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LAUTAL AS A MATERIAL FOR AIRPLANE CONSTRUCTION

By Paul Brenner

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Chemical Composition.- Lautal is a refinable aluminum alloy which, unlike duralumin, contains no magnesium. According to the statements of the Lauta Works, lautal contains, aside from impurities: aluminum, 94%; copper, 4%; silicon, 2%. These figures were essentially confirmed by three quantitative analyses made in Spain with different samples of sheet lautal.

Specific Weight.- Lautal has about the same aluminum and copper content as duralumin. The other constituents of duralumin make up about the same relative weight as the silicon in lautal. The specific weights of duralumin and lautal may therefore be assumed to be practically equal.

Production.- Lautal is made at the Lauta plant (at Lausitz) of Die Vereinigten Aluminium-Werke A.-G. in only one alloy. The producers have not followed, therefore, the precedent of the Düren Metal Works, which make several duralumin alloys to suit the requirements of customers.

Lautal is produced with the aid of an intermediate alloy,

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*This is a translation of portions of a treatise ("Lautal als Baustoff für Flugzeuge") in the 1928 Yearbook of the Deutsche Versuchsanstalt für Luftfahrt, pp. 127-128 and 156-163.

known under the name of "silumin" and likewise made by the United Aluminum Company for the Metallbank und Metallurgischen Gesellschaft of Frankfort-on-the-Main. "Silumin" contains about 13% of silicon and is therefore well adapted for introducing silicon into lautal. Though copper was formerly likewise introduced into lautal through an intermediate alloy, it is now added direct.

The introduction of "silumin" considerably simplifies the production of lautal. Since lautal, like duralumin, contains about 94% aluminum, its production is chiefly dependent on the production of the latter. The German aluminum industry depends principally on bauxite imported from other countries. Europe's largest bauxite deposits are in southern France on the west slope of the Alps. This bauxite contains about 70% alumina. Recently, moreover, the Transylvanian, Dalmatian, and Istrian deposits have been gaining in importance. These deposits have an alumina content of about 58%.* The Lauta Works, which is one of the principal producers of aluminum in Germany, gets its bauxite from its own mines in Hungary.

<u>Refining</u>.- The process of refining lautal, like that of duralumin, and other refinable alloys of aluminum, begins with a kneading process (rolling, hammering or pressing). After this treatment, the metal is heated to about 500°C (932°F.)

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*R. Devar, "Die Aluminium-Industrie," published by Vieweg and Son, Braunschweig, 1925.

and then quenched in water.

A fundamental difference in refining lautal, as compared with duralumin and other aluminum alloys, consists of the process of aging after quenching. While duralumin is left to itself after quenching and is considerably stronger after aging a few days at the room temperature than immediately after quenching, lautal, under the same conditions, shows no noticeable change in its physical properties. The hardness and strength of lautal can be increased only by subsequent thermal treatment (artificial aging). For this purpose, lautal (after quenching) is reheated and kept at a temperature of 120-140°C (248-284°F.) for 16 to 24 hours.

The refining processes of aluminum alloys have not yet been entirely explained. Different investigators* have adopted hypotheses concerning them which are contradictory to some extent and whose validity has not yet been conclusively demonstrated. The solution of the refining problem has made considerable progress, however, during the past few years, which has led to the adoption of a working hypothesis. This hypothesis furnishes valuable criteria for the discovery of new useful aluminum alloys.**

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*Merica, Waltenberg and Scott, "Heat Treatment of Duralumin," Scientific Papers, Bureau of Standards, No. 27.

Merica, Waltenberg and Freeman, Bull. Am. Inst. Min. Eng. 1919, No. 151, p.1031.

W. Fraenkel, "Die Veredelungsvorgänge in vergutbaren Aluminium-Legierungen," Z.f.Met. 1926, p.313.

**K. L. Meissner, "Die Veredelungsvorgänge in vergübaren Aluminium-Legierungen," Zeitschrift für Flugtechnik und Motorluftschiffahrt, 1926, p.112.

