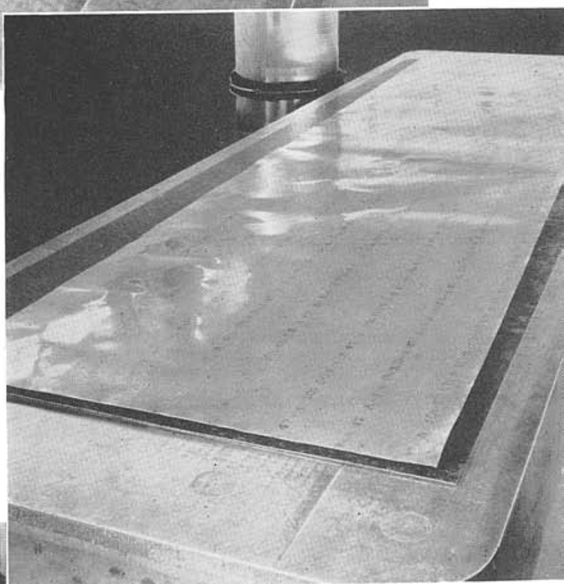
Tools for forming aluminum by the rubber-pad method. Those in the upper group are metal, and those in the lower group are made from synthetic materials having a wood-fiber base.

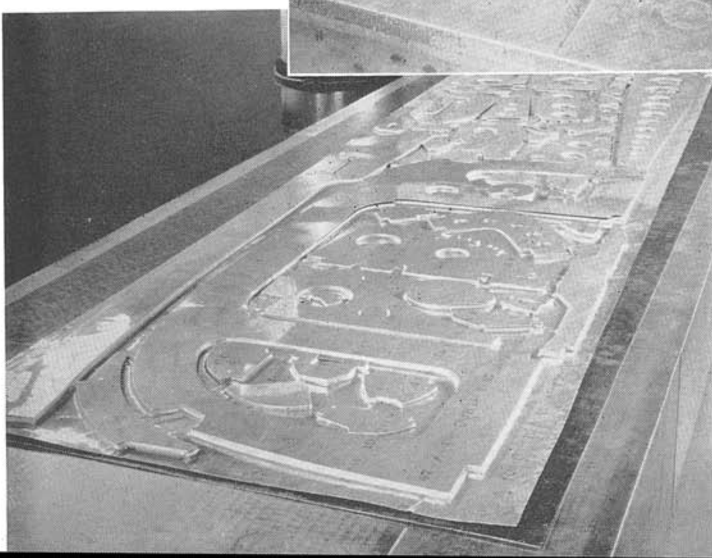


Large hydraulic press using rubber-pad method for blanking and forming. Note that there are four tables on which work is prepared, thus permitting rapid operation of the press.









The rubber-pad method for blanking aluminum. (Above) *Nesting of cutting dies on gang plate.* (Right) *The aluminum alloy sheet in place over the dies.* (Below) *The finished blanks.*

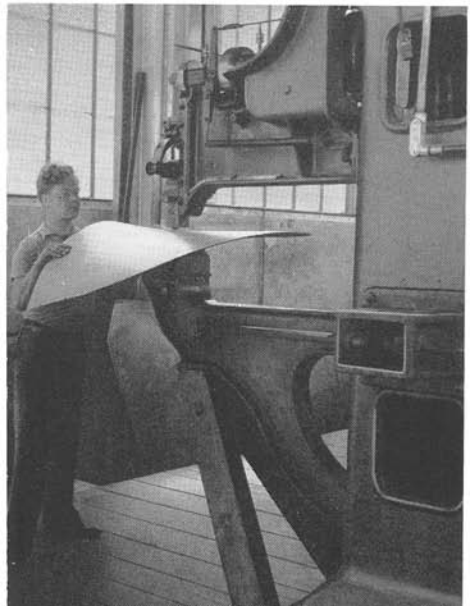
Photos on pages 18 and 19 courtesy Douglas Aircraft Co., Inc.

Courtesy Lockheed Aircraft Corp.

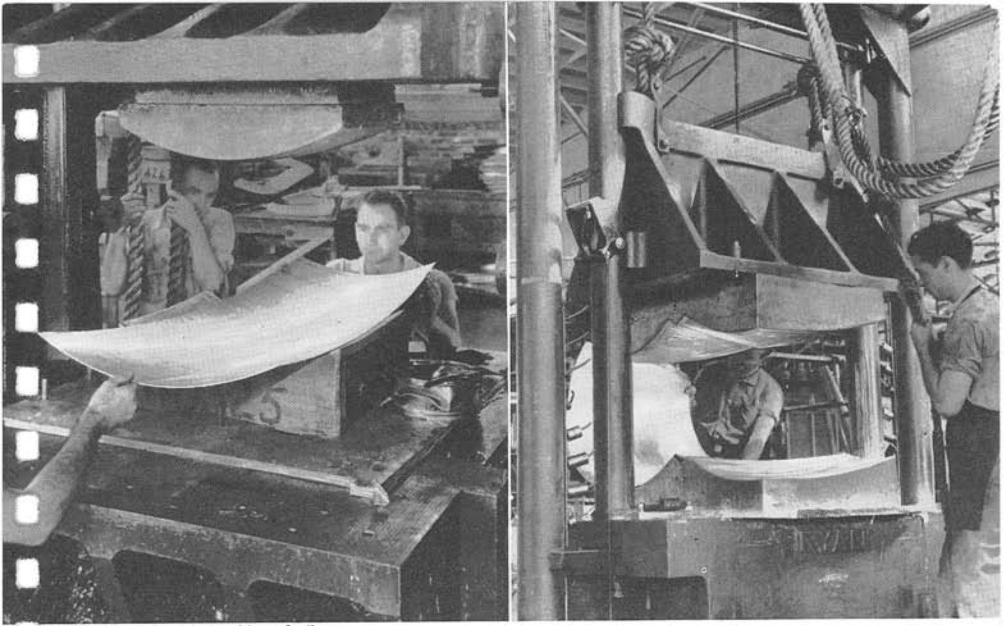
Forming panels on a drop hammer. The plywood spacers are removed between strokes of the hammer. Wrinkles that may form are generally removed by means of a hand hammer.

on a double-action press at a lower unit cost, but a large number of parts is required to justify the higher cost of steel dies. Sheet panels for wing tips, fins and control surfaces as well as fairings and fillets are made by this method.

Sheet panels having very slight double curvature are sometimes formed by stretching them over a metal or hardwood form. The sheet is wrapped over the form and is clamped along two opposite edges. The form is then raised so that the sheet becomes tight over the higher parts. Further motion of the form stretches the tight parts until the panel fits the form at all points.



Power hammering sheet-metal panel. This method requires skill, and is used mainly for experimental ships or other small-quantity jobs.



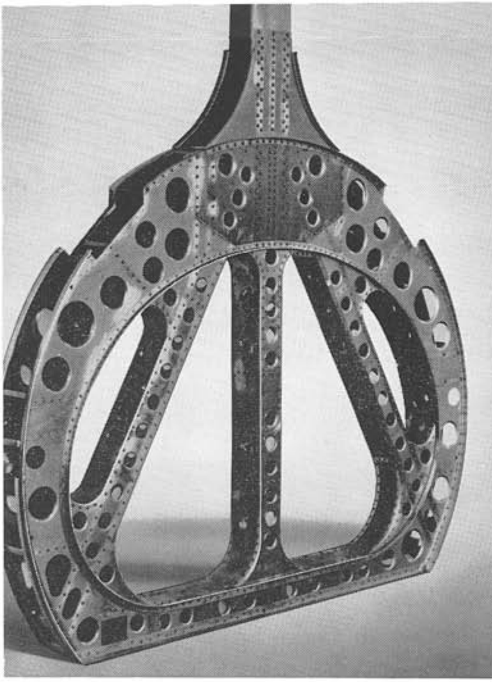
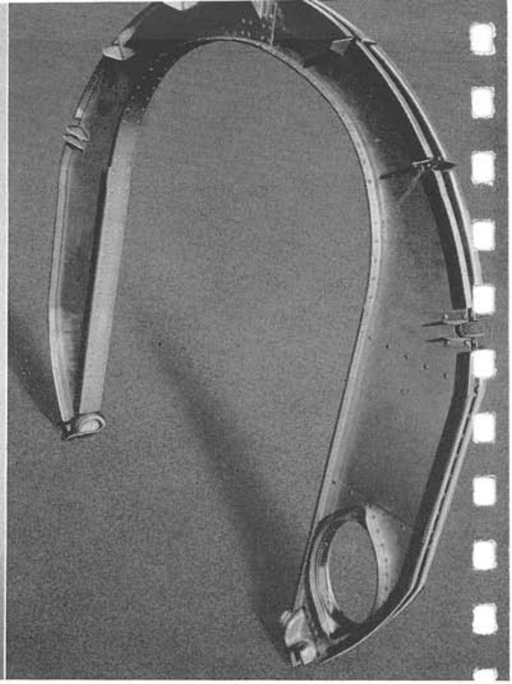
Courtesy Lockheed Aircraft Corp.

Typical drop-hammer operations. The panels shown at the left might also be made by stretching over a form as described on page 20, whereas the part shown at the right would be difficult to make by any means other than a drop hammer.

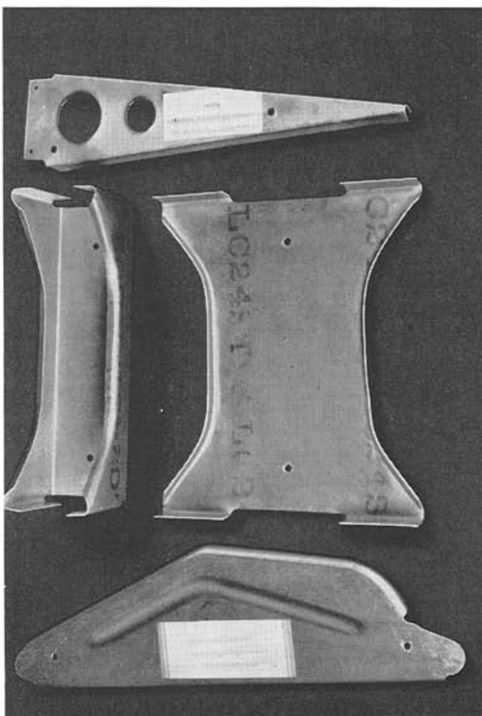
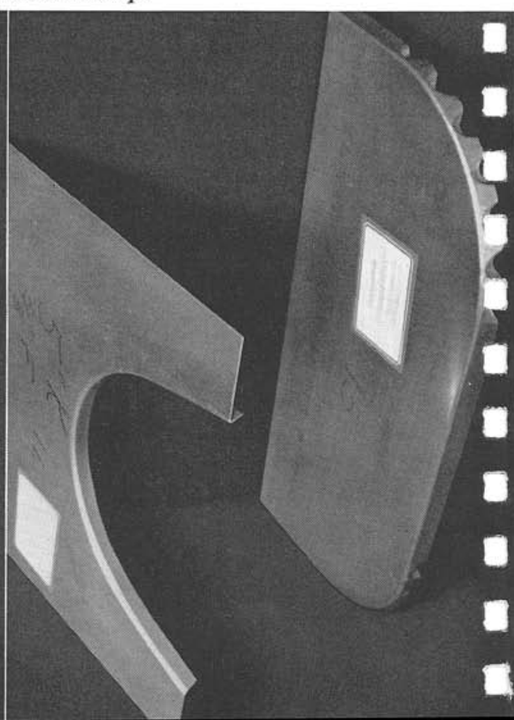
Apron brakes, folders, cornice presses, rolls and draw-benches are used in making the endless variety of parts requiring bends that are not curved. These include corrugated sheet and sheet molding for structural uses in the airframe. This equipment and its operation is typical of that used by the better class sheet-metal shops using other materials as well as aluminum.

Considerable handwork is used in forming aircraft parts. Some of this work is done by skilled power-hammer men who form sheet panels to create the necessary curvature or crown. Other parts are made by hammering over or into various wood forms. Even in production work where tools have been provided, some hand straightening and adjusting may be necessary. In general, larger quantities justify more nearly perfect tools which, in turn, reduce or eliminate handwork. Experimental airplanes sometimes warrant very little tooling.

Tools must be smooth and well-lubricated so that movement of the metal over the tool surface will not be impeded. Rough spots or poor lubrication can cause particles of aluminum to tear out of the work and build up on the tool surface.

Examples of 24S and Alclad 24S parts formed from fully heat-treated stock aged at room temperature. This eliminates expensive heat treating and reshaping. Parts shown below were formed by Douglas Aircraft Co., Inc., on an hydraulic press using the rubber-pad method. The Douglas photo at right, above, illustrates the workability of Alclad 24S-RT. Photo at upper left courtesy Republic Aviation Corp.

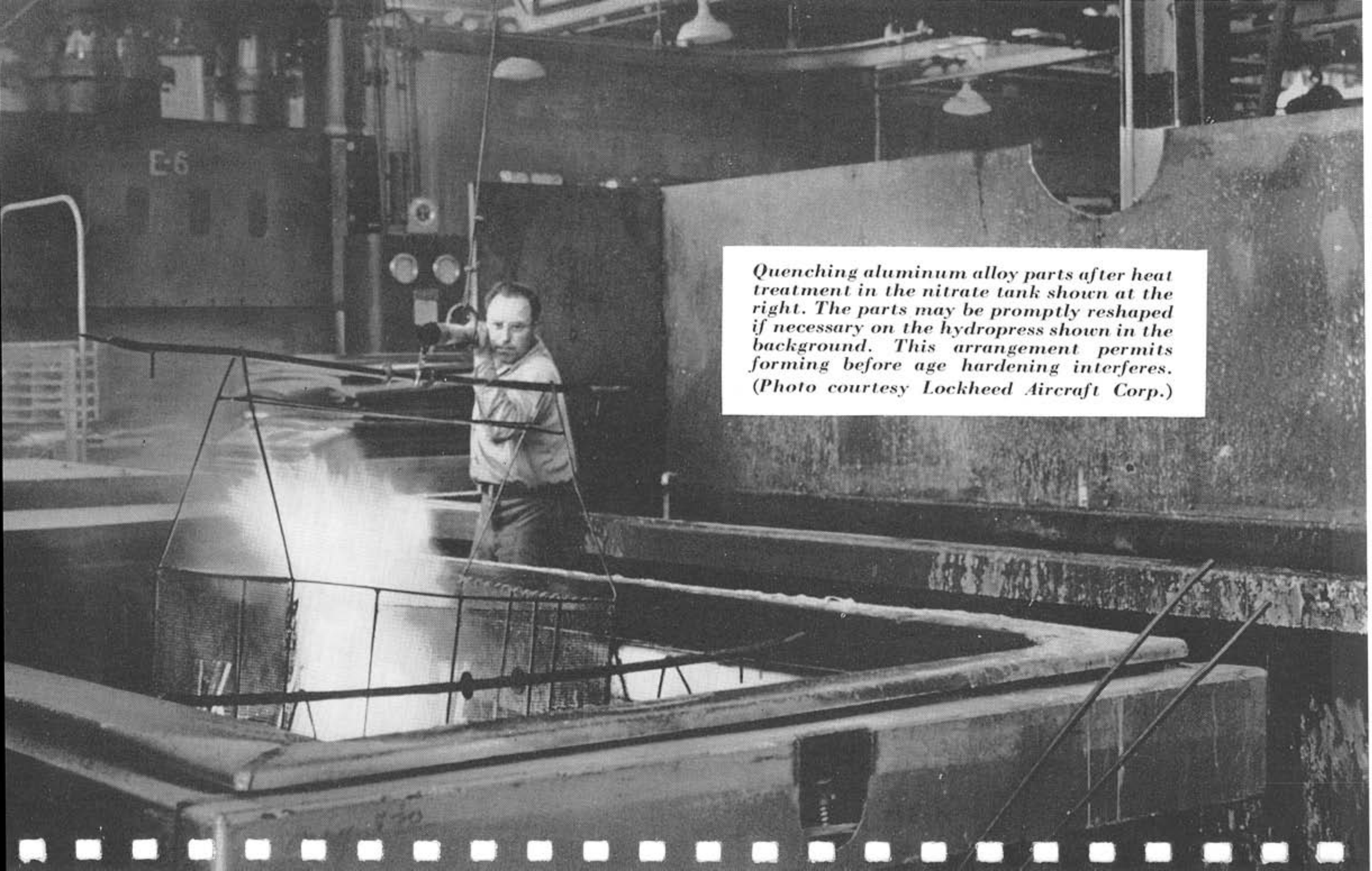
This condition is accumulative and once started becomes progressively worse. In addition to marring the surface of the metal, it may even cause fracture because the metal is unable to slip easily over the tool surfaces.

Soluble oils are sometimes used as lubricants, but more often a mineral oil, tallow, paraffin or a mixture of tallow and paraffin are better for the more severe forming operations such as drawing.

Wherever possible, forming should be done on material in the fully heat-treated and aged condition. When this is not possible, it should be done immediately after heat treating when the metal is in a more workable condition than it is after "aging" (see page 28). Since flat blanks for subsequent forming will warp when they are quenched in cold water, it is sometimes necessary to partially flatten them before they are formed. Much of the heat treatment in the aircraft industry is done after the parts are formed or partially formed from annealed stock. This often involves straightening or reshaping operations, which are most easily done before age hardening has progressed too far. Under these circumstances some work is saved if the entire forming operation is performed on blanks which have been freshly heat treated.

Table 2 on page 66 will serve as an indication of the bending characteristics of various alloys and tempers. The discussion on "Choice of Materials and Processes," beginning on page 45, also has important bearing on the forming problem.

The aircraft industry maintains high standards, and for this reason handling and tool marks must be kept at a minimum to avoid expensive rejections and reworking. Care on the part of the individual workmen in handling the material is of highest importance. Partial protection is sometimes provided by painting the aluminum as early in the fabrication process as is feasible. The priming coat of paint can be used for this purpose or lacquer or varnish, either clear or pigmented, may also be used. These coats are often temporary in character and are removed from the exterior surfaces of the finished airplane. Heat treating, spot welding and anodic treating should be done on unpainted parts.



Quenching aluminum alloy parts after heat treatment in the nitrate tank shown at the right. The parts may be promptly reshaped if necessary on the hydropress shown in the background. This arrangement permits forming before age hardening interferes. (Photo courtesy Lockheed Aircraft Corp.)

HEAT TREATMENT*

The heat treatment of aluminum involves bringing the material to a prescribed temperature, holding it there for a prescribed length of time, and then *promptly* quenching it. The principal conditions necessary for correct heat treatment of various aluminum alloys used in aircraft are shown in the tables on page 67. Either a fused salt bath or an air furnace is used. Although most of the heat treatment in aircraft plants is confined to 24S and Alclad 24S sheet, directions are included for some other alloys. Table 3 indicates the temperature range for the various alloys, and Table 4 indicates the "soaking" period or the time the material is to be held within the prescribed temperature range.

HEATING PROCEDURE AND CONTROL

For air furnaces the tabular values are based on metal temperature as registered by a thermocouple attached to the part of the load that is thought to be the slowest to heat either because of its thickness or its location in the furnace. The soaking time is considered to start when the coldest part of the load has passed the lower limit of the heat-treating temperature range.

Since it is not practicable to attach a thermocouple to the load in a fused salt bath, the values in the tables are based on temperature of the bath itself. Soaking time starts when the bath temperature has reached the lower limit of the heat-treating range after the load has been immersed. When the weight of salt is large compared to that of the load (as is frequently the case with formed sheet parts), the bath temperature does not go below the minimum temperature for heat treatment, and the soaking time becomes the total time required in the bath.

It is important that the specified temperature limits be maintained. When the temperature is too low, optimum mechanical properties are not attained, and when it is too high,

*See "Shop Instructions for Heat Treatment of Alcoa Aluminum Alloys 17S and 24S," published by Aluminum Company of America.

the quality of the material is impaired by melting at the grain boundaries. Heat-treating temperatures are specified as high as is considered safe in this latter respect. Thick material requires a longer soak than thin material, primarily because it has not been so thoroughly worked during the fabrication process.

The soaking times shown in Table 4, page 67, are intended to be a guide for a large variety of equipment and types of work. It is usually satisfactory to employ longer times, while shorter heating periods will often produce good results. Aluminum Company of America is pleased to co-operate in specific instances of this kind and the nearest sales office should be consulted. In the case of Alclad sheet, diffusion of the alloying constituents of the core into the coating at heat-treating temperature tends to adversely alter the composition of the coating material. This diffusion will lower the resistance to corrosion (especially in the case of thin sheet) if the total time at elevated temperature, including the heating period, is too long.