Forms.- Lautal can be made into sheets, bands, rods, wire, forgings and stamped parts. Die Vereinigten Aluminium-Werke A.-G. delivers these forms in the refined state. The manufacture of lautal tubing has also been recently undertaken.

Patent Protection.- Die Vereinigten Aluminium-Werke A.-G. applied for a patent for lautal August 16, 1923. The patent bears the number V18565/40b2, and was published October 16, 1924. The two claims in the patent application are:

1. An aluminum-copper-silicon alloy containing 4% copper and 2% silicon with the commercially usual impurities of the constituents and with a minimum strength of 40 kg/mm² (56,894 lb./sq.in.) at 20% elongation.

2. An aluminum alloy, as per claim 1, distinguished by the fact that, after mechanical treatment (e.g., rolling, pulling, forging, pressing, etc.), it is subjected to a temperature of about 500°C (932°F.), quenched or slowly cooled and then kept at a temperature of about 120°C for 24 hours.

The lautal patent has not yet been issued in Germany, since it conflicts with both domestic and foreign patents. It has already been issued, however, in France and England.

Detachable Joints

Steel screw or key bolts are chiefly used for detachable joints in airplane construction. While screw bolts are suitable for withstanding tensile, bending, and shearing stresses, key bolts are suitable only for the transmission of shearing stresses. Since, however, in inaccurate construction or in the event of deformations during use, forces may easily develop in the axis of the bolt, it is advisable to avoid the use of key bolts as much as possible in airplanes. Screw bolts with secured nuts are much more reliable.

On the basis of the considerations presented in Section D, according to which, in the simultaneous use of two metals of different chemical composition, the resistance of the base metal is unfavorably affected, we must try to avoid, in so far as possible, all steel parts in light-metal construction. The endeavor to save weight would likewise require the substitution of light-metal bolts for steel bolts whenever feasible.

As will be shown farther on, it is doubtless possible in many cases to make connections just as well with light-metal bolts as with steel bolts. There are many cases, however, where the use of light-metal bolts would be disadvantageous, especially when very great stresses are to be transmitted by one or only a few bolts, i.e., when the bolts would require relatively large cross sections, as, for example, in attaching the wings, landing gear or floats, brace wires or struts. Since duralumin and lautal are only about half as strong as steel, bolts made from them would need to be about twice as large. This would necessitate the enlargement of the accessory parts or fittings, which would be especially undesirable when these parts lie in the air flow or when only a limited space is available for them. For the sake of reducing the drag and saving space, the constructor endeavors to give such connections the most compact form, which is best done with high-tensile steel.

It is otherwise where only very small bolts are required, though the saving in weight from the use of light metals is here considerably less. As regards production, assembling and inspection, it is advantageous for such small bolts and accessory parts to have larger dimensions, which they naturally must have when made of light metal.

Regarding the use of light-metal bolts there are, nevertheless, a few fundamental considerations, especially when the bolts are subjected to bending stresses. Even bolts designed for the reception of tensile stresses may be subjected to bending stresses through unfavorable circumstances, as, for example, an oblique position of the head or nut. Though the smooth shaft of the bolt can be easily dimensioned so as to withstand the resulting bending stresses, the threaded portion may be unfavorably affected. In this respect duralumin and lautal are much inferior to high-tensile steel.* These disadvantages of the light metals are partially offset, however, by the fact that, with light-metal bolts, larger core cross sections are available and the thread does not need to be made so sharp as in steel bolts.

Attention should also be called to the fact, already referred to by Bach ("Maschinenelemente," Vol. I, p. 155), that the eccentric loading of screw bolts, under otherwise like conditions, is disadvantageous in proportion to the shortness of the bolt as compared with its diameter and to the ductility of the material. On the above basis, the conditions would be unfavorable for duralumin and lautal in the former respect and favorable in the latter respect.