Heat treating bare 24S (not Alclad sheet) in an air furnace occasionally results in a roughened or minutely blistered surface. Moisture in the air is responsible for this condition, and it is aggravated by excessive periods of heating, particularly in humid weather. Coating the sheet with soluble oil before heat treating or the use of "Alorco Protective Compound" in the furnace will eliminate the trouble. The use of oil presents the possible hazard of an explosive mixture of oil vapors and air in the furnace. In addition to being safer, the protective compound is much easier to use since it is merely placed in the furnace with the load and decomposes when heated. The gaseous products of decomposition form a protective coating on the sheet.

QUENCHING

After removal from the heat-treating furnace or salt bath the material must be completely immersed in cold water with the least possible delay (a matter of a few seconds). A rapid cold water quench is essential to produce material with highest resistance to corrosion. The transfer to the quench tank should be made *quickly* in order that the material be quenched from a temperature as nearly within the heat-treating range as possible. Allowing the metal to cool slowly before quenching produces adverse effects similar to those resulting from using too low a heat-treating temperature. In the case of small loads or thin material the use of guard sheets is often advisable to prevent loss of heat during the transfer from furnace to quench tank.

Although 100°F. is not the highest quenching-water temperature that will produce good resistance to corrosion, it is advisable and usually feasible to regard it as a maximum. Use of a large volume of water in the quench tank minimizes the increase in water temperature as each load is quenched. Continuous addition of cold running water will maintain the desired temperature and also tend to prevent the accumulation of salt in the water if the metal has been heated in a fused salt bath.

Because quenching in cold water has a tendency to warp the material, there is a constant effort to find a suitable quenching method that will not have this effect. Cold oil, boiling water, and sometimes an air blast are usually sufficient to produce specified minimum mechanical properties, but the resistance to corrosion is always impaired. In the case of 24S or 17S, this impairment is so serious that these milder quenches are not recommended, nor are they permitted by U.S. Army and Navy specifications. While the resistance to corrosion of Alclad 17S and Alclad 24S which has been slowly quenched (e.g. in hot water, oil or an air blast) is inferior to that resulting from rapid quenching, it is superior to that of bare 17S or 24S quenched in cold water under best commercial conditions. The foregoing statement presupposes that the alloying elements of the core have not diffused through the relatively pure metal surface layers as a result of heating for too long a period. An alternative is to use 61S and 53S, when their strengths are adequate, since mild quenching has a negligible effect on the resistance to corrosion or mechanical properties of these two alloys.

RINSING

In the case of salt-tank operation it is desirable to provide a rinse tank for removing excess salt which may adhere to the work. The tank should be of adequate size, and the rinse water should be hot, but not boiling. Rinsing is done promptly after quenching.

AGE HARDENING

After quenching, the ultimate tensile and yield strengths of the material start to increase at a rate which is dependent on the alloy and the temperature. Table 5, page 68, shows how this aging progresses at room temperature for 24S, 17S, A17S and 61S. Lower temperatures will retard the aging rate. In the case of 61S-W and 53S-W, higher temperatures are used to artificially age the material to the "T" temper. (See Table 3, page 67.) If it is desirable to maintain the workability to aid in forming, the material is held at a low temperature. This is commonly done with 17S and 24S rivets, and sometimes with sheet which is to be formed or with formed parts which are to be straightened after heat treating. The data on page 68 also cover the aging of 24S and 17S at lowered temperatures.

EQUIPMENT

The requirments for the heating equipment are primarily uniformity and accuracy of temperature. Either a fused salt bath (usually sodium nitrate) or an air furnace can be used.

The salt bath has the advantage of very rapid heating and generally more uniform temperature distribution, without forced circulation. The tank (usually cast iron) may be heated with gas or electricity. Sometimes the heat is applied directly to the bath with the so-called "radiant tube" gas units or with electric immersion heaters. Some manufacturers use the salt itself as the resistor element, passing the current between electrodes which are immersed in the bath.

Air furnaces are perhaps more flexible in operation than fused salt baths, and avoid some of the hazards connected with the latter. It is frequently possible to arrange for more rapid quenching from air furnaces. They are usually electrically heated. Forced air circulation is very beneficial in maintaining uniform temperature throughout the furnace and is necessary for rapid heating. Although manual control of temperature, based on indicating pyrometers, can be used, automatic control is far more satisfactory. Also, it is necessary to have recording devices to provide a permanent record of the time-temperature relations in the furnace.

Equipment should be provided to enable transfer of the load from the furnace to the quenching water in about ten to twenty seconds, depending on the size and character of the load. Purpose of this rapid transfer is to maintain the metal temperature until the instant sudden cooling starts. The quenching water must be kept clean and cool in order to obtain the best results.

As previously mentioned, when fused salt is used for heating, it is usually necessary to provide a second water tank (at about 150°F.) for dissolving off any salt that remains on the material after the quench. The warm water also facilitates drying the parts.

HEAT TREATMENT OF RIVETS

The heat treatment of rivets is best accomplished using equipment suitable for handling a large number of small parts. In air furnaces the rivets can be handled in small steel wire baskets.

Since anodically treated rivets should not be heated in direct contact with nitrates, closed-bottom steel tubes (not perforated) make convenient containers for use in salt-bath equipment. The tube should be only large enough to permit free dumping of the rivets so that heating will be rapid and uniform throughout the load. For such containers, half an hour is usually sufficient heating time. Several expedients are desirable to insure proper metal temperature: Do not let the tube project more than two inches above the bath; have the top rivets in the tube two or three inches below the surface of the bath; keep the tube covered.

Quenching is accomplished by dumping the rivets out of the container in which they were heated, into cold water. A wire basket or other perforated container submerged in the cold water, and into which the rivets are dumped, facilitates their removal.

A detailed discussion of heat-treating equipment is not within the scope of this booklet. However, there are a number of manufacturers of heat-treating equipment who are familiar with the requirements for heat treating aluminum alloys and whose equipment is in commercial use for that purpose.

ANNEALING

When annealed aircraft materials are required, they are normally bought in that condition from the metal manufacturer. However, it is sometimes necessary to anneal either heat-treated or cold-worked material.

In the latter case the material is annealed by bringing it to 650°F. and then cooling at any convenient rate. Alloy 3S, however, because of its chemical composition, requires a temperature of 750°F.

Heat-treatable alloys require special procedure to remove the effects of previous heat treatment and to avoid a heat-treating effect in annealing and cooling. If the material has not previously been heat treated, the above method is entirely satisfactory provided the temperature is not more than 660°F., nor less than 630°F., in any part of the load. When the material has been previously heat treated, this practice will anneal it to a large degree, but not completely. If complete softening is required the temperature must be 750° to 800°F. The metal is held at temperature for about two hours and then cooled not faster than 50°F. per hour to 500°F., after which the cooling rate does not matter.

An air furnace is the most suitable equipment for annealing operations. If a nitrate bath is used, it should contain equal parts of sodium and potassium nitrates because of the lower freezing point of the mixture.

MACHINING*

The equipment for machining aluminum alloys is generally similar to that used for other metals. The cutting tools should be modified, however, in order to secure the best results. The following suggestions are important:

1. Grind more top and side rake on the cutting tools than is common for machining steel.

2. Keep cutting edges sharp and free of burred or wire edges.

3. Maintain smooth, bright tool surfaces free from scratches.

The shapes of the tools used for aluminum are quite different from those used for brass, but approximate those for hard woods. After grinding to the desired shape, they should be finished on a fine abrasive wheel, followed by handstoning or lapping.

Lathe tools are set considerably higher on the work than is the general practice with steel. Twist drills with large spiral angles are usually preferable. Saw and file selection is governed by the same principles as other cutting tools.

In general, best results are obtained by using comparatively high speeds and fine-to-medium feeds; the finer the feed, the higher the speed. Continuous and copious use of a lubricant is quite desirable. For general use, a mixture of equal parts of kerosene and lard oil is satisfactory as a cutting compound. For milling, sawing and drilling, the more economical soluble cutting oils may be used.

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*See also "Machining Aluminum," published by Aluminum Company of America.

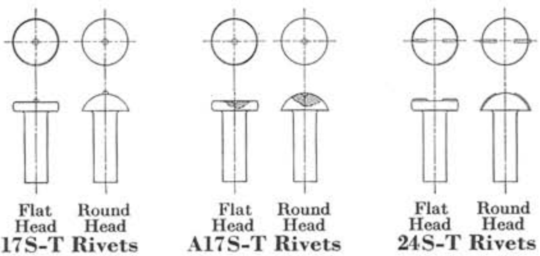
JOINING

In assembling the multitude of individual parts that make up the complete airframe, a variety of methods are involved. They include riveting, welding and the use of various screws and bolts. Although only the standard methods will be discussed here, there are many specialized procedures for use in inaccessible places and other applications.

RIVETING*

Riveting is the most common method of assembling airframes. Standard rivet alloys are A17S-T, 17S-T and 24S-T, all of which are produced with several styles of heads. Rivets of these alloys may be identified by standard head markings as shown in the illustration below. Brazier or mushroom heads are used for interior work, and sometimes for outside surfaces.

High-performance airplanes are usually flush-riveted on the air-stream surfaces with countersunk rivets. The type of countersinking ordinarily depends on the thickness of the part on the outside surface. The thicker parts are frequently machine countersunk, and thin stock is usually dimpled or embossed. Another method is to machine countersink the member being attached to the skin, and then emboss the skin sheet to form a recess for the rivethead in the outer surface of the sheet.

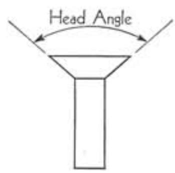


Identification marks for aluminum alloy aircraft rivets.

*See "Riveting Aluminum," published by Aluminum Company of America.

Courtesy Lockheed Aircraft Corp.

Hand driving aluminum alloy rivets. Helper inside cabin is holding buck-up tool against the rivet while the riveter operates the gun.



Countersunk rivet showing head angle.

Head angles in common use on countersunk rivets vary from 78° to 115° (see figure at right). Since larger angles result in thinner heads, there is less tendency for the metal to be strained when the countersink is made by dimpling or embossing. Furthermore, a machined countersink can be used with thinner sheet.

Note that so far only the preformed rivetheads have been discussed. In hand driving aircraft rivets, it is almost universal practice to apply the blow to a set (flat-ended for flush rivets) which is held firmly against the preformed head of the rivet, thus pushing it into the hole and tending to keep it there while the heading is accomplished. A bucking bar or dolly having a flat face is held lightly (so as not to push the rivet out against the thrust from the driving side) against the point

Drilling and riveting operations in the assembly of an airplane fuselage. Millions of rivets go into airplane construction.
Courtesy Lockheed Aircraft Corp.

or end of the rivet shank. The inertia of this tool provides the force that upsets the rivet, forming a flat or pancake type head. It should be noted that the structure in which the rivet is being driven must deflect with each blow to provide the movement necessary for upsetting the rivet. A variety of pneumatic hammers, both slow and fast operating, are available for the hand driving of aircraft rivets.

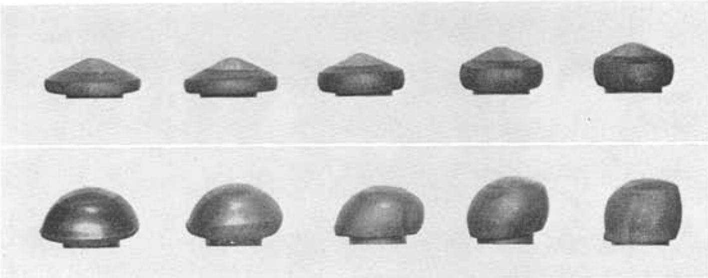
Sub-assemblies are riveted wherever possible in fixed riveting equipment, which may be either of the single-stroke squeeze type or of the slow-operating hammer type. This method is considerably cheaper than the hand method, and usually produces a higher percentage of satisfactory rivets.

Rivets of A17S-T alloy are more widely used than those of 17S-T or 24S-T, and are regularly driven in the fully heat-treated and aged condition. Joints requiring greater strength are made with 17S-T or 24S-T rivets. See table of allowable stresses on page 72. Rivets of both of these alloys are usually reheat treated so that they can be driven before age hardening has progressed very far (although it is possible to head the smaller sizes of fully aged 17S-T rivets). Satisfactory driving characteristics are maintained at room temperature (70°F.) for about an hour after quenching in the case of 17S-T and for about ten minutes in the case of 24S-T. To avoid the necessity for continually heat treating fresh material, 17S-T rivets may be driven after about 24 hours if they are held at the temperature of melting ice (32°F.). Lower temperatures will retard age hardening still longer. In the case of 24S-T rivets a lower temperature is recommended. Packing in Dry Ice (CO_2) is satisfactory. When the rivets are returned to room temperature age hardening proceeds in the normal manner.

INSPECTION OF DRIVEN RIVETS

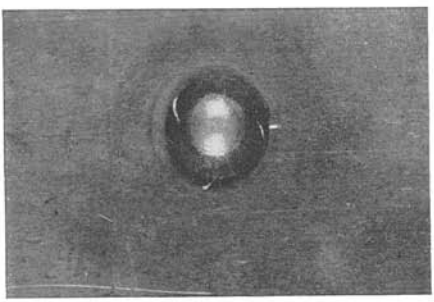
The standards to which driven rivets should conform are frequently uncertain. In addition to dimensions (thickness, diameter) and perfection of shape, inspection is concerned with whether the driven head is co-axial with the shank (not "clinched") and whether the metal is in a sound condition (not badly cracked). Cracking at the edge of the head fre-

Squeeze riveting machine in operation.
Courtesy Consolidated Aircraft Corp.

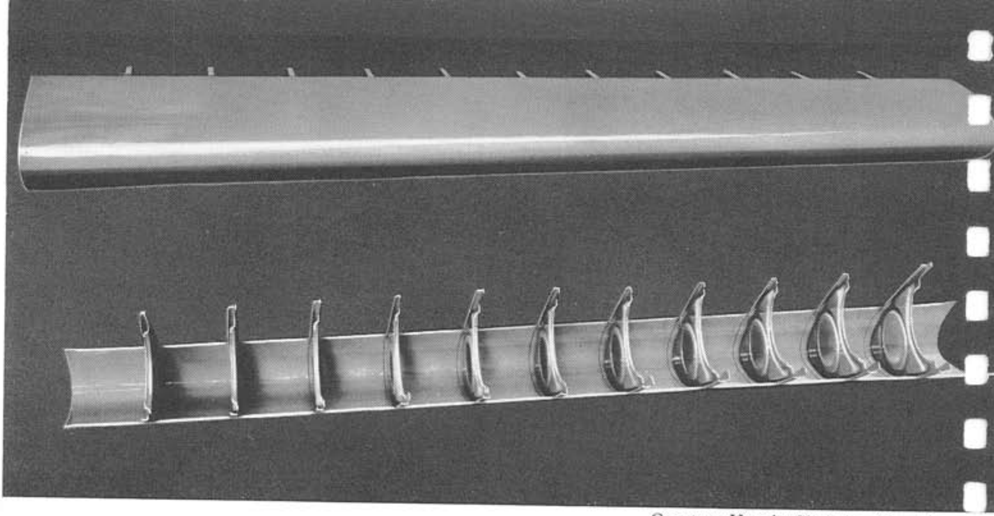


Cone-point and button rivetheads resulting from various driving pressures. The tensile strength of each one was within five per cent of the strongest one.

quently results from overdriving or from driving rivets that have undergone too much age hardening. However, it has been determined that even badly cracked heads are strong enough to develop the full shear and tensile strength of the shank. The series of rivetheads shown above was tested in tension to determine how well formed a head had to be in order to develop full strength. The tensile strengths of all of the rivets in the photograph were within five per cent of the strongest one. The foregoing is presented for the purpose of indicating that superficial cracks in rivetheads and minor deviations from the theoretically desired shape of head are not cause for concern or replacement. The second rivet that is driven in any one hole is likely to be even more defective than the first, because the hole will be enlarged, and the rivet will be more likely to buckle and form an imperfect head.



Example of severe head cracking on 17S-T button-head rivet. Tests indicated that even this degree of cracking had no adverse effect on the tensile and shearing properties.

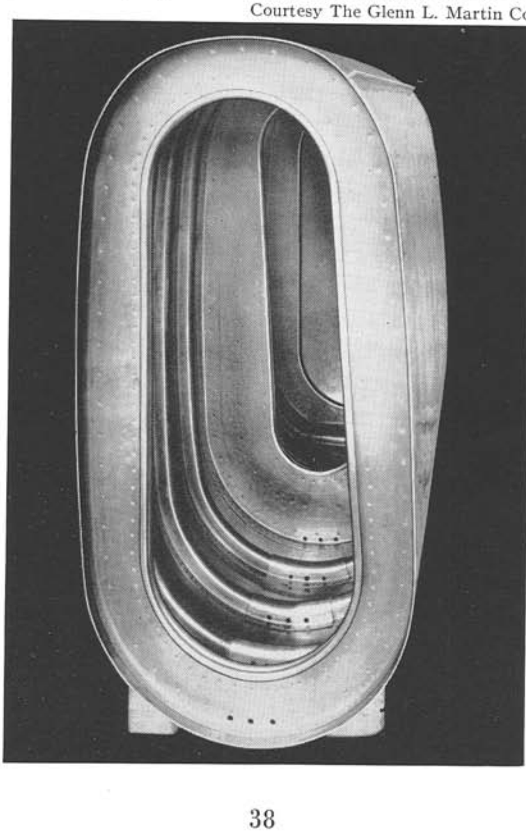


Courtesy Vought-Sikorsky Aircraft

Typical wing leading-edge assembly, showing use of spot welding.

(Below) *An aircraft gasoline tank assembled by spot welding.*

Courtesy The Glenn L. Martin Co.



ELECTRIC-RESISTANCE WELDING*

Electric-resistance spot and seam welding is economical and often results in smoother surfaces than riveting. When a machine can be operated a large part of the time, the higher cost of the equipment compared to that for riveting is often offset by the lower unit cost of spot welds. In spot welding, the design of the parts and their sequence of assembly must be arranged to provide the necessary access for the arms of the welder and the welding electrodes. Special electrodes and electrode holders are frequently used for joints that cannot be reached with standard equipment.

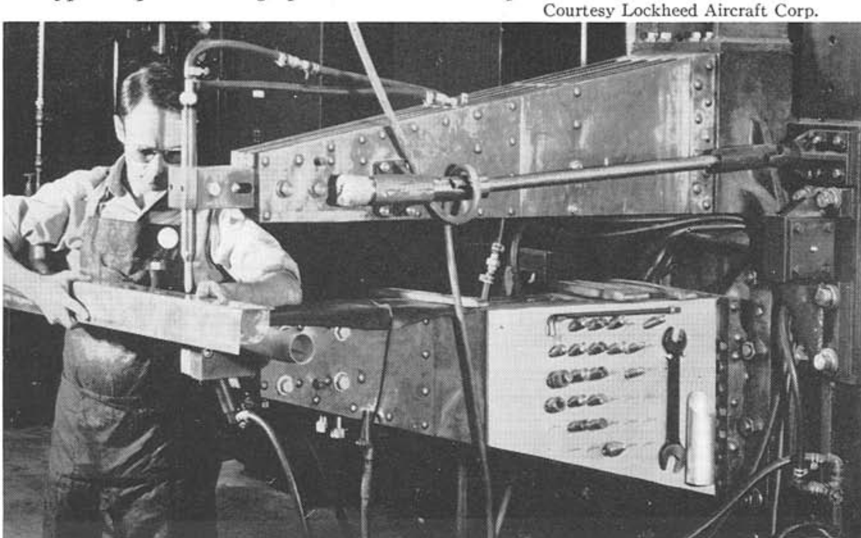
The spot-welding process is ideal for the fabrication of subassemblies which are small enough to be easily handled by one or two operators. It is in this field that spot welding is finding much favor in the aircraft industry.

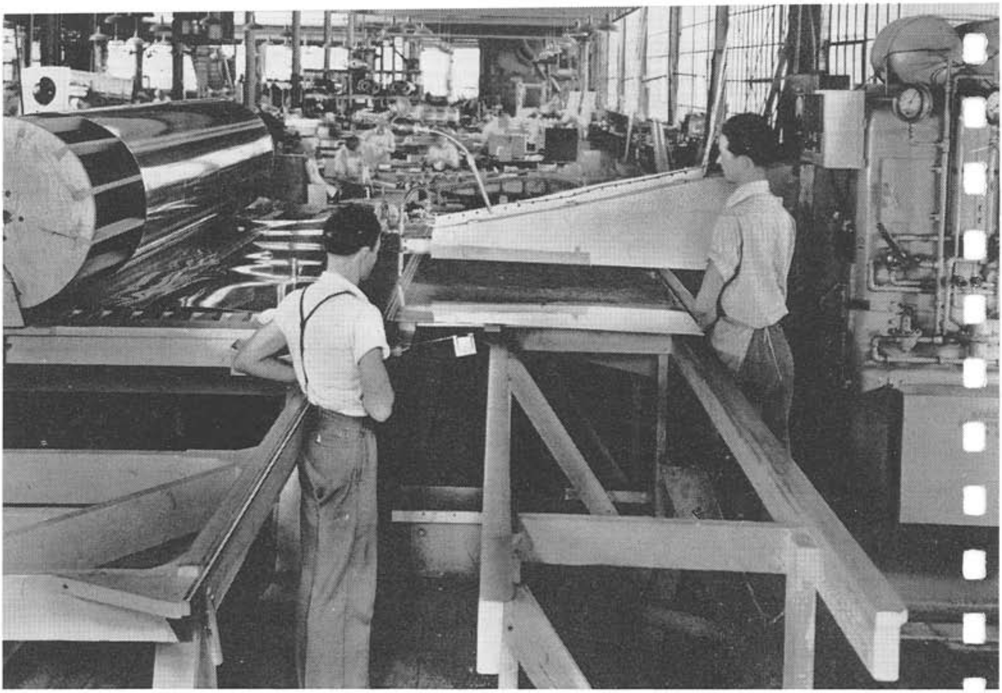
The leading manufacturers of spot-welding equipment are familiar with the requirements for handling aluminum, and are prepared to furnish mechanical and performance details of their individual products. Several types of excellent machines are available.