Screw connections which are subjected to impact or alternating stresses, such as attachment bolts for floats or landing gears, are often not so desirable in light metal, because the bolts and eyes give way sooner than steel ones. This is probably due chiefly to the greater softness and deformability of the light metals. It is possible, however, to employ methods of construction which will allow for these properties of the light metals and enable their use in many cases.

Moreover, it is not expedient to use light metal for bolts and nuts which must be loosened often. It is a fundamental principle in the construction of machinery that parts sliding on one

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*Chrome-nickel steels exhibit a specific impact resistance of 15 mkg/cm², as against 1.5 mkg/cm² for lautal and duralumin. (See "Berichte 3" on p.132 of D.V.L. 1928 Yearbook.)

another should not be made of the same metal. This applies especially to soft metals and above all to aluminum and aluminum alloys which have no good sliding properties. It is preferable to use different metals for the bolts and nuts, in order to prevent galling of the bolt thread or seizing of the nut. It might be advantageous to make one of these two parts of steel, since there would then be a great difference in the hardness, which would improve the sliding properties. In order to save weight, the larger of these parts (generally the bolt) would be made of light metal.

The wing attachments on the Junkers airplanes (Fig. 1) serve as an example of the use of light metals in screw attachments.* The junction pieces b_1 and b_2 are riveted to the tubes a_1 and a_2, which are to be joined, and their suitably shaped ends are held together by the threaded coupling sleeve c. Only this part is steel, all the others being duralumin.

The use of duralumin, instead of steel, for the junction pieces, effects a considerable saving in weight. The spherical shape renders the joint adjustable and avoids the development of bending stresses. This is the best way to avoid eccentric stresses in the threaded light-metal parts. The use of steel for the coupling sleeve is justified by the fact that it must often be loosened and must therefore have good sliding properties. It has been found in practice that duralumim slips well on hardened steel.

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*Hugo Junkers, "Metal Aeroplane Construction," Journal of the Royal Aeronautical Society, Vol. 27 (1923), p. 433, Figure 1.

The field for the use of light metals in screw connections on airplanes has not been investigated very systematically. It was not possible, within the scope of this work, to make corresponding tests with duralumin and lautal connections.

Nondetachable Joints

Riveting.- In airplane construction, light-metal nondetachable joints are made almost exclusively by riveting. Thus far duralumin sheets, sections and tubes have been riveted up to a maximum wall thickness of about 4 mm (0.157 in.). The largest rivets have a diameter of 8 mm (0.315 in.).

The fact that until recently nearly all the riveting in airplane construction was done by hand is ascribable to the poor accessibility of many of the rivets. Recently, however, several airplane factories have introduced machine riveting on a large scale. When we consider that several hundred thousand rivets must be used in the construction of a large airplane, we can see what a saving in wages can be made by machine riveting.

A preliminary condition for the extensive use of machine riveting is the giving of special attention, in the designing of airplanes, to making the rivets as accessible as possible. Structural parts, like spars, ribs, etc., can often be readily designed so that much of the riveting can be done on a stationary riveting machine. In assembling these parts into larger structural units, like fuselages, wings, fins and rudders, with suitable arrangements of the junctions, the riveting can be done largely with light portable riveting hammers operated hydraulically or by compressed air. For hand riveting there then remain only the unavoidable, difficultly accessible riveting places, principally connected with the attachment of the metal covering.

The riveting of tubes (Fig. 2) is often unsatisfactory. The rivets must be headed inside the tube, which is a very difficult process, even with the use of ingenious devices, especially when the tube is very long.*

A simple way to fasten the covering to the framework is shown in Figure 3 (Dornier). The separate sheet-metal strips a are crimped along their longitudinal edges. The attaching strips c are inserted between these edges. The edges are covered by a U section b and the whole riveted together as shown in the figure.

Welding.- Another method of making nondetachable joints is by welding, which has long been used for iron and steel. Its use for aluminum and aluminum alloys is now becoming quite common. The Düren Metal Works do not, however, recommend the welding of duralumin, because the strength and elasticity of the joint is thereby impaired. According to Beck** it is not possible to change the crystalline nature of the weld by subse-

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*Hugo Junkers, "Metal Aeroplane Construction," Journal of the Royal Aeronautical Society, Vol. 27 (1923), p.438, Figure 36.

**R. Beck, "Duralumin, seine Eigenschaften und Verwendungsgebiete." Z.f.Met., Vol. 16 (1924), pp. 122-127.

quent hammering nor to improve the strength characteristics impaired by the welding process.

Since, however, welding has attained great importance in iron and steel construction, and since its use in light-metal airplane construction, despite the above-mentioned disadvantages, may be desirable in certain cases, a few informatory experiments were tried with lautal, which is likewise weldable.

From the standpoint of the airplane constructor, the advantages of welded joints reside principally in the weight saving as compared with riveted ones, because welding eliminates the overlaps, which have to be quite large for high strength requirements. A weld can generally be made more quickly and cheaply than a riveted joint, but is not so reliable as the latter, because its excellence depends too much on the welder.

Riveting Tests.- Many kinds of riveted joints are used in light-metal construction. Metal sheets are sometimes joined by one row of rivets, but usually by two or more rows, by means of overlaps or fishplates. In latticework the lattices are joined to the flanges, the same as in bridge construction, by riveted gussets. The metal covering sheets are riveted to the sections, box girders or tubes of the wing, fuselage or tail framework in greatly differing ways. In many types of construction we find tubular joints made by riveting, in which the tubes are telescoped or are fitted together with suitable intervening pieces.

For simplicity, the experiments were limited to the single-row overlap riveting. This method, however, permits only an imperfect utilization of the strength of the sheet in the rivet seam and would therefore be hardly suitable for joining highly stressed members. However, since we are not investigating riveted joints in general, but only testing the material used for riveting, this limitation of the experiments does not matter.

We will use the following symbols:

P (kg),	loading of riveted joint,
B (mm),	width of strip,
s " ,	thickness of strip,
d " ,	diameter of rivet,
t " ,	distance between rivets,
a " ,	overlap,
n,	number of rivets.

Figure 4 shows a single-row riveted lap joint. When subjected to the force P, the following phenomena occur:

1. The rivet is subjected to a shearing stress in the contact plane of the two sheets;

2. Part II of the sheet is subjected to a compressive stress by pressure of rivet shaft on face of hole;

3. Part III of the sheet, which lies between the rivets, is subjected to a tensile stress.

The magnitudes of the stresses are:

Shearing: $$\sigma_s = \frac{P}{n \frac{\pi d^2}{4}} \text{ kg/mm}^2$$

Compression: $$\sigma_D = \frac{P}{n\ d\ s} \text{ kg/mm}^2$$

Tension: $$\sigma_z = \frac{P}{s\ (B - n\ d)} \text{ kg/mm}^2,$$

A portion of the stress is absorbed by the sliding resistance. This portion is probably not so great, however, for joints with light-metal rivets, which are used cold, as for iron rivets, which are applied hot.

In iron-riveted joints where the rivets are applied hot (e.g., steam-boiler riveting), such a high sliding resistance is produced by the shrinking of the rivets in cooling, that it fully suffices to transmit the stresses to be expected in use. For further details, see C. Bach, Maschinenelemente, Vol. I, p.200 ff.

In order first to obtain some criterion for the shearing strength of duralumin and lautal rivets, test specimens were prepared as shown in Figure 5. The test specimen represents a single row riveted joint with two shear planes. Two test specimens were made of duralumin and two of lautal, two of the four rivets being iron (Fig. 5). The composition and condition of the duralumin and lautal rivets were not known, as they were delivered ready for use by the Düren and Lauta Works, respectively.

The test results are given in Table I.