Both the U.S. Army and Navy approve the use of spot welding, but require qualifying tests on each welding machine for each gauge and alloy that is to be used. The shear

*See "Welding Aluminum," published by Aluminum Company of America.

Typical spot-welding operation. Note the spare electrodes.
Courtesy Lockheed Aircraft Corp.



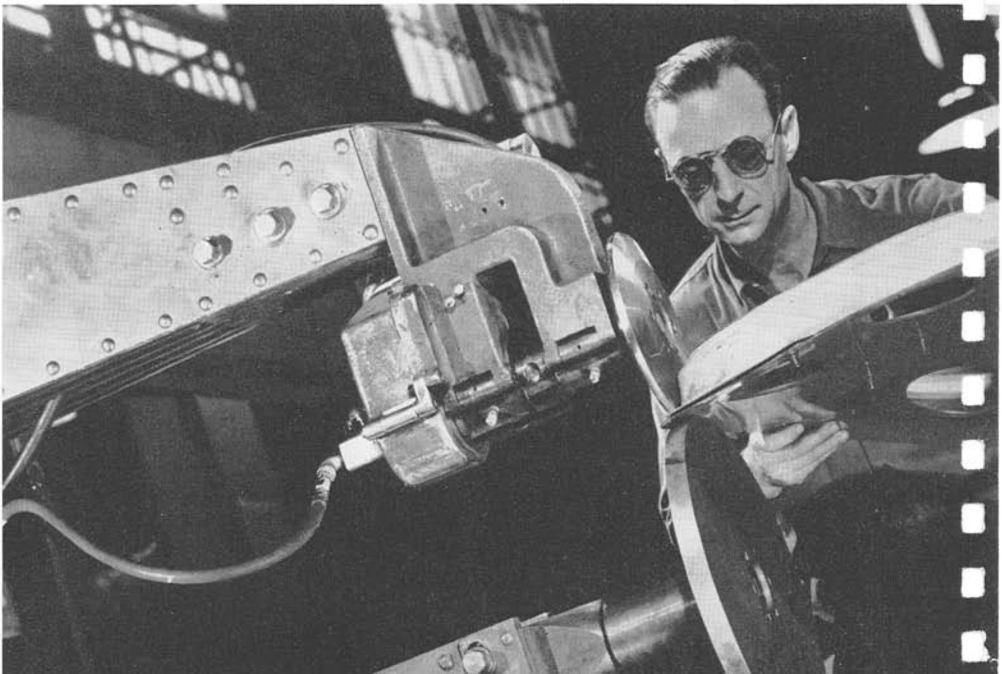


Courtesy Boeing Aircraft Co.

Spot welding Alclad sheet to form the outer wing skin section of a large transport airplane.

(Below) *Seam welding an aircraft assembly made of Alclad sheet and other aluminum alloy parts. Note the spring fasteners which temporarily hold the assembly in place.*

Courtesy Lockheed Aircraft Corp.



strengths required by the U.S. Army are shown in Table 12, page 74. In setting up a machine for a given job, it is customary to make several test welds in scrap strips of the same gauge, alloy and temper as the work itself. These set-up welds are tested by peeling or rolling the sheets apart so that a good spot weld will pull a "button" out of one of the sheets. These buttons should be nearly round and of a diameter about equal to twice the sheet thickness plus 0.060 inch.

TORCH WELDING*

The use of torch welding in aircraft is limited to applications where high unit stresses are not involved. Its chief merit is that it is the simplest way to obtain the gas- or liquid-tight seams required in fuel and other tanks.

The heat of welding anneals a strip of metal on either side of the joint in the case of strain-hardened alloys and seriously affects the heat treatment in the case of heat-treated alloys. For this reason torch welding is almost completely confined to the alloys which are not heat treated. These alloys, especially 2S and 3S, are well suited to welded construction.

Standard welding equipment is suitable for aluminum. Special flux (such as Alcoa No. 22 Torch Welding Flux) and suitable filler material (either 2S wire or 43S wire containing five per cent silicon) are necessary. Acetylene gas is most commonly used for welding aluminum, especially when the operators are accustomed to using it for other metals. However, in some cases hydrogen gas will be more satisfactory.

Since the welding flux is corrosive, it must be completely removed after the weld is made. The use of warm water and a brush or cloth does a fair job when there is easy access to both sides of the weld. It is best practice, however, to follow this type of cleaning with a dip in a five per cent sulfuric acid solution at a temperature of about 150°F. for ten minutes. If it is more convenient to use the dip at room temperature the concentration should be increased to about ten per cent and the time to 30 minutes.

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*See "Welding Aluminum," published by Aluminum Company of America.

PROTECTIVE FINISHING*

Government specifications of the U.S. Army, Navy and Civil Aeronautics Board cover the general requirements for aircraft protective finishes. Details are usually covered in each individual contract, as there are often special procedures required by construction methods or the particular service for which the aircraft are intended. The extent of the protection that is needed depends on the inherent resistance to corrosion of the materials, the environment in which the aircraft is to be used, and to some extent on the completeness and frequency of the cleaning and maintenance practices used.

Alclad sheet on the outside surface of commercial transports and U.S. Army airplanes is customarily left bare except for insignia, or where camouflage paint is applied. The inside surface of the same sheet is frequently given one or more coats of paint applied after assembly. In the case of commercial transports the shop coats intended to minimize scratching and marring are simply left intact on the inside surface. The extruded stringers in the same airplane (which of course are not Alclad material) may be given an anodic oxide treatment before painting which provides still better protection than the paint alone.

Naval airplanes are given a very complete protective finish because they often operate under severe corrosive conditions. Recently, there has been more tendency to place reliance on the ability of Alclad sheet to maintain its appearance and structural integrity without protective painting. The Pan American Airways' Boeing No. 314 Clippers furnish a striking example. Paint was removed from the outside of the hulls, leaving the anodically treated Alclad 24S-T sheet exposed to the elements. This move was based on the results of extensive tests and service trials.

*See "Protection of Aluminum Alloys," Aviation, Feb. 1936, and "The Working of Aluminum Alloys," American Machinist, August 21, 1940. Reprints of these articles, as well as the booklet, "Finishes for Aluminum," are available on request to the nearest sales office of Aluminum Company of America.

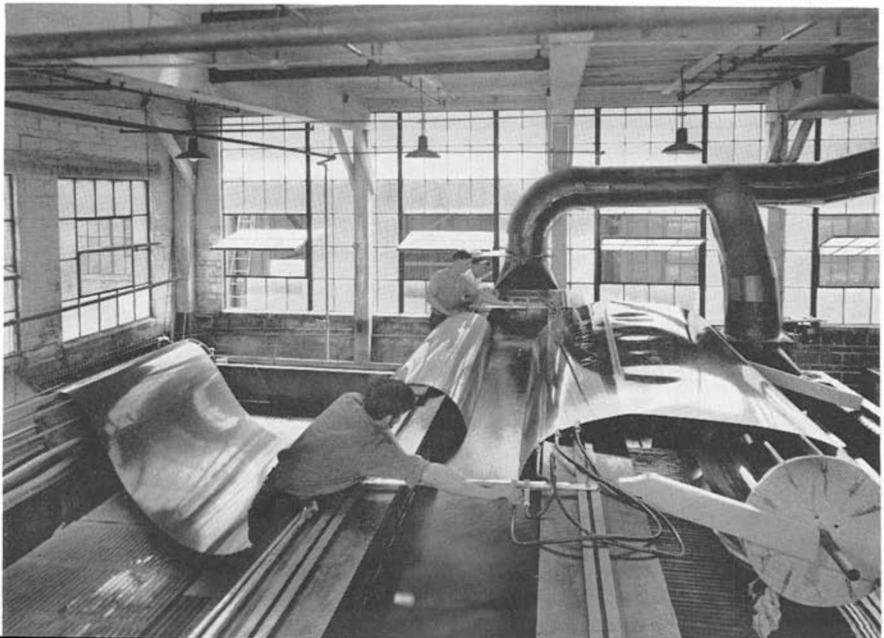
It should be remembered that slowly quenched Alclad sheet is not so resistant to corrosion as material rapidly quenched in cold water. Therefore, Alclad sheet that is not cold-water-quenched should, when intended for use under severe corrosive conditions, receive the same general protective finish employed on plain 24S-T or 17S-T parts.

The fundamental principle of corrosion protection is that *dry aluminum cannot corrode.* Aircraft structures are designed to drain freely and provide ready accessibility of all parts for cleaning, repainting, repair and inspection. Joints and crevices which invite the entrapment of moisture are eliminated as far as possible or are suitably sealed. Measures are taken to insulate dissimilar metals from adjacent aluminum alloy by painting the faying surfaces before assembly and inserting nonhygroscopic gaskets. (Reference to "Protection of Aluminum Alloys" will provide further details.) The benefit of much practical experience is available on application to the nearest sales office of Aluminum Company of America.

In using many of the protective finish systems required, it will be necessary to apply anodic treatments to aluminum alloy parts. These treatments produce artificial oxide coat-

Anodically treating spot-welded aluminum alloy wing skin sheet.

Courtesy Boeing Aircraft Co.



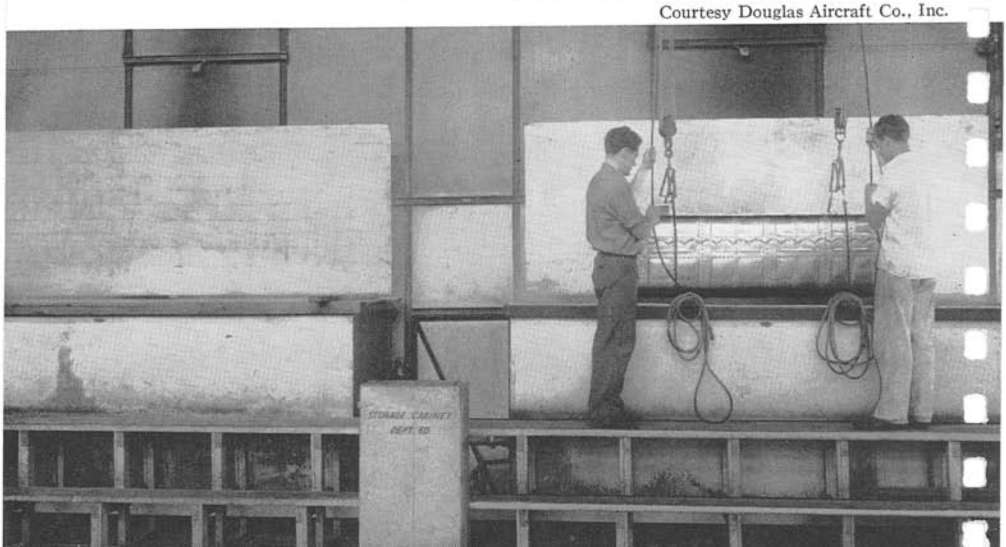
ings on the surface of parts so treated. The results of these treatments are to enhance the inherent resistance to corrosion of the aluminum alloy and to provide for best paint adherence, particularly under severely corrosive conditions. Anodic treatments applicable to aircraft are described in U.S. Army Air Corps and Navy Department specifications. In general, the treatments consist of making the aluminum alloy parts the anode of an electrolytic cell in which the electrolyte is either chromic acid or sulphuric acid. The chromic acid process is the one most generally used in the aircraft industry. Oxide films may be produced by the "Alumilite" process patented by Aluminum Company of America.

Less expensive than anodic treatments are the chemical-dip treatments, some of which are identified by the trade name "Alrok."* Another type of chemical treatment consists of alkaline cleaning followed by a five-minute dip in a five per cent chromic-acid bath at 140°F. Certain of these treatments provide paint adherence only slightly less effective than do the anodic treatments. The processes are approved by the U.S. Army Air Corps under certain specific conditions.

*Registered trademark of Aluminum Company of America.

Applying the inexpensive Alrok treatment to an aircraft gasoline tank. The parts are first given an oxide coating, then are boiled in dichromate solution.

Courtesy Douglas Aircraft Co., Inc.



CHOICE OF MATERIALS AND PROCESSES

Because certain of the aluminum alloys and alloy products provide highly desirable properties, their use has grown in the aircraft industry until they have become the standard in many plants. At the same time, the development of design specifications and fabrication methods has been based on the use of these alloys. Techniques have been worked out in accordance with their characteristics.

In these developments, it has been fully recognized that no single alloy possesses the optimum of all the properties desired for a given application, and that the selection of a material is necessarily determined by a balancing of its properties. Therefore certain disadvantages have been accepted in order to make use of the material's desirable characteristics and the advantages of the processing technique in use.

The extensive program of standardizing on materials has been of great help to the industry. At the same time designers should not lose sight of alternate alloys and methods that may serve just as well and may eliminate some of the disadvantages of the more familiar materials and fabricating techniques. Therefore it is well to consider a few alternatives in the selection of materials and processes which may assist the manufacturer in solving problems that have become important due to increased production.

The most commonly recognized properties of a structural material are its tensile strength and yield strength. These are usually given primary consideration, and in many cases determine the material to be used. Resistance to corrosion is another important factor which must be considered in conjunction with the intended service and the protective coatings, if any, that will be used. For example, Alclad 24S-T sheet has slightly lower strength than ordinary 24S-T sheet, but its greater resistance to corrosion makes it a very attractive material for most structural applications.

In order to standardize, some aircraft manufacturers tend to make almost everything from 24S-T or Alclad 24S-T, which they generally have on hand. However, where high strength is not the controlling factor, alloys other than 24S-T or Alclad 24S-T may be used for ease of fabrication or because of some other desirable characteristics. Where existing stocks of 24S or Alclad 24S material do not significantly influence the decision, advantage should be taken of the more economical lower-strength alloys when their mechanical properties are adequate for the service intended.

Likewise for forgings, instead of the usual 14S-T alloy, it is worthwhile to consider A51S-T or 53S-T where their properties are adequate, since they are more readily forged.

Similarly in choosing the form of material to be used, such as a casting or a forging, or in making a choice between other products, the designer must consider the relative properties of each. For example, a stiffener made of formed sheet can have the resistance to corrosion of Alclad sheet, while an extruded member offers the designer more choice in regard to cross section.

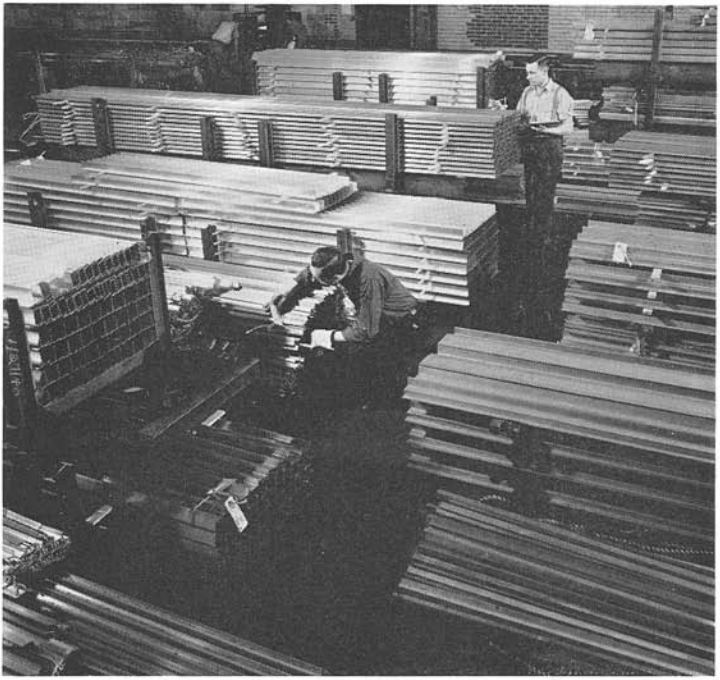
At some time during the design of each part, the question of proper temper must be considered. In the case of heat-treatable alloys, *the material is always in the "T" or fully heat-treated temper when it is finally installed in the airplane structure.* In many cases it is possible to form the material in the fully heat-treated condition as received from the metal supplier, and there are so many inherent advantages to this procedure that every effort should be made to use it as extensively as possible. The changing of a single detail may make it possible to form the part in the "T" condition, thus avoiding the expense and other disadvantages of heat treating the material in the aircraft plant.

The second choice in this matter, as indicated in the earlier discussion on forming, is to purchase annealed metal and form it after heat treating, but before too much workability is lost by aging. In the case of 24S and 17S, which age harden after quenching to their specified mechanical properties at room temperature within a few days, the period during which they retain adequate workability is rather short, so special handling methods are necessary to get the work done before aging progresses too far. (See discussion on age hardening on page 28 and the data on page 68.) The amount of aging that can be tolerated before the forming is done depends on the severity of the individual job and is usually determined by trial. In the case of 53S or 61S, which require "artificial" aging at slightly elevated temperatures, many forming operations that are too severe to be accomplished in the "T" temper can be performed on material purchased in the "W" temper. Although this procedure eliminates the special handling requirements for 24S and 17S, it is necessary to age the formed parts in a furnace or oven to obtain the "T" temper. An important advantage of this procedure is that parts do not warp or distort as a result of this artificial aging treatment.

In the event that the forming is too severe for either of the above procedures, and the design cannot be modified to make it easier, the material must be purchased in the annealed temper and formed before heat treating. Aside from the expense of the heat-treating operation itself, the principal disadvantage of this procedure is that usually the formed part will warp when quenched and will require straightening operations that may be more expensive than the forming itself. However, a solution is to form the part only partially in the first operation before heat treating. Then there will be left a definite amount of work to be done after the part is heat treated, thus giving the metal a good "set." This procedure permits the straightening to be done in the forming tools rather than as a hand operation.

The section on Heat Treatment (page 25) discusses the use of mild quenching media for avoiding warping that results from quenching in cold water. It is again pointed out that these methods are in no way suitable for ordinary (not Alclad) 24S or 17S. However, they are applicable to 61S and 53S material. They are also applicable to Alclad sheet provided the heat treating has been conducted so as to avoid excessive diffusion.* Further, it is recommended that for severe corrosive conditions Alclad sheet parts, so treated, be given protective finishes similar to those used for plain 24S-T or 17S-T parts.

*Refer to pages 26 and 27.



Alcoa aluminum extruded shapes ready for shipment.

MAINTENANCE*

The same general principles that apply to the handling of the aluminum alloys in aircraft construction are equally applicable in the case of alterations, repairs and overhauls. Since aircraft are usually repaired singly or overhauled in small groups, improvised tooling is often necessary. Unless finished parts from the factory are available, hand forming over wood forms is often used. Replacement parts should, in general, be of the same materials used in the original structure. Heat treatment is done in accordance with the principles previously set forth, although every effort should be made to make replacement parts from fully heat-treated stock as received from the material manufacturer. If the original protective coatings have been satisfactory, similar coatings should replace them.

Many aircraft, particularly commercial transports, are covered with unpainted Alclad 24S-T sheet. It is necessary to regularly clean and periodically polish these surfaces if their luster is to be maintained. As an aid in avoiding use of cleaning and polishing materials detrimental to the aluminum alloy, simple tests have been devised to determine "safe" cleaners and polishes. These tests are as follows:

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*The U.S. Civil Aeronautics Board issues detailed instructions regarding repair and alterations of aircraft.

TESTS FOR CLEANERS USED IN AQUEOUS SOLUTIONS

Specimens about 3″ x 0.75″ x 0.064″ thick of aluminum alloy of the type under consideration are exposed at 172°F. for five hours to each of the following concentrations of the cleaner: 0.25, 0.50, 0.75, 1, 1.5, 2, 3, 5, 10 and 20 per cent. For each specimen 50 c.c. of solution should be used.

Some of the undiluted cleaner is placed on other specimens which are stored in an atmosphere saturated with water vapor at 77°F. for 24 hours.

In addition to the two tests described above, specimens are cleaned following precisely the instructions furnished by the manufacturer of the cleaner. This cleaning operation is repeated *twenty* times.

If none of the specimens in the above three tests are discolored, etched or pitted, the cleaner is considered "safe."

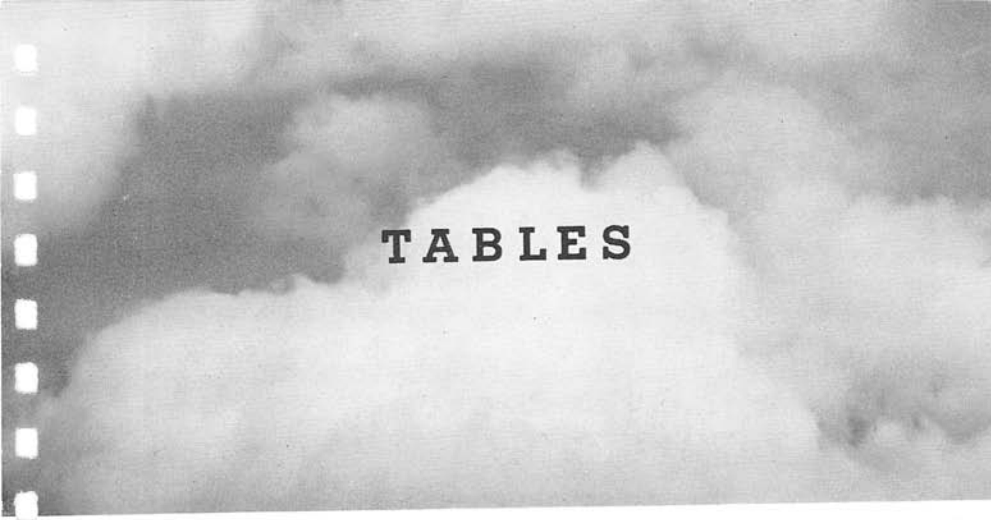
For anodically coated material, the same procedure as outlined above is followed.

POLISHES, ABRASIVE CLEANERS, OIL CLEANERS

Specimens of the aluminum alloy for which the cleaner is intended are cleaned twenty times, following in detail the instructions furnished by the manufacturer of the cleaner.

Some of the cleaner is also placed on additional specimens which are stored in an atmosphere saturated with water vapor at 77°F. for 24 hours. If the specimens are not discolored, etched or pitted, the polishing material is considered "safe." Furthermore, to be classified as completely safe, it must not abrade the aluminum alloy in question to an extent greater than No. 0 steel wool.

The results of these tests can be used more or less as a "go" and "no go" gauge for determining whether or not individual cleaning or polishing materials are harmful to aluminum. The tests are rather severe and some judgment in interpreting them is indicated. It may seem desirable in certain instances to supplement these tests with service tests.



TABLES

The values in the tables of mechanical properties have been obtained using standard A.S.T.M. testing methods or by procedure outlined in applicable U.S. Government Specifications. It should be noted that the values for any given product, composition and temper may vary with size or thickness. In the case of rolled, drawn or forged products, the most marked variation is a decrease in elongation values as thickness increases. In the case of 24S-T extruded products, there is a significant increase in strength as the thickness of the section increases.

Minimum specification values of mechanical properties, which are used as criteria for acceptance or rejection, are given in the tables for wrought and cast products. Typical values, not guaranteed, are also included.

Mechanical property values may be affected by the relationship which the direction of loading in test bears to the direction in which the metal has been worked. For example, values secured on rolled stock in the direction of rolling are referred to as longitudinal or "with-grain" properties and are usually noticeably greater than those secured in a direction at right angles to the direction of rolling which are called transverse or "cross-grain" properties. Likewise tests made in compression may produce results different from those made in tension. The tables presented in this section do not provide detailed information on these so-called "directional properties," although "ANC-5, Strength of Aircraft Elements,"* issued by the U.S. Army-Navy-Civil Committee on Aircraft Requirements, does cover some of the more important directional properties.

Mechanical property values are also affected by the cold working involved in flattening and straightening operations.† Flat sheet, extruded shapes and tubing, for example, are largely flattened and straightened by means of stretching. This operation raises the tensile yield strength of the material and also to a somewhat lesser degree the ultimate tensile strength, coupled with some sacrifice in ductility. The compressive strengths of 17S-T and 24S-T alloy products straightened or flattened by stretching are not so great as are the corresponding tensile properties. For small amounts of stretching (up to about two per cent), the compressive yield strength of this class of materials is slightly reduced. However, as the amount of stretching increases, the compressive yield strength rises, but not at the same rate as the yield strength in tension. Reheat treating of stretched material causes some reduction in the tensile properties, but at the same time the tensile and compressive strengths become substantially equal in value. It may be of interest to note that sufficient data have been secured in the case of flat sheet, as commercially produced in alloys of the type in question, to establish that the transverse yield strength in tension is approximately equal to the longitudinal yield strength in compression and vice versa.

For 24S and 17S products, the minimum specification mechanical properties in the tables are tensile properties and include the following conditions:

1. *Heat-treated Sheet and Plate:* Tested cross-grain.

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*This publication may be obtained from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. (25c per copy).

†See "Some Stress-Strain Studies of Metals," Journal of Aeronautical Sciences, March, 1940.

2. *Annealed Sheet and Plate:* Tested cross-grain in the annealed condition in order to establish maximum specification values. There is a further requirement which provides that testing shall be conducted using material heat treated from the annealed stock, tested transversely and not stretched after heat treatment. It should be particularly noted that in most cases these last-mentioned requirements are the conditions which impose the minimum mechanical property values in specifications for heat-treated products of this class, even though material as supplied in the heat-treated temper may have somewhat higher properties.

3. *Extruded Shapes:* Tested with-grain, using appropriate test specimens. Heat-treated shapes are tested in the stretched condition.

4. *Tubing:* Tested full size up to 2-inch outside diameter. When greater than 2-inch outside diameter, or equivalent, standard specimens are cut from the wall of the tube.

5. *Rod and Bar:* Full-size, standard sheet specimens used for thicknesses up to ½ inch. Standard round specimens used for thicknesses greater than ½ inch. Up to 1½-inch thickness, specimens are cut from the center of the stock. Above 1½-inch thickness, specimens are cut halfway between the center and the surface.

6. *Forged Fittings Stock*:* Standard ½-inch round specimens machined from stock and tested with-grain.

From the above it is readily seen that tests made on "as-received," heat-treated material may result in values considerably greater than those shown in the tables. This is especially true if "as-received" heat-treated sheet is tested longitudinally.

For aircraft fittings intended to carry structural loads, die-forged material, forged as nearly as possible to final dimensions, is to be preferred. However, economic and other reasons may not permit this in all cases. Aircraft fittings, especially those intended for small production, experimental models or replacements, are sometimes machined from rolled

*17S-T and 14S-T alloys.

bar stock, plate, hand-forged blocks or extruded sections. As has been pointed out, all these products exhibit a difference in mechanical properties when tested in the direction of working, as opposed to tests made at right angles or normal to the direction of working. This is also true of die-forged fittings. In a great many instances, however, die-forged fittings may be designed in such fashion as to take advantage of the direction of flow or working of the metal in order that the stresses will be parallel to this direction of working. This result may be obtained more readily in die-forged fittings than in fittings that are machined from other types of wrought materials.

For plate, the minimum guaranteed values are the transverse properties. Plate is always tested transversely, and the specification values are given in Table 16, page 78, and Table 17, page 80. The longitudinal properties of plate are, however, always higher than the transverse properties.

Table 15, page 77, presents the minimum mechanical properties of rolled bar stock and hand-forged blocks as derived from tests made in the direction of working and also at right angles to the direction of working. In the case of rolled bar stock, hand forgings and extruded shapes, routine inspection testing is done in the direction of working. Transverse tests of products other than plate should not be included as a part of purchase specifications. Although routine transverse mechanical property tests are not made as a part of regular inspection procedure, it should be borne in mind that, wherever possible, sufficient testing is done transversely on wrought material to insure that transverse mechanical properties are in line with the values shown in Table 15.

INDEX TO TABLES

GENERAL INFORMATION

MECHANICAL PROPERTIES

COMMERCIAL TOLERANCES

SHEET SIZES

WIRE, ROD AND BAR SIZES

TUBING SIZES

RIVET SIZES

EXPLANATION OF TERMS USED IN TABLES

1. For all Alcoa alloys, wrought and cast, the following data apply:

   (a) Young's Modulus of Elasticity................10,300,000 lb./sq. in.

   (b) Modulus of Rigidity........................ 3,850,000 lb./sq. in.

   (c) Poisson's Ratio............................ 0.33

   (d) Bearing strength is equal to 1.8 times the tensile strength provided the edge distance, in the direction of stressing, is not less than twice the diameter of the hole.

2. Yield strength is the stress which produces a permanent set of 0.2 per cent of the initial gauge length (American Society for Testing Materials Specification for Methods of Tension Testing—E8-40T).

3. Shearing strengths are single-shear values obtained from double-shear tests.

4. Endurance limits are based on 500,000,000 cycles of completely reversed stress using the R. R. Moore type of machine and specimen.

5. Elongation varies with the form and size of test specimen. When round specimens are used the gauge length for the measurement of elongation is equal to four times the diameter of the reduced section of the specimen.

6. Dimensions given in tables for the following products are as listed below.

Sheet and Plate:	Thickness
Tubing:	Outside diameter
Forgings:	Diameter or thickness
Wire, Rod and Bar:	Diameter or least distance between parallel surfaces, or where so stated maximum area of cross section. Maximum size of hexagon is 2 inches; of octagon, $1\frac{3}{16}$ inches; of square, 4 inches.

TABLE 1

Government Specifications for Alcoa Aluminum Alloy Products

Aluminum Products and Nominal Composition[1]	Tempers	Federal[2]	Army[2]	Navy[2]	Typical Aircraft Uses
WROUGHT PRODUCTS					
2S (99.0% Min. Aluminum)					
Sheet	O, ½H, ¾H, H	QQ-A-561	57-151-1	47A2	Tanks
Plate	As Rolled	QQ-A-561	57-151-1	47A2	Nonstructural
Wire	O, ½H, ¾H, H	QQ-A-411	Federal	46A3	General, nonstructural
Bar, Rod and Shapes	O, As Fabricated	QQ-A-411	Federal	46A3	General, nonstructural
Tubing, Round	O, ½H, ¾H, H	WW-T-783	Federal	44T19	Conduit, electric
Rivets	As Fabricated	....	25526(3)	43R5	Nonstructural
Rivet Wire and Rod	Special	....	....	43R5	Nonstructural rivets
Welding Rods	....	QQ-R-571	Federal	46R7	Welding 2S or 3S
Wire for Metal Spraying	....	....	10285(3)	......	Corrosion-resistant coatings
3S (1.2% Manganese)					
Sheet	O, ½H, ¾H, H	QQ-A-359	Federal	47A4	Tanks
Plate	As Rolled	QQ-A-359	Federal	47A4	Nonstructural
Wire	O, ½H, ¾H, H	QQ-A-356	Federal	46A6	General, nonstructural
Bar, Rod and Shapes	O, As Fabricated	QQ-A-356	Federal	46A6	General, nonstructural
Tubing, Round	O, ½H, ¾H, H	WW-T-788	Federal	44T20	Conduit, electric
Rivets	As Fabricated	....	....	43R5	Nonstructural
Rivet Wire and Rod	Special	....	....	43R5	Nonstructural rivets

[1] Balance is commercially pure aluminum.
[2] Revisions not indicated. Refer to latest issue.
[3] Air Corps Specification.

TABLE 1—*Continued*

Government Specifications for Alcoa Aluminum Alloy Products

Aluminum Products and Nominal Composition[1]	Tempers	Federal[2]	Army[2]	Navy[2]	Typical Aircraft Uses
WROUGHT PRODUCTS—*Continued*					
14S (4.4% Cu, 0.8% Si, 0.8% Mn, 0.4% Mg)					
Forgings	T	QQ-A-367	Federal	46A7	Structural fittings
17S (4.0% Cu, 0.5% Mn, 0.5% Mg)					
Sheet and Plate	O, T	QQ-A-353	Federal	47A3	Miscellaneous structural
Bar, Rod, Wire, Shapes	O, T	QQ-A-351	Federal	46A4	Machined fittings
Tubing, Round	O, T	WW-T-786	Federal	44T21	Hydraulic lines
Tubing, Streamline	T	....	57-187-2	44T22	Struts
Forgings	T	QQ-A-367	Federal	46A7	Structural fittings
Rivets	T	....	25526(3)	43R5	Structural rivets
Rivet Wire and Rod	Special	....	....	43R5	Rivets
Bolts and Nuts	T	....	29-59	......	Fastenings
Bolts, Nuts, Studs	T	FF-B-571	....	43B11	Fastenings
Machine Screws	T	FF-S-91	Federal	42S5	Fastenings
Alclad **17S** Sheet (17S Core)	O, T	QQ-A-361	57-152-2	47A6	Highly corrosion-resistant structural

See notes on page 59.

TABLE 1—*Continued*

Government Specifications for Alcoa Aluminum Alloy Products

Aluminum Products and Nominal Composition[1]	Tempers	Federal[2]	Army[2]	Navy[2]	Typical Aircraft Uses
WROUGHT PRODUCTS—*Continued*					
A17S (2.5% Cu, 0.3% Mg)					
Rivets	T	....	25526(3)	43R5	General purpose
Rivet Wire and Rod	Special	....	....	43R5	General-purpose rivets
18S (4.0% Cu, 0.5% Mg, 2.0% Ni)					
Forgings	T	QQ-A-367	Federal	46A7	Pistons
24S (4.5% Cu, 0.6% Mn, 1.5% Mg)					
Sheet and Plate	O, T, RT (4)	QQ-A-355	Federal	47A10	Structural
Tubing, Round	O, T	....	10235(3)	44T28	Structural
Tubing, Streamline	T	....	57-187-2	44T31	Struts
Bar, Rod, Wire, Shapes	O, T	QQ-A-354	Federal	46A9	Structural fittings
Rivets	T	....	25526(3)	43R5	High-strength joints
Rivet Wire and Rod	Special	....	....	43R5	Rivets
Machine Screws, Nuts	T	....	....	43S4	Fastenings
Bolts and Nuts	T	....	29-59	43B13	Fastenings

[1] Balance is commercially pure aluminum.
[2] Revision not indicated. Refer to latest issue.
[3] Air Corps Specification.
[4] Also includes as-fabricated flattened wire.

TABLE 1—*Continued*

Government Specifications for Alcoa Aluminum Alloy Products

Aluminum Products and Nominal Composition[1]	Tempers	Federal[2]	Army[2]	Navy[2]	Typical Aircraft Uses
WROUGHT PRODUCTS—*Continued*					
Alclad **24S** Sheet (24S Core)	O, T, RT	QQ-A-362	11067(3)	47A8	Highly corrosion-resistant structural
25S (4.5% Cu, 0.8% Si, 0.8% Mn) Forgings	T	QQ-A-367	Federal	46A7	Propellers, engine parts
32S (0.9% Cu, 12.5% Si, 1.0% Mg, 0.9% Ni) Forgings	T	QQ-A-367	Federal	46A7	Pistons
43S (5.0% Si) Welding Rods		QQ-R-571	Federal	46R7	Welding castings
A51S (1.0% Si, 0.6% Mg, 0.25% Cr) Forgings	T	QQ-A-367	Federal	46A7	Fittings and engine parts

See notes on page 61.

TABLE 1—*Continued*

Government Specifications for Alcoa Aluminum Alloy Products

Aluminum Products and Nominal Composition[1]	Tempers	Federal[2]	Army[2]	Navy[2]	Typical Aircraft Uses
WROUGHT PRODUCTS—*Concluded*					
52S (2.5% Mg, 0.25% Cr)					
Sheet	O, ¼H, ½H, ¾H, H	QQ-A-318	Federal	47A11	Tanks and fairings
Plate	As Rolled(4)	QQ-A-318	Federal	47A11	....
Tubing	O	WW-T-787	57-187-3	44T32	Oil, fuel, instrument, etc. lines
Wire	O, ½H, ¾H, H	....	....	46A11	....
Bar and Rod	O, As Fabricated	....	....	46A11	....
53S (0.7% Si, 1.3% Mg, 0.25% Cr)					
Sheet and Plate	O, W, T	QQ-A-334	Federal	47A12	Fairings
Bar, Rod, Wire, Shapes	O, W, T	QQ-A-331	Federal	46A10	Semi-structural uses
Tubing, Round	O, W, T	WW-T-790	11327	44T30	Conduit, electrical
Rivets	W	....	....	43R5	Rivets
61S (0.25% Cu, 0.6% Si, 1.0% Mg, 0.25% Cr)					
Sheet	O, W, T	....	11326(3)	......	Engine baffles, fairings

1 Balance is commercially pure aluminum.
2 Revisions not indicated. Refer to latest issue.
3 Air Corps Specification.
4 The Federal Specification includes ¼H and ½H plate.

TABLE 1—*Continued*

Government Specifications for Alcoa Aluminum Alloy Products

Aluminum Products and Nominal Composition[1]	Tempers	Federal[2]	Army[2]	Navy[2]	Typical Aircraft Uses
SAND CASTINGS					
43 (5.0% Si)	As Cast	QQ-A-601	AN-QQ-A-405	AN-QQ-A-405	Nonstructural fittings
122 (10.0% Cu, 1.2% Fe, 0.2% Mg)	T2, T61	QQ-A-601	Federal	M212	Engine cylinder heads
142 (4.0% Cu, 1.5% Mg, 2.0% Ni)	T2, T61(4)	QQ-A-601	AN-QQ-A-379	AN-QQ-A-379	Engine cylinder heads
195 (4.0% Cu)	T4, T6	QQ-A-601	AN-QQ-A-390	AN-QQ-A-390	General high-strength structural parts
214 (3.8% Mg)	As Cast	QQ-A-601	AN-QQ-A-402	AN-QQ-A-402	Nonstructural fittings (high resistance to corrosion)
220 (10.0% Mg)	T4	....	AN-QQ-A-392	AN-QQ-A-392	High-strength structural fittings

See notes on page 63.

TABLE 1—*Continued*

Government Specifications for Alcoa Aluminum Alloy Products

Aluminum Products and Nominal Composition[1]	Tempers	Federal[2]	Army[2]	Navy[2]	Typical Aircraft Uses
SAND CASTINGS—*Concluded*					
355 (1.3% Cu, 5.0% Si, 0.5% Mg)	T6	QQ-A-601	AN-QQ-A-376	AN-QQ-A-376	Structural fittings, crankcases
A355 (1.4% Cu, 5.0% Si, 0.5% Mg, 0.8% Ni, 0.8% Mn)	T51	QQ-A-601	Federal	M-212	Cylinder heads, small engines
356 (7.0% Si, 0.3% Mg)	T4, T6(3)	QQ-A-601	AN-QQ-A-394	AN-QQ-A-394	Structural fittings

[1] Balance is commercially pure aluminum.
[2] Revisions not indicated. Refer to latest issue.
[3] AN specification covers T6 temper only.
[4] AN specification does not cover T2 temper.

TABLE 1—*Continued*

Government Specifications for Alcoa Aluminum Alloy Products

Aluminum Products and Nominal Composition[1]	Tempers	Federal[2]	Army[2]	Navy[2]	Typical Aircraft Uses
PERMANENT-MOLD CASTINGS					
43 (5.0% Si)	As Cast	QQ-A-596	....	46A15	Tank fittings
A132 (0.8% Cu, 0.8% Fe, 12.0% Si, 1.0% Mg, 2.5% Ni)	T551, T4(3)	QQ-A-596	AN-QQ-A-386	AN-QQ-A-386	Engine pistons
B195 (4.5% Cu, 2.5% Si)	T4	QQ-A-596	....	....	Miscellaneous engine parts, landing wheels
355 (1.3% Cu, 5.0% Si, 0.5% Mg)	T6	QQ-A-596	AN-QQ-A-376	AN-QQ-A-376	Miscellaneous small parts
356 (7.0% Si, 0.3% Mg)	T4, T6	QQ-A-596	....	46A15	Small engine parts

See notes on page 65.

TABLE 1—*Concluded*

Government Specifications for Alcoa Aluminum Alloy Products

Aluminum Products and Nominal Composition[1]	Tempers	Federal[2]	Army[2]	Navy[2]	Typical Aircraft Uses
DIE CASTINGS					
13 (12.0% Si)	As Cast	QQ-A-591	AN-QQ-A-366	AN-QQ-A-366	Junction boxes, small housings and covers, misc. small non-structural parts
85 (4.0% Cu, 5.0% Si)	As Cast	QQ-A-591	AN-QQ-A-366	AN-QQ-A-366	
218 (8.0% Mg)	As Cast	QQ-A-591	AN-QQ-A-366	AN-QQ-A-366	

1 Balance is commercially pure aluminum.
2 Revisions not indicated. Refer to latest issue.
3 AN specification covers T4 and T7 tempers.