TABLE I.

Shearing tests with duralumin and lautal rivets

Rivet material	Specimen No.	Thickness of sheet and of fishplates mm	d mm	Area of rivet section mm²	Load kg	Shearing strength k_s kg/mm²
Duralumin	1 2	2	2.45 2.45	19.0	510 515	26.8 27.2
					Mean	27.0
Lautal	3 4	2	2.60 2.60	21.2	570 570	26.9 26.9
					Mean	26.9

The mean shearing strength of 27 kg/mm² (38,403 lb./sq.in.) for duralumin rivets agrees with Beck's statement that rivets with a shearing strength of 26-28 kg/mm² are made from a special Duren alloy. The tested lautal rivets exhibit about the same shearing strength as the duralumin rivets.

Lautal strips and wires of various thicknesses were available for making joints with three to five rivets. The rivet spacing t was adopted in accord with the results of the customary calculation method for iron rivets, according to which

$$\frac{\pi\ d^2}{4} K_s = 2 \times 0.5\ b\ s\ K_z \quad \text{(Fig. 6)}$$

From this we get

$$b = \frac{\pi\ d^2\ K_s}{4\ s\ K_z}.$$

Since

$$\frac{K_s}{K_z} = \frac{27}{38} = \sim 0.7,$$

therefore

$$b = 0.7 \frac{0.25 \pi d^2}{s} = 0.7 \frac{\text{cross section of rivet}}{\text{thickness of strips}}$$

and the rivet spacing $t = b + d$. The overlap was 2.5 to 3d. The test specimens had the form shown in Figure 7. The dimensions of the rivets are given in Table II. The lautal strips, of 0.5, 1, and 1.5 mm (0.02, 0.04, and 0.06 in.) thickness, were in the ordinary refined state. The rivets were made from lautal wire of 2 to 4 mm (0.08 to 0.16 in.) diameter.

The experiments were tried first with hard rivet wire of about 40 kg/mm² (56,894 lb./sq.in.) breaking strength and 15% elongation. The values obtained for the shearing, compressive and tensile strengths were quite high (Table II), but it was found, in doing the riveting, that the wire was too hard, so that slight cracks appeared in the edges of the rivet heads, especially of the larger rivets. In testing specimen No. 6, the rivet heads crumbled prematurely, indicating that the metal was too brittle. The subsequent test specimens were made from softer wire of about 36 kg/mm² (51,200 lb./sq.in.) breaking strength and 23% elongation. In riveting with this wire no difficulties were encountered, but the strengths were considerably below those obtained with the hard wire (Table II).

On the basis of these experiments, it is deemed advisable to use moderately hard lautal wire of about 38 kg/mm² (54,050 lb./sq.in.) tensile strength, which can be readily worked and makes strong rivets.

Some characteristic breaks are shown in Figures 8-10. Specimen 1 (Fig. 8) tore through the section weakened by the rivet holes, the rivets being uninjured. In specimen 5 two rivet heads broke off, and a corner of the metal strip tore off. The rivets were too hard. Specimen 6 (Fig. 9) tore through the section weakened by the rivet holes, leaving the rivets uninjured. In specimen 7 the section weakened by the rivet holes tore off in the middle, while pieces were torn out of the sheet by the outer rivets, none of the rivets being injured. In specimen 10 (Fig. 10), two rivets were sheared off, while the head of the other rivet crumbled. In specimen 11 all three rivets were sheared neatly off.

The calculated strengths in Table II enable a comparison with the results obtained by Rettew and Thumin in 26 tensile tests with various single-row riveted duralumin lap joints. Refined duralumin gave the following results:

Shearing strength	K_s = 30 kg/mm²	(42,670 lb./sq.in.)
Compressive "	K_D = 74 "	(105,254 ")
Tensile "	K_z = 38 "	(54,050 ")

The lautal riveting tests gave the maximum values.