TABLE 2

Approximate Inside Radii for 90° Cold Bend in Sheet

Minimum permissible radius varies with nature of forming operation, type of forming equipment and design and condition of tools. Minimum working radius for given material or hardest alloy and temper for a given radius can be ascertained only by actual trial under contemplated conditions of fabrication. The values in this table may be considered a relative index of workability.

Alloy and Temper	Bend Classification[1]	Alloy and Temper	Bend Classification[1]
2S-O	A	24S-O (2)	B
2S-¼H	B	24S-T (2) (3)	J
2S-½H	B	24S-RT (2)	K
2S-¾H	D		
2S-H	F	52S-O	A
		52S-¼H	C
3S-O	A	52S-½H	D
3S-¼H	B	52S-¾H	F
3S-½H	C	52S-H	G
3S-¾H	E		
3S-H	G	53S-O	A
		53S-W	F
17S-O (2)	B	53S-T	G
17S-T (2) (3)	H		
		61S-O	B
		61S-W	E
		61S-T	F

[1] For corresponding bend radii see table below.

[2] Alclad 17S and Alclad 24S can be bent over slightly smaller radii than the corresponding tempers of the uncoated alloy.

[3] Immediately after quenching, these alloys can be formed over appreciably smaller radii.

Radii Required for 90° Bend in Terms of Thickness, t

	Approximate Thickness					
B&S Gauge Inch Inch	26 0.016 1/64	20 0.032 1/32	14 0.064 1/16	8 0.128 1/8	5 0.182 3/16	2 0.258 1/4
Bend Classification A	0	0	0	0	0	0
B	0	0	0	0	0–1t	0–1t
C	0	0	0	0–1t	0–1t	½t–1½t
D	0	0	0–1t	½t–1½t	1t–2t	1½t–3t
E	0–1t	0–1t	½t–1½t	1t–2t	1½t–3t	2t–4t
F	0–1t	½t–1½t	1t–2t	1½t–3t	2t–4t	2t–4t
G	½t–1½t	1t–2t	1½t–3t	2t–4t	3t–5t	4t–6t
H	1t–2t	1½t–3t	2t–4t	3t–5t	4t–6t	4t–6t
J	1½t–3t	2t–4t	3t–5t	4t–6t	4t–6t	5t–7t
K	2t–4t	3t–5t	3t–5t	4t–6t	5t–7t	6t–10t

TABLE 3

Conditions for Heat Treatment of Aluminum Alloys

Alloy	Solution Heat Treatment[1]			Precipitation Heat Treatment		
	Temperature, Deg. F.	Quench[2]	Temper Designation	Temperature, Deg. F.	Time of Aging	Temper Designation
14S (3)	930–950	Boiling water		335–345	10 hours	14S-T
17S	930–950	Cold water		Room	4 days (4)	17S-T
A17S	930–950	Cold water		Room	4 days (4)	A17S-T
24S	910–930	Cold water		Room	4 days (4)	24S-T
53S	960–980	Water (5)	53S-W	315–325 or 345–355	18 hours or 8 hours	53S-T
61S (6)	960–980	Water (5)	61S-W	315–325 or 345–355	18 hours or 8 hours	61S-T

1 See Table 4, below, for soaking times.

2 It is essential that the quench be made with a minimum time loss in transfer from the furnace.

3 Alloy 14S forgings should be held at heat-treating temperature for 12 hours. Details of heat treatment for forgings may vary somewhat, depending on the size and shape. Aluminum Company of America is pleased to consult on any special problems that arise.

4 More than 90 per cent of the maximum properties are obtained during the first day of aging.

5 The water temperature is not critical.

6 Precipitation heat treatment at elevated temperatures is patented.

TABLE 4

Typical Soaking Times for Heat Treatment

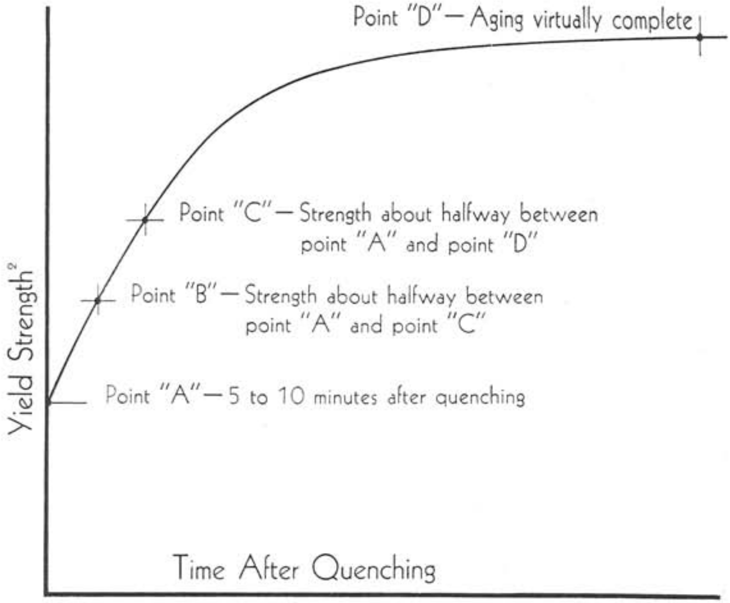
Thickness	Time in Minutes for Various Alloys		
	17S and Alclad 17S	24S	Alclad 24S
Up to 0.032″	20	30	20
0.032″ to 1/8″	20	30	30
1/8″ to 1/4″	30	40	40
Over 1/4″	60	60	60

Notes: 1. Soaking time starts when the metal (or the molten bath) reaches a temperature within the range specified above (Table 3).

2. The soaking time shown for 17S can also be used for alloys 53S and 61S.

TABLE 5

Aging Data at Various Temperatures



Alloy	Yield Strength,[1] Lb./Sq. In. at Point "A"	Temperature of Metal				
		70°F.			32°F. (3)	
		Time to Reach Point			Time to Reach Point	
		B	C	D	B	C
17S(4)	18,000	2 hr.	4 hr.	4 days	3½ days	......
A17S	9,500	1½ hr.	6 hr.	4 days	....	......
24S(4)	22,000	1 hr.	2 hr.	1 day	1 day	4 days
61S	9,000	2½ hr.	12 hr.	1 month	....	......

[1] Typical values. See Table 6.

[2] Ultimate tensile strength increases at approximately the same rate.

[3] When material is returned to room temperature, aging proceeds at normal rate.

[4] Alloys 17S and 24S show no increase in strength in 7 days at a temperature of 0°F.

TABLE 6

Typical[1] Mechanical Properties of Wrought Aluminum Alloys[2]

For Guaranteed Minimum Values, See Tables 13 to 19.

Alloy and Temper	TENSION				HARDNESS	SHEAR	FATIGUE
	Yield Strength[2] (Set = 0.2%), Lb./Sq. In.	Ultimate Strength, Lb./Sq. In.	Elongation,[2] Per Cent in 2 In.		Brinell, 500-kg. Load 10-mm. Ball	Shearing Strength,[2] Lb./Sq. In.	Endurance Limit,[2] Lb./Sq. In.
			Sheet Specimen (1/16 Inch Thick)	Round Specimen (1/2 Inch Diameter)			
2S-O	5,000	13,000	35	45	23	9,500	5,000
2S-¼H	13,000	15,000	12	25	28	10,000	6,000
2S-½H	14,000	17,000	9	20	32	11,000	7,000
2S-¾H	17,000	20,000	6	17	38	12,000	8,500
2S-H	21,000	24,000	5	15	44	13,000	8,500
3S-O	6,000	16,000	30	40	28	11,000	7,000
3S-¼H	15,000	18,000	10	20	35	12,000	8,000
3S-½H	18,000	21,000	8	16	40	14,000	9,000
3S-¾H	21,000	25,000	5	14	47	15,000	9,500
3S-H	25,000	29,000	4	10	55	16,000	10,000
17S-O	10,000	26,000	20	22	45	18,000	11,000
17S-T	40,000	62,000	20	22	100	36,000	15,000
Alclad 17S-T	33,000	56,000	18	..	..	32,000	......
A17S-T	24,000	43,000	..	27	70	26,000	13,500
24S-O	10,000	26,000	20	22	42	18,000	12,000
24S-T	45,000	68,000	19	22	105	41,000	18,000
24S-RT	55,000	70,000	13	..	116	42,000	......
Alclad 24S-T	41,000	62,000	18	..	..	40,000	......
Alclad 24S-RT	50,000	66,000	11	..	..	41,000	......
52S-O	14,000	29,000	25	30	45	18,000	17,000
52S-¼H	26,000	34,000	12	18	62	20,000	18,000
52S-½H	29,000	37,000	10	14	67	21,000	19,000
52S-¾H	34,000	39,000	8	10	74	23,000	20,000
52S-H	36,000	41,000	7	8	85	24,000	20,500
53S-O	7,000	16,000	25	35	26	11,000	7,500
53S-W	20,000	33,000	22	30	65	20,000	10,000
53S-T	33,000	39,000	14	20	80	24,000	11,000
61S-O	8,000	18,000	22	..	30	12,500	8,000
61S-W	21,000	35,000	22	..	65	24,000	12,500
61S-T	39,000	45,000	12	..	95	30,000	12,500

[1] These values are NOT guaranteed.

[2] See page 56 for explanation of terms; also additional data. See Table 14 for forging alloys.

TABLE 7

Mechanical Properties of Aluminum Sand-Casting Alloys[1]

ALLOY	Minimum Values for Specifications: Tension[2]		TYPICAL VALUES (Not Guaranteed): Tension[2]			Compression[3]	Hardness[2]	Shear	Fatigue	Density
	Ultimate Strength, Lb./Sq. In.	Elongation, Per Cent in 2 Inches	Yield Strength[1] (Set = 0.2%), Lb./Sq. In.	Ultimate Strength, Lb./Sq. In.	Elongation, Per Cent in 2 Inches	Yield Strength[1] (Set = 0.2%), Lb./Sq. In.	Brinell, 500-kg. Load 10-mm. Ball	Shearing Strength,[1] Lb./Sq. In.	Endurance Limit,[1] Lb./Sq. In.	Lb./Cu. In.
43	17,000	3.0	9,000	19,000	6.0	10,000	40	14,000	6,500	0.096
122-T2	23,000	(4)	20,000	25,000	1.0	20,000	75	21,000	9,500	0.103
122-T61	30,000	(4)	30,000	36,000	1.0	43,000	100	29,000	.....	0.103
142-T2	23,000	(4)	18,000	27,000	1.0	18,000	75	21,000	6,500	0.099
142-T61	32,000	(4)	32,000	37,000	0.5	47,000	100	32,000	8,000	0.099
195-T4 (5)	29,000	6.0	16,000	31,000	8.5	16,000	65	24,000	6,000	0.100
195-T6	32,000	3.0	22,000	36,000	5.0	25,000	80	30,000	6,500	0.100
214	22,000	6.0	12,000	25,000	9.0	12,000	50	20,000	5,500	0.095
220-T4 (5)	42,000	12.0	25,000	45,000	14.0	26,000	75	33,000	7,000	0.092
355-T6	32,000	2.0	25,000	35,000	3.5	29,000	80	30,000	8,500	0.097
355-T7	35,000	(4)	35,000	38,000	1.0	35,000	85	26,500	.....	0.097
A355-T51	25,000	(4)	24,000	28,000	1.5	24,000	65	22,000	8,500	0.099
356-T4 (5)	26,000	5.0	16,000	28,000	6.0	18,000	55	22,000	.....	0.095
356-T6	30,000	3.0	22,000	32,000	4.0	22,000	70	27,000	8,000	0.095

[1] See page 56 for explanation of terms; also additional data.

[2] Tension and hardness values determined from standard half-inch diameter tensile test specimens, individually cast in green sand molds, and tested without machining off the surface.

[3] Results of tests on specimens having an l/r ratio of 12.

[4] Not specified. The error in determining low elongations is comparable with the value being measured.

[5] On standing at room temperature for several weeks, properties approach those of T6 condition.

TABLE 8

Mechanical Properties of Aluminum Permanent-Mold Casting Alloys[1]

ALLOY	Minimum Values for Specifications		TYPICAL VALUES (Not Guaranteed)								
	Tension[2]		Tension[2]			Compression[3]	Hardness[2]	Shear	Fatigue	Density
	Ultimate Strength, Lb./Sq. In.	Elongation, Per Cent in 2 Inches	Yield Strength[1] (Set = 0.2%), Lb./Sq. In.	Ultimate Strength, Lb./Sq. In.	Elongation, Per Cent in 2 Inches	Yield Strength[1] (Set = 0.2%), Lb./Sq. In.	Brinell, 500-kg. Load 10-mm. Ball	Shearing Strength,[1] Lb./Sq. In.	Endurance Limit,[1] Lb./Sq. In.	Lb./Cu. In.
43	21,000	2.5	9,000	24,000	6.0	10,000	40	18,000	.....	0.097
A132-T4	34,000	(4)	30,000	38,000	1.5	30,000	100	29,000	.....	0.097
A132-T551	31,000	(4)	28,000	36,000	0.5	30,000	105	24,000	.....	0.097
B195-T4 (5)	33,000	4.5	22,000	40,000	10.0	22,000	75	30,000	9,500	0.101
B195-T6	35,000	2.0	33,000	45,000	5.0	33,000	90	32,000	10,000	0.101
A214	22,000	2.5	16,000	27,000	5.0	17,000	60	22,000	.....	0.096
355-T6	37,000	1.5	26,000	43,000	4.0	26,000	90	30,000	9,000	0.097
356-T4 (5)	28,000	5.0	18,000	32,000	9.0	18,000	60	......	.....	0.095
356-T6	33,000	3.0	24,000	40,000	5.0	24,000	90	......	.....	0.095

[1] See page 56 for explanation of terms; also additional data.

[2] Tension and hardness values obtained from standard half-inch diameter tensile test specimens, individually cast in a permanent mold, and tested without machining off the surface.

[3] Results of tests on specimens having an l/r ratio of 12.

[4] Not specified. The error in determining low elongations is comparable with the value being measured.

[5] On standing at room temperature for several weeks, properties approach those of T6 condition.

TABLE 9

Typical Mechanical Properties of Aluminum Die-Casting Alloys [1]

Alloy	Typical Mechanical Properties[1, 2]			
	Tensile Strength,[2] Lb./Sq. In.	Yield Strength,[1] Lb./Sq. In.	Elongation,[1] Per Cent in 2 Inches	Endurance Limit,[1] Lb./Sq. In.
13	33,000	18,000	1.8	15,000
85	35,000	19,000	2.7	17,000
218	38,000	23,000	5.0	18,000

[1] See page 56 for explanation of terms.

[2] Tensile properties are average values obtained from A.S.T.M. standard round die-cast test specimen, ¼ inch in diameter.

TABLE 10

Allowable Single Shear Strength of Aluminum Alloy Rivets

(Values from ANC-5—"Strength of Aircraft Elements," issued by Army-Navy-Civil Committee on Aircraft Requirements)

Rivet Alloy	Allowable Shear (Lb.) for Various Rivet Diameters							
	1/16"	3/32"	1/8"	5/32"	3/16"	1/4"	5/16"	3/8"
A17ST (F_{su} = 27,000 lb./sq. in.)	83	186	331	518	745	1,325	2,071	2,984
17ST (F_{su} = 30,000 lb./sq. in.)	92	206	368	573	828	1,472	2,300	3,313
24ST (F_{su} = 35,000 lb./sq. in.)	107	241	429	670	966	1,718	2,684	3,865

TABLE 11

Allowable Bearing Strength of Aluminum Alloy Sheet

(Values from ANC-5—"Strength of Aircraft Elements," issued by Army-Navy-Civil Committee on Aircraft Requirements)

Sheet Thickness, Inches	Allowable Bearing Strength (Lb.) for Various Rivet Diameters							
	1/16"	3/32"	1/8"	5/32"	3/16"	1/4"	5/16"	3/8"
24S-T SHEET (F_{br}=90,000 lb./sq. in.)								
0.014	78	...	...	...	...	.....	.....	.....
0.016	90	...	...	...	...	.....	.....	.....
0.018	101	151	...	...	...	.....	.....	.....
0.020	112	168	...	...	...	.....	.....	.....
0.025	140	210	281	...	...	.....	.....	.....
0.032	180	269	360	449	...	.....	.....	.....
0.036	202	303	405	506	607	.....	.....	.....
0.040	225	337	450	562	675	.....	.....	.....
0.045	253	379	506	632	759	.....	.....	.....
0.051	286	430	573	716	860	1,147	.....	.....
0.064	360	539	720	899	1,080	1,440	1,800	.....
0.072	405	607	810	1,012	1,215	1,620	2,025	2,430
0.081	455	683	910	1,138	1,366	1,822	2,278	2,733
0.091	511	767	1,023	1,279	1,535	2,047	2,559	3,071
0.102	573	860	1,147	1,434	1,721	2,295	2,868	3,442
0.128	720	1,079	1,440	1,799	2,160	2,880	3,600	4,320
5/32	878	1,317	1,757	2,195	2,635	3,514	4,393	5,271
3/16	1,054	1,581	2,109	2,635	3,164	4,218	5,273	6,328
1/4	1,406	2,108	2,812	3,514	4,218	5,625	7,031	8,437
ALCLAD 24S-T SHEET (F_{br}=82,000 lb./sq. in.)								
0.014	71	...	...	...	...	....	....	....
0.016	82	...	...	...	...	....	....	....
0.018	92	138	...	...	...	....	....	....
0.020	102	153	...	...	...	....	....	....
0.025	128	192	256	...	...	....	....	....
0.032	164	245	328	409	...	....	....	....
0.036	184	276	369	461	553	....	....	....
0.040	205	307	410	512	615	....	....	....
0.045	230	345	461	576	691	....	....	....
0.051	261	391	522	653	784	1,045	....	....
0.064	328	491	656	819	984	1,312	1,640	.....
0.072	369	553	738	922	1,107	1,476	1,845	2,214
0.081	415	622	830	1,037	1,245	1,660	2,075	2,490
0.091	466	699	932	1,165	1,399	1,865	2,331	2,798
0.102	522	783	1,045	1,306	1,568	2,091	2,613	3,136
0.128	656	983	1,312	1,639	1,968	2,624	3,280	3,936
5/32	800	1,200	1,601	2,000	2,401	3,202	4,002	4,803
3/16	960	1,440	1,921	2,401	2,882	3,843	4,804	5,765
1/4	1,281	1,920	2,562	3,202	3,843	5,125	6,406	7,687

TABLE 12

Shear Strength[1] of Spot Welds

Minimum strength required for qualification under U. S. Army Air Corps Specification No. 20011-B. Single spot specimens tested in shear.

Metal Thickness,[2] Inches	Shear Strength in Pounds	
	Alclad 24S-T (3)	52S (4) and 61S (4)
0.012	80	75
0.016	110	105
0.020	140	137
0.024	175	170
0.028	214	200
0.030	235	217
0.035	290	260
0.040	345	310
0.045	405	365
0.050	465	427
0.065	705	632
0.070	800	705
0.080	1,025	852
0.090	1,265	1,000

[1] The tabular values are approximately 65 per cent of actual average results. The use of spacing less than eight times metal thickness or edge distance less than four times metal thickness will substantially decrease the strength of spot welds.

[2] When sheets of different thicknesses are joined, strength listed for thinner sheet applies.

[3] Values for Alclad 17S-T are 90 per cent of those for Alclad 24S-T.

[4] Any temper.

TABLE 13

Mechanical Properties Specifications
Sheet and Plate 2S, 3S, 52S

SHEET

Grade and Temper	Tensile Strength, Lb./Sq. In. Minimum Except for Soft (O) Temper	Minimum Elongation,[1] Per Cent in 2 Inches								
		.249″–.204″	5–6 Gauge .203″–.162″	7–9 Gauge .161″–.114″	10–16 Gauge .113″–.051″	17–20 Gauge .050″–.032″	21–24 Gauge .031″–.020″	25–28 Gauge .019″–.013″	29–32 Gauge .012″–.008″	33–35 Gauge .007″–.006″
2S-O	15,500 (2)	30	30	30	30	25	20	15	15	15
2S-¼H	14,000	10	10	10	9	7	5	4	..	..
2S-½H	16,000	7	7	7	7	5	4	3	2	..
2S-¾H	19,000	..	..	4	4	3	2	1	1	1
2S-H	22,000	..	..	4	4	3	2	1	1	1
3S-O	19,000 (2)	25	25	25	25	23	20	20	18	16
3S-¼H	17,000	9	9	8	7	6	5	4	..	..
3S-½H	19,500	8	8	7	6	5	4	3	2	..
3S-¾H	23,500	..	..	4	4	3	2	1	1	1
3S-H	27,000	..	..	4	4	3	2	1	1	1
52S-O	31,000 (2)	20	20	20	20	20	18	15	..	..
52S-¼H	31,000	10	10	10	8	6	6	5	..	..
52S-½H	34,000	8	8	8	7	5	5	4	..	..
52S-¾H	37,000	..	..	4	4	4	3	3	..	..
52S-H	39,000	..	..	4	4	4	3	3	..	..

PLATE

2S, 3S, 52S, As Rolled—No physical tests required.

¼H, ½H { Physical properties same as for 0.249-inch sheet in same alloy and temper.

MAXIMUM AND MINIMUM COMMERCIAL THICKNESS OF FLAT AND STRIP SHEET IN ALL TEMPERS

Temper	FLAT SHEET		STRIP SHEET	
	Thickness, Inches		Thickness, Inches	
	Maximum	Minimum	Maximum	Minimum
O	0.249	0.006	0.102	0.006
¼H	0.249	0.017	0.102	0.017
½H	0.249	0.0095	0.085	0.0095
¾H	0.162	0.006	0.053	0.006
H	0.128	0.006	0.102	0.006

[1] In the ¼H and ½H tempers, strip sheet may have an elongation one per cent lower than the above values. Test specimens taken parallel to direction of rolling from flat and strip sheet in ¼H and ½H tempers.

[2] Maximum. So specified to insure complete annealing.

TABLE 14

Mechanical Properties of Aluminum Alloy Forgings[1]

Alloy	Minimum Specification Values				Typical Values (Not Guaranteed)		
	Tension[2]			Hardness[2]	Shear	Fatigue	Density
	Yield Strength[1] (Set = 0.2%), Lb./Sq. In.	Ultimate Strength, Lb./Sq. In.	Elongation,[1] Per Cent in 2 Inches	Brinell, 500-kg. Load 10-mm. Ball	Shearing Strength,[1] Lb./Sq. In.	Endurance Limit,[1] Lb./Sq. In.	Lb./Cu. In.
14S-T	50,000	65,000	10.0	130	45,000	16,000	0.101
17S-T	30,000	55,000	16.0	100	36,000	15,000	0.101
18S-T	40,000	55,000	10.0	100	......	14,500	0.103
25S-T	30,000	55,000	16.0	100	35,000	15,000	0.101
32S-T	40,000	52,000	5.0	115	38,000	14,000	0.097
A51S-T	34,000	44,000	14.0	90	32,000	10,500	0.097
53S-T	30,000	36,000	14.0	75	24,000	11,000	0.097

[1] These properties apply to forgings up to 4 inches in diameter or thickness. Long axis of test specimen taken parallel to direction of grain flow. See page 56 for explanation of terms; also additional data.

[2] Tension and hardness values determined from standard half-inch diameter test specimens. Values in compression at least equal to values in tension.

TABLE 15

Minimum Longitudinal and Transverse Mechanical Properties of Aircraft Fittings Stock [1]

(Longitudinal properties are guaranteed; transverse properties not guaranteed)

Class	Grade and Temper	Mechanical Properties [3]	Sizes [2]: Up to 5" x 5" or 25 sq. in.		Up to 6" x 6" or 36 sq. in.		Up to 8" x 8" or 64 sq. in.		Greater than 8" x 8" or 64 sq. in.	
			Long.	Trans.	Long.	Trans.	Long.	Trans.	Long.	Trans.
Rod and bar	17S-T	Ultimate Tensile Strength	55,000	50,000	55,000	50,000	55,000	......	......	......
		Yield Strength..........	32,000	28,000	32,000	28,000	32,000	......	......	......
		Elongation............	16	8	16	8	16	......	......	......
	24S-T (4)	Ultimate Tensile Strength	62,000	55,000	......	......	......	......	......	......
		Yield Strength..........	40,000	38,000	......	......	......	......	......	......
		Elongation............	14	6	......	......	......	......	......	......
Specially processed hand forgings [5]	17S-T	Ultimate Tensile Strength	55,000	52,000	55,000	51,000	53,000	50,000	52,000	50,000
		Yield Strength..........	30,000	30,000	30,000	30,000	30,000	28,000	30,000	28,000
		Elongation............	16	12	16	10	14	8	12	6
	14S-T	Ultimate Tensile Strength	65,000	62,000	65,000	61,000	62,000	60,000	62,000	60,000
		Yield Strength..........	50,000	50,000	50,000	50,000	50,000	48,000	50,000	48,000
		Elongation............	10	6	10	5	8	4	7	3

[1] Longitudinal properties for smaller sizes of 24S-T and 17S-T rod and bar and transverse properties for 24S-T and 17S-T plate are given in Tables 16 and 17.

[2] Standard sizes of rod and bar are shown in Table 31.

[3] Ultimate tensile and yield strengths are in pounds per square inch. Elongations are in per cent of the gauge length (2 inches for standard round test specimens, four times the diameter of the specimens for sub-size test specimens, where required). Where flat specimens are used the elongation is in per cent of 2 inches.

[4] Maximum cross section for 24S-T rod and bar is 24 square inches.

[5] The transverse properties listed apply to forged blanks having a length not greater than twice the width.

TABLE 16

Mechanical Properties Specifications—17S Alloy Products [1]

Material	Dimensions,[1] Inches	Tensile Strength, Lb./Sq. In. Minimum Except for 17S-O[2]	Yield Strength[1] (Set = 0.2%), Lb./Sq. In. Minimum	Elongation Per Cent in 2 Inches or in 4D[1] (Minimum)
Sheet and Plate				
17S-O	0.010–0.500	35,000 (2)	....	12
17S-T	0.010–0.020	58,000	34,000 (3)	15
	0.021–0.040	58,000	34,000 (3)	17 (4)
	0.041–0.128	58,000	34,000 (3)	18
	0.129–0.258	58,000	34,000 (3)	15
	0.259–0.500	58,000	34,000 (3)	12
	0.501–1.000	58,000	34,000 (3)	10
	1.001–1.500	58,000	34,000 (3)	9
	1.501–2.000	55,000	34,000 (3)	8
	2.001–3.000	55,000	34,000 (3)	6
Alclad 17S-O	0.010–0.032	30,000 (2)	....	8
	0.033–0.064	30,000 (2)	....	10
	0.065–0.500	30,000 (2)	....	12
Alclad 17S-T	0.010–0.020	52,000	30,000	13
	0.021–0.128	52,000	30,000	16
	0.128–0.250	52,000	30,000	13
	0.251–0.500	52,000	30,000	11
Wire, Rod, Bar and Shapes				
17S-O Wire	up to 0.124	35,000 (2)	....	..
17S-O Bar, rod, shapes	0.125–8.000	35,000 (2)	....	12
17S-T Wire	up to 0.124	55,000	....	..
17S-T Rounds, squares, hexagons, octagons, (rolled)	0.125–3.000	55,000	32,000	18
	3.001–8.000	55,000	32,000	16
17S-T Rectangular bars (rolled)	up to 0.750	55,000	32,000	16
	0.751–3.000	55,000	32,000	16
17S-T Structural shapes (rolled)	....	55,000	32,000	16
17S-T Extruded shapes	....	50,000	35,000	12

TABLE 16—*Concluded*

Mechanical Properties Specifications—17S Alloy Products [1]

Material	Dimensions,[1] Inches	Tensile Strength, Lb./Sq. In. Minimum Except for 17S-O[2]	Yield Strength[1] (Set = 0.2%), Lb./Sq. In. Minimum	Elongation Per Cent in 2 Inches or in 4D[1] (Minimum)
Tubing				
17S-O	All sizes	35,000 (2)	....	..
17S-T	*Diameter ¼″ to 2″*			
	Wall thickness:			
	0.025–0.049	58,000	34,000 (5)	12
	0.050–0.259	58,000	34,000 (5)	14
	0.260–0.500	58,000	34,000 (5)	16
	Diameter greater than 2″ to 8″			
	Wall thickness:			
	0.025–0.049	58,000	34,000 (5)	10
	0.050–0.259	58,000	34,000 (5)	12
	0.260–0.500	58,000	34,000 (5)	14
Forgings				
17S-T	up to 4	55,000	30,000	16

1 See page 56 for explanation of terms; also additional data.

2 Maximum. So specified to insure complete annealing.

3 Sheet and plate heat treated by the user may have a minimum yield strength of 33,000 pounds per square inch.

4 For sheets less than 30 inches wide, elongation shall be 18 per cent in 2 inches.

5 The tensile yield strength of 17S-T tubing usually exceeds this value by a substantial amount because of straightening operations.

TABLE 17

Mechanical Properties Specifications—24S Alloy Products [1]

Material	Dimensions,[1] Inches	Tensile Strength, Lb./Sq. In. Minimum Except for 24S-O	Yield Strength[1] (Set = 0.2%), Lb./Sq. In. Minimum	Elongation Per Cent in 2 Inches or in 4D[1] (Minimum)
Sheet and Plate				
24S-O	0.010–0.500	35,000 (2)	......	12
24S-T	0.010–0.020	62,000	40,000	12
	0.021–0.051	62,000	40,000	13
	0.052–0.128	62,000	40,000	15
	0.129–0.250	62,000	40,000	15
	0.251–0.500	62,000	40,000	12
	0.501–1.000	62,000	40,000	8
	1.001–1.500	60,000	40,000	7
	1.501–2.000	60,000	40,000	6
24S-RT	0.020–0.031	68,000	50,000	10
	0.032–0.036	68,000	50,000	11
	0.037–0.188	68,000	50,000	12
Alclad 24S-O	0.010–0.032	33,000 (2)	......	8
	0.033–0.064	33,000 (2)	......	10
	0.065–0.500	33,000 (2)	......	12
Alclad 24S-T	0.010–0.020	56,000	37,000	12
	0.021–0.128	56,000	37,000	15
	0.129–0.250	56,000	37,000	13
	0.251–0.500	56,000	37,000	11
Alclad 24S-RT	0.020–0.031	62,000	46,000	8
	0.032–0.040	62,000	46,000	9
	0.041–0.188	62,000	46,000	10
Wire, Rod, Bar and Shapes				
24S-O Wire	up to 0.124 incl.	35,000 (2)	......	..
24S-O Bars, rods, shapes	0.125–8.000	35,000 (2)	......	12
24S-T Wire	up to 0.124	62,000	......	..
24S-T Rounds	0.125–5.500	62,000	40,000	14
24S-T Squares, hexagons, octagons (rolled)	0.125–4.000	62,000	40,000	14
24S-T Rectangular bars (rolled)	up to 24 sq. in. cross section	62,000	40,000	14
24S-T Extruded shapes	Min. section:			
	Less than 0.250	57,000	42,000 (3)	12
	0.250 to 1.499	60,000	44,000 (3)	12
	1.500 and over (4)	70,000	52,000 (3)	10

TABLE 17—*Concluded*

Mechanical Properties Specifications—24S Alloy Products [1]

Material	Dimensions,[1] Inches	Tensile Strength, Lb./Sq. In. Minimum Except for 24S-O[2]	Yield Strength[1] (Set = 0.2%), Lb./Sq. In. Minimum	Elongation Per Cent in 2 Inches or in 4D[1] (Minimum)
Tubing				
24S-O	All	35,000 (2)	....	..
24S-T	*Diameter ¼" to 2"*			
	Wall thickness:			
	0.025–0.049	64,000	42,000 (3)	12
	0.050–0.259	64,000	42,000 (3)	14
	0.260–0.500	64,000	42,000 (3)	16
	Diameter greater than 2" to 8"			
	Wall thickness:			
	0.025–0.049	64,000	42,000 (3)	10
	0.050–0.259	64,000	42,000 (3)	11
	0.260–0.500	64,000	42,000 (3)	12

[1] See page 56 for explanation of terms; also additional data.

[2] Maximum. So specified to insure complete annealing.

[3] Material heat treated by the user may have a lower yield strength than that guaranteed for material as supplied in the heat-treated temper. The tensile yield strength of 24S-T tubing usually exceeds this value by a substantial amount because of straightening operations.

[4] Up to a maximum cross-sectional area of 10 square inches.

TABLE 18

Mechanical Properties Specifications—53S Alloy Products

Material	Dimensions,[1] Inches	Tensile Strength, Lb./Sq. In. Minimum Except for 53S-O[2]	Yield Strength[1] (Set = 0.2%), Lb./Sq. In. Minimum	Elongation Per Cent in 2 Inches or in 4D[1] (Minimum)
Sheet and Plate				
53S-O	0.010–0.032	19,000 (2)	......	20
	0.033–0.128	19,000 (2)	......	22
	0.129–0.500	19,000 (2)	......	25
53S-W	0.010–0.032	28,000	16,000	12
	0.033–0.050	28,000	16,000	15
	0.051–0.258	28,000	16,000	17
	0.259–0.500	28,000	16,000	18
	0.501–2.000	28,000	16,000	12
53S-T	0.010–0.031	35,000	28,000	8
	0.032–2.000	35,000	28,000	10
Wire, Rod, Bar and Shapes				
53S-O Wire	up to 0.124	19,000 (2)	......	..
53S-O (Rolled)	0.125–3.000	19,000 (2)	......	20
53S-O Extruded	....	19,000 (2)	......	18
53S-W Wire	up to 0.124	25,000	......	..
53S-W Rounds, squares, hexagons, octagons, rectangles (rolled)	0.125–3.000	25,000	14,000	18
53S-W Shapes (rolled or extruded)	....	25,000	14,000	16
53S-T Wire	up to 0.124	32,000	......	..
53S-T Rounds, squares, hexagons, octagons (rolled)	0.125–3.000	32,000	25,000	14
53S-T Rectangles (rolled)	Thickness: up to 0.750	32,000	25,000	14
	0.751–3.000	32,000	25,000	14
53S-T Shapes (extruded or rolled)	....	32,000	25,000	10
53S-T5 (extruded)	All	22,000	16,000	10

TABLE 18—*Concluded*

Mechanical Properties Specifications—53S Alloy Products

Material	Dimensions,[1] Inches	Tensile Strength, Lb./Sq. In. Minimum Except for 53S-O[2]	Yield Strength[1] (Set = 0.2%), Lb./Sq. In. Minimum	Elongation Per Cent in 2 Inches or in 4D[1] (Minimum)
Tubing				
53S-O	All	19,000 (2)	......	..
53S-W	*Diameter ¼″ to 2″* Wall thickness:			
	0.025–0.049	28,000	14,000	16
	0.050–0.259	28,000	14,000	18
	0.260–0.500	28,000	14,000	20
	Diameter greater than 2″ to 8″ Wall thickness:			
	0.025–0.049	28,000	14,000	14
	0.050–0.259	28,000	14,000	16
	0.260–0.500	28,000	14,000	18
53S-T	*Diameter ¼″ to 2″* Wall thickness:			
	0.025–0.049	35,000	28,000	12
	0.050–0.259	35,000	28,000	14
	0.260–0.500	35,000	28,000	16
	Diameter greater than 2″ to 8″ Wall thickness:			
	0.025–0.049	35,000	28,000	8
	0.050–0.259	35,000	28,000	10
	0.260–0.500	35,000	28,000	12
Forgings				
53S-T	up to 4 inches	36,000	30,000	14

[1] See page 56 for explanation of terms; also additional data.

[2] Maximum. So specified to insure complete annealing.

TABLE 19

Mechanical Properties Specifications—61S Alloy Products[1]

Material	Dimensions,[1] Inches	Tensile Strength, Lb./Sq. In. Minimum Except for 61S-O[2]	Yield Strength[1] (Set = 0.2%), Lb./Sq. In. Minimum	Elongation Per Cent in 2 Inches or in 4D[1] (Minimum)
Sheet and Plate				
61S-O	0.010–0.020	22,000 (2)	......	14
	0.021–0.128	22,000 (2)	......	16
	0.129–0.500	22,000 (2)	......	18
61S-W	0.010–0.020	30,000	16,000	14
	0.021–0.250	30,000	16,000	16
	0.251–0.500	30,000	16,000	18
61S-T	0.010–0.020	42,000	35,000	8
	0.021–0.250	42,000	35,000	10
	0.251–0.500	42,000	35,000	10
Extruded Shapes				
61S-O	All sizes	22,000 (2)	......	20
61S-W	All sizes	26,000	16,000	16
61S-T	All sizes	38,000	35,000	10
Tubing				
61S-O	All sizes	22,000 (2)	......	..
61S-W	*Diameter ¼″ to 2″* Wall thickness:			
	0.025–0.049	30,000	16,000	16
	0.050–0.259	30,000	16,000	18
	0.260–0.500	30,000	16,000	20
	Diameter greater than 2″ to 8″ Wall thickness:			
	0.025–0.049	30,000	16,000	14
	0.050–0.259	30,000	16,000	16
	0.260–0.500	30,000	16,000	18
61S-T	*Diameter ¼″ to 2″* Wall thickness:			
	0.025–0.049	42,000	35,000	10
	0.050–0.259	42,000	35,000	12
	0.260–0.500	42,000	35,000	14
	Diameter greater than 2″ to 8″ Wall thickness:			
	0.025–0.049	42,000	35,000	8
	0.050–0.259	42,000	35,000	10
	0.260–0.500	42,000	35,000	12

[1] See page 56 for explanation of terms; also additional data.

[2] Maximum. So specified to insure complete annealing.

TABLE 20

Commercial Thickness Tolerances for Sheet and Plate

(Plus or Minus)

FLAT SHEET[1] 2S AND 3S

Standard[2] Thickness, Inches	Tolerance in Per Cent of Nominal Thickness or in Inches				
	Widths up to 36″	Widths over 36″ to 54″	Widths over 54″ to 72″	Widths over 72″ to 90″	Widths over 90″ to 102″
0.249, 0.204, 0.188, 0.156	4%	5%	6%	7%	8%
0.125, 0.102	0.0045	0.005	0.007	0.009	0.010
0.091, 0.081	0.003	0.004	0.006	0.008	.....
0.064, 0.051	0.003	0.004	0.005	0.007	.....
0.040	0.0025	0.003	0.004	.....	.....
0.032, 0.025, 0.020, 0.018	0.002	0.0025	.....	.....	.....
0.016, 0.014, 0.012	0.0015	......	.....	.....	.....
0.010	0.0015	......	.....	.....	.....

FLAT SHEET[1] 52S

Standard[2] Thickness, Inches	Tolerance in Per Cent of Nominal Thickness or in Inches							
	Widths up to 36″	Widths over 36″ to 42″	Widths over 42″ to 48″	Widths over 48″ to 54″	Widths over 54″ to 60″	Widths over 60″ to 66″	Widths over 66″ to 72″	Widths over 72″ to 84″
0.249, 0.204, 0.188, 0.156	4%	5%	5%	5%	6%	8%	10%	11%
0.125, 0.102	0.0045	0.005	0.005	0.005	0.007	0.010	0.012	....
0.091, 0.081	0.003	0.004	0.004	0.005	0.006	0.008	0.010	....
0.064, 0.051	0.003	0.004	0.004	0.005	0.006	.....	.....	....
0.040	0.0025	0.003	0.004	0.004	0.005	.....	.....	....
0.032	0.0025	0.003	0.004	.....	.....	.....	.....	....
0.025	0.0025	0.003	.....	.....	.....	.....	.....	....
0.020	0.002	0.003	.....	.....	.....	.....	.....	....
0.018, 0.016	0.002	.....	.....	.....	.....	.....	.....	....
0.014 (3)	0.0015	.....	.....	.....	.....	.....	.....	....
0.012 (3)	0.0015	.....	.....	.....	.....	.....	.....	....
0.010 (3)	0.0015	.....	.....	.....	.....	.....	.....	....

STRIP SHEET[1] 2S, 3S, 52S

Standard[2] Thickness, Inches	Thickness Tolerance, Inches			Standard[2] Thickness, Inches	Thickness Tolerance, Inches		
	Widths up to 12″	Widths over 12″ to 24″	Widths over 24″		Widths up to 12″	Widths over 12″ to 24″	Widths over 24″
0.102, 0.091	0.003	0.003	0.004	0.018	0.0015	0.002	...
0.081	0.003	0.003	0.003	0.016, 0.014, 0.012	0.0015	0.002	...
0.064, 0.051	0.0025	0.003	0.003	0.010, 0.009, 0.008	0.001	0.0015	...
0.040, 0.032	0.002	0.0025	0.0025	0.007, 0.006	0.001	0.001	...
0.025, 0.020	0.002	0.002	0.002				

[1] These tolerances apply only to commercial sizes.

[2] Intermediate thicknesses take the tolerance of the next heavier standard thickness up to the maximum commercial width.

[3] Tolerance applies up to maximum width of 30 inches in these thicknesses.