	Hard rivets		Soft rivets	
	kg/mm²	lb./sq.in.	kg/mm²	lb./sq.in.
Shearing strength K_s	32.0	45,515	25.9	36,839
Compressive " K_D	73.0	103,830	74.6	106,107
Tensile " K_z	33.6	47,790	34.6	49,213

Hence the values $K_s = 28$, $K_D = 70$, and $K_z = 35$ kg/mm², (49,780 lb./sq.in.) proposed by Rettew and Thumin on the basis of their experimental results for the calculation of duralumin rivets, would also do for lautal with the use of ordinary refined rivets and sheet metal. The use of harder lautal for the rivets cannot be recommended, because of the difficulty in working it and the unreliability of the rivets. With softer rivets, as used in some of the tests, we do not attain the values proposed by Rettew and Thumin, especially as regards the shearing strength.

With lautal it is also possible to use soft rivets quenched at 500°C (932°F) and not tempered, provided the finished joint can be subjected to thermal treatment (See "Berichte 15," D.V.L. 1928 Yearbook, p.144). By tempering at higher temperatures and for longer periods, we may expect to obtain similar strengths to those obtained with rivets made from hard wire. We will have more to say on this point later. Here we will only state that, as deduced from our experiments, lautal is as suitable as duralumin for riveting, and that riveted lautal joints need not compare unfavorably with duralumin joints.

TABLE II. Tests of Joints Made with Lautal Rivets

Specimen No.	Dimensions in mm*					No. of units n	Cross section in mm				Breaking load P in kg
	s	B	d	t	a		$F = B\ s$	$F_s = 0.25\pi d^2 n$	$F_D = n\ d\ s$	$F_z = F - F_D$	
						a) Hard rivets					
1	1.05	36.3	3.8	12	12	3	38.1	34.0	12.0	26.1	877
2	1.53	36.0	3.8	12	12	3	55.1	34.0	17.4	37.7	945
3	1.49	35.5	3.8	12	12	3	52.9	34.0	17.0	35.9	1088
4	1.50	36.0	4.0	12	12	3	54.0	37.7	18.0	36.0	1090
5	1.50	36.0	4.0	12	12	3	54.0	37.7	18.0	36.0	1165
						b) Soft rivets					
6	0.51	31.5	2.0	6	8	5	16.1	15.7	5.1	11.0	380
7	0.50	31.5	2.0	6	8	5	15.8	15.7	5.0	10.8	360
8	1.01	37.2	3.0	9	10	4	37.6	28.2	12.1	25.5	680
9	1.06	37.3	3.0	9	10	4	39.5	28.2	12.7	26.8	730
10	1.47	36.0	4.2	12	12	3	52.9	41.6	18.5	34.4	995
11	1.46	36.1	4.2	12	12	3	52.7	41.6	17.8	34.9	990

*See Figure 4.

TABLE II. Tests of Joints Made with Lautal Rivets (Cont.)
(The underlined numbers indicate breaking stresses)

Specimen No.	Stresses in kg/mm²				Remarks
	$\sigma = P/F$	$\sigma_s = P/F_s$	$\sigma_D = P/F_D$	$\sigma_z = P/F_z$	
				a) Hard rivets	
1	23.0	25.8	$\underline{73.0}$	$\underline{33.6}$	Torn through section F_z; rivet holes elongated; rivets uninjured (Fig. 8).
2	17.2	$\underline{27.8}$	54.3	25.1	Sheet metal uninjured; rivet heads crumbled.
3	20.6	$\underline{32.0}$	$\underline{64.0}$	30.3	Sheet metal uninjured; rivets sheared off; rivet holes elongated.
4	20.2	$\underline{28.9}$	60.6	$\underline{30.3}$	Rivets sheared off; corners of strip torn.
5	21.6	$\underline{30.9}$	64.8	$\underline{32.4}$	Two rivets crumbled; strip partially torn (Fig. 8).
				b) Soft rivets	
6	23.6	24.2	$\underline{74.6}$	$\underline{34.6}$	Torn through section F_z; holes elongated (Fig. 9).
7	22.8	22.9	$\underline{72.0}$	$\underline{33.7}$	Strip torn; rivets uninjured (Fig. 9).
8	18.1	$\underline{24.1}$	56.2	26.7	Two rivets sheared off (stressed obliquely).
9	18.5	$\underline{25.9}$	57.4	27.2	Four rivets sheared off.
10	18.8	$\underline{23.9}$	53.8	28.9	Rivets sheared off; strip unharmed.
11	18.8	$\underline{23.8}$	55.6	28.4	Rivets sheared off; strip unharmed (Fig. 10).