TABLE 20—*Concluded*

Commercial Thickness Tolerances for Sheet and Plate

(*Plus or Minus*)

FLAT SHEET[1] 17S, ALCLAD 17S, 53S, 61S

(Also 24S and Alclad 24S in Widths to Left of Heavy Line)

Standard[2] Thickness, Inches	Tolerance in Per Cent of Nominal Thickness or in Inches					
	Widths up to 36″	Widths over 36″ to 42″	Widths over 42″ to 48″	Widths over 48″ to 54″	Widths over 54″ to 60″	Widths over 60″ to 66″
0.249, 0.204, 0.188, 0.156	4%	5%	5%	5%	6%	8%
0.125, 0.102	0.0045	0.005	0.005	0.005	0.007	0.010
0.091, 0.081	0.003	0.004	0.004	0.005	0.006	0.008
0.064	0.003	0.004	0.004	0.005	0.006	0.006
0.051	0.003	0.004	0.004	0.005	0.006	0.006
0.040	0.0025	0.003	0.003	0.004	0.005	.....
0.032	0.002	0.0025	0.0025	.....	.....	.....
0.025, 0.020	0.002	0.0025	......	.....	.....	.....
0.018, 0.016	0.002	......	......	.....	.....	.....
0.014 (3), 0.012 (3), 0.010 (3)	0.0015	......	......	.....	.....	.....

Standard[2] Thickness, Inches	Tolerance in Per Cent of Nominal Thickness or in Inches					
	Widths over 66″ to 72″	Widths over 72″ to 78″	Widths over 78″ to 84″	Widths over 84″ to 90″	Widths over 90″ to 96″	Widths over 96″ to 102″
0.249, 0.204, 0.188, 0.156	10%	10%	11%	11%	12%	14%
0.125, 0.102	0.012	0.013	0.014	0.016	0.018	0.020
0.091, 0.081	0.010	0.010	0.011	0.012	.....	.....
0.064	0.007	0.008	0.009	.....	.....	.....
0.051	0.007	.....	.....	.....	.....	.....

[1] These tolerances apply only to commercial sizes of sheet as shown in Tables 27 to 29.

[2] Intermediate thicknesses take the tolerance of the next heavier standard thickness up to the maximum width shown in Tables 27 to 29.

[3] Maximum width to which the tolerances apply is 28 inches in these thicknesses.

STRIP SHEET[1] 17S, ALCLAD 17S, 24S, ALCLAD 24S, 53S, 61S

Standard[2] Thickness, Inches	Thickness Tolerance in Inches	
	Widths up to 18″	Widths over 18″ to 24″
0.064, 0.051	0.0025	0.003
0.040, 0.032	0.002	0.0025
0.025, 0.020, 0.018	0.0015	0.002
0.016, 0.014, 0.012	0.0015	0.0015

[1] These tolerances apply only to commercial widths as shown in Table 30.

[2] Intermediate thicknesses take the tolerance of the next heavier standard thickness.

PLATE—ALL ALLOYS

Thickness, Inches	Tolerance in Per Cent of Nominal Thickness			
	Widths up to 54″	Widths over 54″ to 72″	Widths over 72″ to 90″	Widths over 90″ to 120″
3.000 to 1.001	3	3	4	5
1.000 to 0.501	4	4	5	6
0.500 to 0.375	5	5	6	7
0.374 to 0.250	5	6	7	8

TABLE 21

Commercial Tolerances for Sheet and Plate, All Alloys

(*Width, Length, Diameter*)

FLAT SHEET AND FLAT STRIP (0.102″-0.006″)—SHEARED

Width Tolerance (Plus or Minus), Inches

Thickness, Inches	Widths ¼″ to 4″	Widths over 4″ to 18″	Widths over 18″ to 36″	Widths over 36″ to 54″	Widths over 54″ to 72″	Widths over 72″ to 102″
0.249 to 0.103	. .	3/32 (2)	⅛	3/16	3/16	¼
0.102 to 0.006	1/32 (1)	1/16	3/32	⅛	5/32	3/16

Length Tolerance (Plus or Minus), Inches

Thickness	Lengths up to 18″	Lengths over 18″ to 48″	Lengths over 48″ to 120″	Lengths over 120″ to 180″	Lengths over 180″ to 540″
All	1/16	3/32	⅛	5/32	¼

COILED STRIP—SHEARED

Width Tolerance (Plus or Minus), Inches

Thickness, Inches	Widths ¼″ to 3″	Widths over 3″ to 24″	Widths over 24″
0.102 to 0.006	1/64	1/32	3/64

SHEET CIRCLES—SHEARED

Diameter Tolerance (Plus or Minus), Inches

Thickness	Diameters 5″ to 18″	Diameters over 18″
All	1/32	3/64

SHEET AND PLATE—SAWED

Dimension Tolerance (Plus or Minus), Inches

Thickness, Inches	Dimensions up to 10″	Dimensions over 10″ to 36″	Dimensions over 36″ to 60″	Dimensions over 60″ to 130″
Up to 3	1/32	1/16	3/32	3/32

1 For widths of 4 inches or less the maximum thickness of flat sheet which can be sheared is 0.093 inch. Thicker sheet must be sawed.

2 For flat sheet in thicknesses of 0.201 inch to 0.249 inch the minimum width which can be sheared is 5 inches. Narrower widths must be sawed.

TABLE 22

Commercial Tolerances for Wire, Rod and Bar

ROLLED ROD ROUND (ALL ALLOYS)

Diameter, Inches	Tolerance, Inches		Diameter, Inches	Tolerance, Inches	
	Plus	Minus		Plus	Minus
1.501 to 3.499	0.008	0.008	5.001 to 8.000	1/16	1/32
3.500 to 5.000	1/32	1/64			

ROLLED BAR (ALL ALLOYS)

(Squares, Hexagons,[1] Rectangles)

Least Distance Across Flats, Inches	Tolerance, Inches Plus or Minus	Width (of Rectangles), Inches	Tolerance, Inches Plus or Minus
up to 0.500	0.006	up to 1.500	1/64
0.501 to 0.750	0.008	1.501 to 4.000	1/32
0.751 to 1.000	0.012	4.001 to 6.000	3/64
1.001 to 2.000	0.016	6.001 to 10.000	1/16
2.001 to 3.000	0.020		

COLD-FINISHED WIRE, ROD AND BAR (ALL ALLOYS)

(Rounds, Squares, Hexagons, Octagons)

Rectangles up to 3 inches wide (provided area is not greater than 3 square inches)

Diameter or Distance Across Flats, Inches	Tolerance, Inches Plus or Minus		
	Rounds	Squares Hexagons Octagons	Rectangles
up to 0.0359	0.0005	......	......
0.036 to 0.064	0.001	0.0015	0.0015
0.065 to 0.500	0.0015	0.002	0.002
0.501 to 1.000	0.002	0.0025	0.0025
1.001 to 1.500	0.0025	0.003	0.003
1.501 to 3.000	......	.....	0.005

COLD-FINISHED RECTANGLES[2] 2S, 3S, 52S and 53S

Thickness, Inches	Tolerance, Inches Plus or Minus	Width, Inches	Tolerance, Inches Plus or Minus
up to 0.250	0.0025	2.000 to 4.000	1/32
0.251 to 0.500	0.0035		
0.501 to 0.750	0.005		
0.751 to 1.500	0.008		

CENTERLESS GROUND WIRE AND ROD, ROUND (ALL ALLOYS)

Diameter, Inches	Tolerance, Inches Plus or Minus
0.0625 to 0.625	0.0005
0.626 to 1.500	0.001
1.501 to 2.500	0.0015

[1] Available in sizes greater than 1.5 inches; smaller sizes cold-finished.

[2] Widths greater than 3 inches and/or area greater than 3 square inches. Maximum dimensions 1.5 inches by 4 inches.

TABLE 23

Commercial Tolerances of Rough-Rolled, Round-Cornered Squares and Rectangles—All Alloys

Size		Tolerance, Inches	
Thickness, Inches	Width, Inches	Thickness, Plus or Minus	Width, Plus or Minus
2 to 2.99 by	10⅛ to 16	1/32	1/4
3 to 5.99 by	4 to 16	1/16	1/4
6 to 8.00 by	6 to 12	1/16	1/4

TABLE 24

Commercial Tolerances of Flattened Wire and Flattened and Slit Wire—All Alloys

FLATTENED WIRE (Round Edges)				FLATTENED AND SLIT WIRE (Slit Edges)			
Dimensions	Commercial Sizes, Inches		Tolerance, Inches Plus or Minus	Dimensions	Commercial Sizes, Inches		Tolerance, Inches Plus or Minus
	Minimum	Maximum			Minimum	Maximum	
Thicknesses	0.010	0.020	0.001	Thicknesses	0.010	0.020	0.001
	0.021	0.060	0.0015		0.021	0.060	0.0015
	0.061	0.187	0.002		0.061	0.080	0.002
Widths	0.030	0.875	0.007	Widths	0.125	0.625	0.0025
	0.876	2.000	0.010		0.626	1.500	0.004
					1.501	5.000	0.006

TABLE 25

Commercial Tolerances for Tubing

ROUND TUBING, DIAMETER TOLERANCE

Nominal Diameter, Inches	Tolerance, Inches (Plus or Minus)		
	Mean Diameter[1] or Pi-Tape Measurement—2S, 3S, 17S, 24S, 52S, 53S, 61S	Individual Measurement of Diameter (Out-of-Roundness)	
		2S, 3S, 52S, except Soft (O), or thin wall tubes[2]	17S, 24S, 53S, 61S
⅜ to ½ incl.	0.003	0.003	0.006
Greater than ½ to 1 incl.	0.004	0.004	0.008
Greater than 1 to 2 incl.	0.005	0.005	0.010
Greater than 2 to 3 incl.	0.006	0.006	0.012
Greater than 3 to 5 incl.	0.008	0.008	0.016
Greater than 5 to 6 incl.	0.010	0.010	0.020
Greater than 6 to 8 incl.	0.015	0.015	0.030
Greater than 8 to 10 incl.	0.020	0.020	0.040
Greater than 10 to 12 incl.	0.025	0.025	0.050

ROUND TUBING, WALL THICKNESS TOLERANCE

Nominal Wall Thickness (T), Inch	Tolerance, Inches (Plus or Minus)		
	Mean Wall Thickness[3]	Individual Measurements of Wall Thickness	
	17S, 24S, 53S, 61S	17S, 24S, 53S, 61S	2S, 3S, 52S
0.010 to 0.035	0.002	10% of T	0.002
0.036 to 0.049	0.003	10% of T	0.003
0.050 to 0.120	0.004	10% of T	0.004
0.121 to 0.203	0.005	10% of T	0.005
0.204 to 0.300	0.008	10% of T	0.008
0.301 to 0.375	0.012	10% of T	0.012
0.376 to 0.500	0.032	10% of T	0.032

1 Mean diameter is the average of any two measurements of diameter taken at right angles to each other at any point along the length of the tube.

2 Thin wall tubes, i.e. tubes having a wall thickness less than 2.5 per cent of the diameter or less than 0.020 inch, and tubes in the soft (O) temper shall be commercially round. The deviations of individual measurements from the nominal will vary with the alloy and the ratio of wall thickness to diameter.

3 Mean wall thickness is the average of the two measurements taken at opposite ends of any diameter of the tube.

TABLE 25—*Concluded*

Commercial Tolerances for Tubing

ROUND TUBING, LENGTH TOLERANCES—ALL ALLOYS[1]

Nominal Diameter, Inches	Plus Tolerance, Inches				Plus
	Lengths 2′ or Less	Lengths over 2′ to 20′	Lengths over 20′ to 30′	Lengths over 30′	Coiled Tubing
To 1/4 incl.	1/8	1/4	3/8	1/2	3%
Greater than 1/4 to 2 incl.	1/16	1/8	3/16	3/8	2%
Greater than 2 to 3 incl.	1/8	3/16	1/4	5/16	...
Greater than 3 to 10 incl.	3/16	1/4	5/16	3/8	...
Greater than 10 to 12 incl.	1/4	5/16	3/8	..	...

ROUND TUBING, STRAIGHTNESS TOLERANCE—ALL ALLOYS.
ALL TEMPERS EXCEPT SOFT[1]

Outside Diameters,[2] Inches	Tolerance
3/8 to 12	0.1 inch in 10 feet or one part in 1200 parts of length.

PIPE—STANDARD AND EXTRA HEAVY I. P. S.—2S, 3S

Size, Inches	O. D. Tolerance, Inches	I. D. Tolerance, Inches	Straightness	Length
1/8 to 1/2 incl.	+0.005,−0	+0,−0.003	Same as on commercial round tubing	Same as on commercial round tubing
Greater than 1/2 to 2 incl.	+0.008,−0	+0,−0.005		
Greater than 2 to 4 incl.	+0.010,−0	+0,−0.007		
Greater than 4 to 6 incl.	+0.012,−0	+0,−0.008		
Greater than 6 to 8 incl.	+0.014,−0	+0,−0.009		
Greater than 8 to 10 incl.	+0.016,−0	+0,−0.012		

[1] A tolerance of 1/64″ per inch of O. D., or fraction thereof, will apply on the squareness of all saw cuts.

[2] Tubing in the soft temper or in diameters less than 3/8 inch is supplied commercially straight, substantially free from kinks and short bends.

TABLE 26

Standard Sizes of Aircraft Sheet[1]
Alclad 24S or 24S Annealed or Heat Treated

Thickness, Inches	48-Inch Widths				36-Inch Widths				24-Inch Widths		
	Length, Inches				Length, Inches				Length, Inches		
	144	120	96	72	144	120	96	72	120	96	72
0.250	..	..	..	..	X*	X	..	..	X	..	X
0.187	X*	X	X	X	X	X	X	X	X	X	X
0.125	X*	X	X	X	X	X	X	X	X	X	X
0.102	X*	X	X	X	X	X	X	X	X	X	X
0.091	X*	X	X	X	X	X	X	X	X	X	X
0.081	X*	X	X	X	X	X	X	X	X	X	X
0.072	X*	X	X	X	X	X	X	X	X	X	X
0.064	X*	X	X	X	X	X	X	X	X	X	X
0.051	X*	X	X	X	X	X	X	X	X	X	X
0.045	X*	X	X	X	X	X	X	X	X	X	X
0.040	X*	X	X	X	X	X	X	X	X	X	X
0.032	X*	X	X	X	X*	X	X	X	X	X	X
0.028	...	..	..	..	X*	X	X	X	X	X	X
0.025	...	..	..	..	X*	X	X	X	X	X	X
0.020	...	..	..	..	X*	X	X	X	X	X	X
0.016	...	..	..	..	X*	X	X	X	X	X	X
0.012	...	..	..	..	..	..	..	..	X*	X	X

[1] Sizes marked X are standard sizes, normally carried in stock. Sizes marked * are those regularly rolled.

TABLE 27

Commercial Sizes of Heat-Treatable Alloy Flat Sheet

17S, Alclad 17S, in O and T Tempers
53S and 61S in O, W and T Tempers

Thickness, Inches	Basic Width Range,[1] Inches	Maximum Rolling Limits		Diameter of Circle, Inches	Stretcher Maximum
		Width, Inches	Length, Feet		
0.249–0.136	12–48	102	24	96	90″ x (2)
0.135–0.096	12–48	102	24	96	88″ x (2)
0.095–0.068	12–48	90	24	90	86″ x (2)
0.067–0.061	12–48	84	24	84	(2)
0.060–0.048	12–48	72	18	72	(2)
0.047–0.038	12–48	60	18	60	(2)
0.037–0.030	12–36	48	18	48	(2)
0.029–0.019	12–36	42	16	42	(2)
0.018–0.015	12–36	36	14	36	(2)
0.014–0.010	12–28	28	14	28	(2)

[1] Basic width range is the range of widths to which base price is applicable
[2] Greater than rolling limits.

TABLE 28

Commercial Sizes of 24S and Alclad 24S Alloy Sheet

Thickness, Inches	Basic Width Range,[1] Inches	Maximum Commercial Dimensions[2]	
		Width, Inches	Length, Feet
0.249–0.061	12–48	60	24
0.060–0.038	12–48	60	18
0.037–0.030	12–36	48	18
0.029–0.019	12–36	42	16
0.018–0.015	12–36	36	14
0.014–0.010	12–28	28	14

[1] Basic width range is the range of widths to which base price is applicable.
[2] All these sizes are within the limits of the stretcher.
Maximum diameter of circle same as maximum width of sheared sheet.

TABLE 29

Commercial Sizes of Flat Sheet 24S-RT and Alclad 24S-RT

Thickness, Inches	Basic Size Range[1]		Rolling Limits, Maximum Width, Inches	
	Width, Inches	Maximum Length, Feet	Lengths up to 12 Feet	Lengths Greater Than 12 Feet to 18 Feet
0.249–0.136	12–36	12	48	..
0.135–0.096	12–36	12	48	..
0.095–0.077	12–36	12	48	..
0.076–0.061	12–36	12	48	42
0.060–0.048	12–30	12	42	36
0.047–0.038	12–30	12	36	36
0.037–0.030	12–30	12	36	36
0.029–0.024	12–24	12	30	..
0.023–0.022	12–24	12	24	..
0.021–0.019	12–24	12	24	..

[1] Basic size range is range of sizes to which base price is applicable.

TABLE 30

Maximum Commercial Widths of Heat-Treatable Alloy Coiled Strip[1]

17S, Alclad 17S, 24S, Alclad 24S in O and T Tempers
53S and 61S in O, W and T Tempers

Thickness, Inches	Basic Width Range,[2] Inches		Maximum Rolling Limit, Inches	
	W and T	O and As Rolled	W and T	O and As Rolled
0.081–0.065	....	3–24	..	24
0.064–0.048	3–16	3–24	16	24
0.047–0.030	3–16	3–24	16	32
0.029–0.024	3–14	3–24	14	32
0.023–0.019	3–14	3–24	14	24
0.018–0.015	3–12	3–24	12	24
0.014–0.012	3–12	3–16	12	16

[1] Supplied only in coils.
[2] Basic width range is range of widths to which base price is applicable.

TABLE 31

Standard Sizes of Wire, Rod and Bar for Aircraft

COILED RIVET WIRE

Diameter, Inches	A17S	24S	Diameter, Inches	A17S	24S
0.061	X	X	0.153	X	X
0.092	X	X	0.184	X	X
0.123	X	X	0.247	X	X
0.140	....	X	0.310	X	X

WELDING WIRE

Diameter, Inches	Coiled			36-Inch Straight Lengths	
	2S-O	2S-H	5% Silicon	2S-O	5% Silicon
1/16	...	X	X	...	X
3/32	...	X	X	...	X
1/8	X	X	X	X	X
5/32	...	...	X	...	...
3/16	X	X	X	X	X
1/4	X	X	X	X	X

WIRE: STRAIGHTENED—STANDARD 12-FOOT LENGTHS

(A = 17S-T; B = 24S-T)

Dimension,[1] Inches	Shape	Dimension,[1] Inches	Shape		
	Round		Round	Hexagonal	Square
1/16	AB	3/16	AB	AB	...
3/32	AB	13/64	A	...	...
1/8	AB	7/32	AB	A	...
9/64	A	1/4	AB	AB	B
5/32	AB	17/64	A	...	...
11/64	A	9/32	AB	...	...
..	...	5/16	AB	AB	B
..	...	11/32	AB	A	...

[1] See page 56 for explanation of terms.

TABLE 31—*Continued*

Standard Sizes of Wire, Rod and Bar for Aircraft

COLD-FINISHED ROD AND BAR—STANDARD 12-FOOT LENGTHS

(A = 17S-T; B = 24S-T)

Dimension,[1] Inches	Shape			Dimension,[1] Inches	Shape		
	Round	Hexagonal	Square		Round	Hexagonal	Square
3/8	AB	AB	B	7/8	AB	AB	B
13/32	AB	. . .	. .	15/16	AB	AB	. .
7/16	AB	AB	B	31/32	A	. . .	. .
15/32	A	. . .	. .	1	AB	AB	B
1/2	AB	AB	B	1 1/32	A	. . .	. .
17/32	A	. . .	. .	1 1/16	AB	AB	. .
9/16	AB	AB	B	1 1/8	AB	AB	B
19/32	A	. . .	. .	1 5/32	A	. . .	. .
5/8	AB	AB	B	1 3/16	AB	A	. .
21/32	A	. . .	. .	1 1/4	AB	AB	B
11/16	AB	AB	. .	1 5/16	AB	AB	. .
3/4	AB	AB	B	1 3/8	AB	AB	B
25/32	A	. . .	. .	1 7/16	AB	AB	. .
13/16	AB	AB	. .	1 1/2	AB	AB	B

ROLLED ROD AND BAR—STANDARD 12-FOOT LENGTHS

(A = 17S-T; B = 24S-T)

Dimension,[1] Inches	Shape			Dimension,[1] Inches	Shape	
	Round	Hexagonal	Square		Round	Square
1 9/16	AB	A	. . .	2 3/4	AB	. . .
1 5/8	AB	AB	B	2 7/8	AB	. . .
1 11/16	AB	. . .	. . .	3	AB	. . .
1 3/4	AB	AB	B	3 1/16	A	. . .
1 13/16	AB	. . .	. . .	3 1/8	AB	. . .
1 7/8	AB	AB	B	3 1/4	AB	B[2]
1 15/16	AB	. . .	. . .	3 3/8	AB	. . .
2	AB	AB	B	3 1/2	AB[2]	. . .
2 1/16	AB	. . .	. . .	3 3/4	AB[2]	. . .
2 1/8	AB	. . .	. . .	4	AB[2]	B[2]
2 3/16	AB	. . .	. . .	4 1/4	AB[2]	. . .
2 1/4	AB	. . .	. . .	4 1/2	AB[2]	. . .
2 5/16	AB	. . .	. . .	4 3/4	AB[2]	. . .
2 3/8	AB	. . .	. . .	5	AB[2]	. . .
2 7/16	AB	. . .	. . .	5 1/4	B[2]	. . .
2 1/2	AB	. . .	. . .	5 1/2	AB[2]	. . .
2 9/16	AB	. . .	. . .	6	A[2]	. . .
2 5/8	AB	. . .	. . .	7	A[2]	. . .
2 11/16	B	. . .	. . .	8	A[2]	. . .

[1] See page 56 for explanation of terms. [2] Random straight lengths.

TABLE 31—*Concluded*

Standard Sizes of Wire, Rod and Bar for Aircraft

24S-T SQUARE-EDGE RECTANGULAR BAR—STANDARD 12-FOOT LENGTHS, COLD-FINISHED (CF) AND ROLLED (R)

Width, Inches	Thickness, Inches																			
	1/8	3/16	1/4	5/16	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3
3/8	CF	...	CF	...	(1)	...	...	...	...	...	...	...	...	...	..	..	..	..	..	..
1/2	CF	CF	CF	CF	CF	(1)	...	...	...	...	...	...	...	...	..	..	..	..	..	..
5/8	CF	CF	CF	CF	CF	CF	(1)	...	...	...	...	...	...	...	..	..	..	..	..	..
3/4	CF	CF	CF	CF	CF	CF	CF	(1)	...	...	...	...	...	...	..	..	..	..	..	..
7/8	CF	CF	CF	CF	CF	CF	CF	...	(1)	...	...	...	...	...	..	..	..	..	..	..
1	CF	CF	CF	CF	CF	CF	CF	CF	CF	(1)	...	...	...	...	..	..	..	..	..	..
1 1/4	CF	CF	CF	...	CF	CF	CF	CF	...	CF	...	(1)	...	...	..	..	..	..	..	..
1 1/2	CF	CF	CF	CF	CF	CF	CF	CF	CF	CF	...	CF	CF	(1)	..	..	..	..	..	..
1 3/4	...	CF	CF	...	CF	CF	...	...	...	CF	...	CF	...	...	(1)	..	..	..	..	..
2	CF	CF	CF	CF	CF	CF	CF	CF	CF	CF	CF	CF	CF	CF	..	(1)	..	..	..	..
2 1/4	...	...	...	...	...	...	...	CF	...	...	...	...	...	...	..	R	..	..	..	..
2 1/2	...	...	CF	CF	CF	CF	CF	CF	CF	CF	CF	CF	...	R	..	R	..	..	..	..
2 3/4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	..	R	..	..	..	..
3	...	...	CF	CF	CF	CF	CF	CF	CF	CF	R	R	R	R	R	R	..	..	..	..
3 1/2	...	...	...	...	R	...	...	R	R	R	R	R	...	...	..	R	..	..	..	..
4	...	...	R	...	R	R	...	R	R	R	...	R	R	R	R	R	R	R	R	R
4 1/2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	..	..	..	R	..	..
5	...	...	R	...	...	...	...	...	...	...	...	...	...	...	..	R	R	R	..	..
6	...	...	R	R	R	R	R	R	R	R	...	R	R	R	R	R	R	R	R	R
8	...	...	...	...	...	R	...	R	...	R	...	R	...	R	..	R	..	..	..	..
10	...	...	...	R	R	R	R	R	R	R	R	R	R	R	R	R	..	..	..	..

[1] Square is also available. See page 96.

TABLE 32

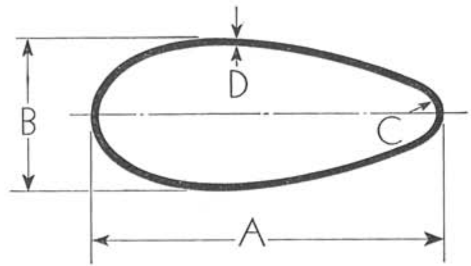
Standard Sizes of Aluminum Alloy Round Tubing for Aircraft

STANDARD 12-FOOT LENGTHS

Alloy and Temper	Wall Thickness, Inches	Outside Diameter, Inches																	
		⅛	3/16	¼	5/16	⅜	7/16	½	⅝	¾	⅞	1	1¼	1½	1¾	2	2¼	2½	3
2S-½H	0.022	..	X	X	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..
	0.028	..	..	..	..	..	..	X	X	..	..	..	..	..	..	..	..	..	..
	0.035	..	..	..	..	..	..	..	..	X	..	X	..	..	..	..	..	..	..
	0.042	..	..	..	..	..	..	..	..	..	..	..	X	X	..	..	..	..	..
	0.049	..	..	..	..	..	..	..	..	..	..	..	..	..	X	X	..	..	..
	0.058	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X	..
17S-T	0.028	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..
	0.035	..	..	X	X	X	X	X	X	X	..	X	X	..	..	..	..	..	..
	0.049	..	..	..	..	X	..	X	X	X	X	X	X	X	X	X	..	..	..
	0.065	..	..	..	..	X	..	X	X	X	X	X	X	X	X	X	X	X	X
	0.120	..	..	..	..	..	..	..	..	..	..	X	X	X	..	X	X	..	X
24S-T	0.035	..	..	X	..	..	..	X	X	X	..	X	X	..	..	..	..	..	..
	0.049	..	..	..	..	..	..	..	..	X	..	X	X	X	X	..	..	..	..
	0.058	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X	..	..	..
	0.065	..	..	..	..	..	..	..	..	..	..	..	X	X	..	X	..	..	..
52S-O	0.032	X	X	X	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..
	0.042	..	..	..	X	X	X	X	X	..	..	..	..	..	..	..	..	..	..
	0.049	..	..	..	..	X	..	X	..	X	..	X	X	X	..	..	..	..	..
	0.058	..	..	..	..	..	..	X	..	..	..	..	X	X	..	..	..	..	..
	0.065	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X	..	..	..

TABLE 33

Commercial Sizes of Streamline Aluminum Alloy Tubing



Drawing No.	A Major Axis, Inches	B Minor Axis, Inches	C Trailing Edge Inside Radius, Inches	D Wall Thickness, Inches	SECTION ELEMENTS: Area of Wall, Sq. In.	SECTION ELEMENTS: Fineness Ratio, Major to Minor	SECTION ELEMENTS: Least Moment of Inertia, Inches	SECTION ELEMENTS: Least Radius of Gyration, Inches	Estimated Weight, Pound per Foot	Equiv. Diam. of Round Tubing, Inches
T-483	0.600	0.250	0.058	0.022	0.038	2.400	(1)	(1)	0.046	7/16
608	0.688	0.187	0.031	0.035	0.051	(1)	(1)	(1)	0.061	7/16
638	0.812	0.320	0.062	0.012	0.041	(1)	(1)	(1)	0.049	5/8
655	0.875	0.324	0.058	0.020	0.039	(1)	(1)	(1)	0.047	5/8
T-532	0.875	0.312	0.011	0.020	0.038	(1)	(1)	(1)	0.046	5/8
T-533	0.875	0.312	0.054	0.040	0.076	2.804	0.0022	0.170	0.092	5/8
T-58	1.219	0.414	0.047	0.035	0.101	2.944	0.0019	0.137	0.122	7/8
T-541(2)	1.349	0.571	0.073	0.035	0.106	(3)	(3)	(3)	0.127	1

See notes on page 103.

TABLE 33—*Continued*

Commercial Sizes of Streamline Aluminum Tubing

Drawing No.	A Major Axis, Inches	B Minor Axis, Inches	C Trailing Edge Inside Radius, Inches	D Wall Thickness, Inches	SECTION ELEMENTS Area of Wall, Sq. In.	Fineness Ratio, Major to Minor	Least Moment of Inertia, Inches	Least Radius of Gyration, Inches	Estimated Weight, Pound per Foot	Equiv. Diam. of Round Tubing, Inches
T-517	1.375	0.656	0.043	0.035	0.124	2.096	0.0318	0.507	0.150	1 1/8
T-516	1.375	0.500	0.043	0.035	0.120	2.750	0.0284	0.487	0.145	1 1/16
T-366 (2)	1.685	0.714	0.101	0.035	0.141	2.360	0.0089	0.251	0.171	1 1/4
T-326 (2)	1.685	0.714	0.087	0.049	0.191	2.361	0.012	0.250	0.231	1 1/4
T-93	1.874	0.781	0.113	0.035	0.163	2.399	0.012	0.271	0.197	1 3/8
T-156	2.000	0.875	0.124	0.042	0.199	2.286	0.019	0.309	0.241	1 1/2
T-118	2.000	0.875	0.117	0.049	0.212	2.286	0.022	0.322	0.257	1 1/2
T-157	2.000	0.875	0.108	0.058	0.261	2.286	0.025	0.309	0.316	1 1/2
T-542 (2)	2.023	0.857	0.114	0.049	0.210	2.361	0.0212	0.318	0.254	1 1/2
T-170	2.063	0.876	0.059	0.049	0.231	2.355	0.023	0.316	0.280	1 9/16
T-116	2.095	0.747	0.084	0.058	0.237	2.805	0.018	0.276	0.287	1 5/16
T-106 (2)	2.360	1.000	0.141	0.049	0.294	2.360	0.034	0.340	0.356	1 3/4
T-163	2.528	1.071	0.138	0.065	0.382	2.360	0.054	0.376	0.462	1 7/8
T-102	2.625	0.314	0.015	0.032	0.168	8.360	0.0020	0.109	0.203	1 3/4
T-97	2.684	1.030	0.147	0.049	0.292	2.606	0.041	0.376	0.353	1 15/16
T-543 (2)	2.697	1.143	0.159	0.058	0.353	2.360	0.061	0.414	0.427	2
720	2.697	1.143	0.182	0.035	0.216	(1)	(1)	(1)	0.259	2
T-105	2.700	1.144	0.176	0.042	0.254	2.360	0.046	0.423	0.307	2
T-45	2.700	1.144	0.160	0.058	0.360	2.360	0.061	0.410	0.436	2
T-491	2.700	1.144	0.135	0.083	0.500	(1)	(1)	(1)	0.600	2

See notes on page 103.

TABLE 33—*Continued*

Commercial Sizes of Streamline Aluminum Tubing

Drawing No.	A Major Axis, Inches	B Minor Axis, Inches	C Trailing Edge Inside Radius, Inches	D Wall Thickness, Inches	SECTION ELEMENTS				Estimated Weight, Pound per Foot	Equiv. Diam. of Round Tubing, Inches
					Area of Wall, Sq. In.	Fineness Ratio, Major to Minor	Least Moment of Inertia, Inches	Least Radius of Gyration, Inches		
T-172	2.703	1.140	0.169	0.049	0.308	2.371	0.052	0.411	0.373	2
T-293	3.032	1.536	0.217	0.098	0.698	1.974	0.204	0.541	0.845	2 3/8
T-504 (2)	3.035	1.286	0.186	0.058	0.402	2.360	0.087	0.466	0.487	2 1/4
T-21	3.125	1.188	0.045	0.049	0.351	2.630	0.065	0.430	0.425	2 1/4
T-50	3.125	1.188	0.171	0.057	0.389	2.630	0.074	0.436	0.471	2 1/4
T-30	3.125	1.188	0.094	0.057	0.425	2.630	0.074	0.417	0.514	2 1/4
T-158	3.125	1.188	0.163	0.065	0.467	2.630	0.083	0.421	0.565	2 1/4
T-68	3.125	1.188	0.281	0.090	0.642	2.630	0.109	0.412	0.777	2 1/4
T-16	3.350	1.500	0.188	0.065	0.474	2.233	0.149	0.560	0.574	2 5/8
T-365 (2)	3.372	1.429	0.206	0.065	0.479	2.360	0.134	0.529	0.580	2 1/2
T-215	3.375	1.430	0.215	0.057	0.436	2.360	0.120	0.525	0.528	2 1/2
T-44	3.375	1.430	0.207	0.065	0.477	2.360	0.135	0.531	0.577	2 1/2
T-180	3.450	1.380	0.076	0.049	0.384	2.500	0.098	0.505	0.465	2 1/2
T-130	3.492	1.245	0.153	0.083	0.646	2.805	0.126	0.442	0.782	2 1/2
T-544 (2)	3.708	1.571	0.233	0.065	0.548	(1)	(1)	(1)	0.658	2 3/4
T-43	3.710	1.572	0.233	0.065	0.533	2.360	0.181	0.582	0.645	2 3/4
T-159	3.110	1.572	0.215	0.083	0.729	2.360	0.224	0.554	0.882	2 3/4
T-294	3.977	1.694	0.187	0.138	1.244	2.348	0.431	0.589	1.505	2 15/16
T-47	4.018	1.760	0.320	0.065	0.580	2.283	0.249	0.655	0.702	3
T-545 (2)	4.045	1.714	0.243	0.083	0.761	2.360	0.294	0.618	0.930	3

See notes on page 103.

TABLE 33—*Continued*
Commercial Sizes of Streamline Aluminum Tubing

Drawing No.	A Major Axis, Inches	B Minor Axis, Inches	C Trailing Edge Inside Radius, Inches	D Wall Thickness, Inches	SECTION ELEMENTS Area of Wall, Sq. In.	Fineness Ratio, Major to Minor	Least Moment of Inertia, Inches	Least Radius of Gyration, Inches	Estimated Weight, Pound per Foot	Equiv. Diam. of Round Tubing, Inches
T-162	4.050	1.716	0.284	0.042	0.407	2.360	0.158	0.623	0.492	3
T-161	4.050	1.716	0.261	0.065	0.605	2.360	0.237	0.626	0.732	3
T-42	4.050	1.716	0.243	0.083	0.731	2.360	0.295	0.635	0.926	3
T-119	4.062	1.710	0.260	0.065	0.610	2.375	0.236	0.622	0.738	3
T-546 (2)	4.383	1.857	0.270	0.083	0.826	(3)	(3)	(3)	0.991	3¼
T-41	4.389	1.860	0.270	0.083	0.823	2.360	0.379	0.678	0.996	3¼
T-73	4.389	1.860	0.258	0.095	0.934	2.360	0.427	0.676	1.130	3¼
T-534	4.389	1.860	0.223	0.120	1.240	2.360	0.521	0.648	1.501	3¼
T-724	4.720	2.000	0.315	0.065	0.701	(1)	(1)	(1)	0.841	3½
T-468	4.720	2.000	0.279	0.083	0.897	2.360	0.475	0.728	1.073	3½
T-547 (2)	4.720	2.000	0.285	0.095	1.016	(1)	(1)	(1)	1.219	3½
T-46	4.720	2.000	0.285	0.095	1.023	2.360	0.535	0.723	1.238	3½
T-745	4.720	2.000	0.130	0.250	2.553	(1)	(1)	(1)	3.064	3½
T-380	4.885	1.743	0.239	0.095	1.042	2.803	0.407	0.625	1.261	3½
T-469	5.057	2.143	0.324	0.083	0.974	2.360	0.588	0.777	1.166	3¾
T-435 (2)	5.057	2.143	0.312	0.095	1.076	2.360	0.664	0.785	1.287	3¾
T-164	5.057	2.143	0.298	0.109	1.255	2.360	0.749	0.773	1.519	3¾
T-746	5.057	2.143	0.157	0.250	2.749	(1)	(1)	(1)	3.299	3¾
T-566	5.240	3.180	0.311	0.095	1.304	1.648	1.646	1.123	1.578	4⅜
T-548 (2)	5.394	2.285	0.314	0.120	1.463	(1)	(1)	(1)	1.756	4

See notes on page 103.

TABLE 33—*Concluded*

Commercial Sizes of Streamline Aluminum Tubing

Drawing No.	A Major Axis, Inches	B Minor Axis, Inches	C Trailing Edge Inside Radius, Inches	D Wall Thickness, Inches	SECTION ELEMENTS				Estimated Weight, Pound per Foot	Equiv. Diam. of Round Tubing, Inches
					Area of Wall, Sq. In.	Fineness Ratio, Major to Minor	Least Moment of Inertia, Inches	Least Radius of Gyration, Inches		
T-59	5.428	2.300	0.328	0.109	1.332	2.360	0.934	0.837	1.612	4 1/8
T-60	5.428	2.300	0.444	0.148	1.784	2.360	1.215	0.825	2.159	4 1/8
T-725	5.732	2.428	0.378	0.083	1.086	(1)	(1)	(1)	1.303	4 1/4
T-549 (2)	5.732	2.428	0.327	0.134	1.741	(1)	(1)	(1)	2.089	4 1/4
T-550 (2)	6.069	2.571	0.332	0.156	2.129	(3)	(3)	(3)	2.555	4 1/2
T-378	6.280	2.241	0.315	0.110	1.558	2.802	1.014	0.807	1.885	4 1/2
T-689	6.406	2.714	0.444	0.072	1.058	(1)	(1)	(1)	1.270	4 3/4
T-604	6.406	2.714	0.382	0.134	2.033	2.360	1.877	0.961	2.460	4 3/4
T-551 (2)	6.406	2.714	0.328	0.188	2.694	(1)	(1)	(1)	3.233	4 3/4
T-61	6.474	2.760	0.402	0.134	1.984	2.346	1.967	0.996	2.401	4 7/8
T-434	7.080	3.000	0.453	0.109	1.790	2.360	2.132	1.091	2.143	5 1/4
T-492	7.080	3.000	0.412	0.150	2.425	2.360	2.834	1.081	2.934	5 1/4
T-433	7.750	3.290	0.491	0.134	2.454	2.356	3.412	1.179	2.937	5 3/4
T-437	8.183	3.489	0.553	0.125	2.410	2.345	3.829	1.261	2.884	6 1/8
T-408	8.183	3.489	0.530	0.148	2.807	2.345	4.458	1.260	3.359	6 1/8
T-425	9.440	4.000	0.651	0.109	2.394	2.360	5.170	1.470	2.865	7 1/8
T-407	10.909	4.652	0.747	0.156	3.887	2.345	11.391	1.712	4.652	8
T-424	11.330	4.800	0.792	0.120	3.140	2.360	9.892	1.775	3.757	8 1/2

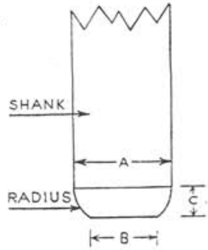
[1] Tools available, but section elements not yet available.
[2] These sections specified in Navy Specifications 44-T-22 and 44-T-31 and Army Specification 57-187-2.
[3] Tools not available.

TABLE 34

Standard Sizes of Rivets with Chamfered Shank

A = Shank Diameter
B = Diameter of End
C = Length of Radius

Formulas
$C = 0.25 \times A$
$\text{Radius} = 0.3125 \times A$



Diameter of Rivet, Inches	B, Inches	Diameter of Rivet, Inches	B, Inches
1/16	0.047	5/32	0.118
3/32	0.071	3/16	0.137
1/8	0.092	1/4	0.185

Length, Inches	Diameter (Inches) and Head Type*											
	1/16		3/32		1/8		5/32		3/16		1/4	
	A	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*
1/16	X	X										
1/8	X	X	X	X	X	X						
3/16	X	X	X	X	X	X	X	X				
1/4	X	X	X	X	X	X	X	X	X	X	X	X
5/16	X	X	X	X	X	X	X	X	X	X	X	X
3/8	X	X	X	X	X	X	X	X	X	X	X	X
7/16	X		X	X	X	X	X	X	X	X	X	X
1/2	X		X	X	X	X	X	X	X	X	X	X
9/16			X	X	X	X	X	X	X	X	X	X
5/8			X		X	X	X	X	X	X	X	X
11/16			X		X	X	X	X	X	X	X	X
3/4			X		X	X	X	X	X	X	X	X
13/16					X		X	X	X	X	X	X
7/8					X		X	X	X	X	X	X
15/16					X		X	X	X	X	X	X
1					X		X		X	X	X	X
1 1/8							X		X	X	X	X
1 1/4							X		X		X	X
1 3/8									X		X	X
1 1/2									X		X	X
1 5/8											X	
1 3/4											X	
1 7/8											X	
2											X	

* *A* covers standard round, button, brazier or mushroom heads.
B covers standard flat, flat countersunk or oval countersunk heads.