Welding Tests.- In a way similar to that employed in welding and other weldable metals, the parts to be joined are heated at the welding place by a welding burner and fused with an aluminum wire which is likewise heated to the melting temperature. Since aluminum in contact with the air becomes coated with a film of aluminum oxide, it is necessary to use a suitable flux for dissolving the aluminum oxide as it forms.

In the welding of cast parts we have a similar nature of the weld and adjacent material. Both exhibit the same cast-metal texture, since they are both cooled from the melting temperature to that of the room under the same external conditions. No noticeable difference between the strength characteristics of the weld and the rest of the material is therefore distinguishable. Quite different is the behavior of cold-compressed material such as cold-rolled sheet metal, in which a recrystallization is produced by the heating of the weld. Hence such sheets are not so strong at the weld.

In the welding of aluminum alloys which owe their good strength characteristics to a particular thermal treatment with previous mechanical treatment, a considerable impairment of the strength of the weld has to be taken into account. The weld itself has a cast-metal texture, because the material at that point is brought to the melting temperature. The material adjacent to the weld acquires temperatures up to a glow heat of about 600°C (1112°F). This region includes places in a faintly glowing condition at 400°C (752°F) with a strength of about 22 kg/mm² (31,292 lb./sq.in.).

The welded piece will break either in the weld, which has a strength of about 21 kg/mm² (29,870 lb./sq.in.), or in the annealed portion at some distance from the weld. In the most favorable case such a welded joint has about 60% of the strength of ordinary refined lautal (See "Bericht 10," D.V.L. 1928 Yearbook, p.139).

The experiments described below have to do with the problem as to how fas it is possible through subsequent mechanical and thermal treatment, to convert the material at the weld into the refined condition and thus impart to the welded joint the strength characteristics of refined lautal.

The experiments were performed as follows. First, several specimens of sheet lautal 1 and 1.5 mm (0.04 and 0.06 in.) thick were butt-welded, the weld being made with an ordinary welding burner with the aid of a lautal wire to furnish the welding material. The surfaces to be welded were carefully cleaned in advance. Since the surface of the lautal, in the refining process in the salt bath, becomes coated with a thin layer of difficultly soluble substance, care must be taken that this layer be completely removed. This is best done mechanically by scraping with a knife, because the flux cannot dissolve it quickly. It is necessary to use a flux, however, as oxides are formed continuously during the welding.* The flux used was "Autogal," made by the I. G. Farbenindustrie, of Griesheim. With attention to these points, the welding of lautal presented no difficulty.

Various mechanical and thermal treatments were undertaken with the specimens thus welded. The mechanical treatment consisted in hammering in the vicinity of the weld. All the specimens, except Nos. 1-3, which received no after-treatment, were uniformly hammered, first at a temperature of 350°C (662°F) and

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*V. Fuss, "Schweissen von Aluminium und Aluminium-Legierungen."

then again cold. By this treatment of the welds, the conditions were established for a subsequent refining process. This was followed by a refining treatment, which consisted of quenching at 480-500°C (896-932°F) and a 24-hour tempering at 120°C (248°F). Specimens 10-12 were hammered cold somewhat more strongly than the other specimens. After the treatment was finished, flat pieces were cut out in such a way that the weld came in the middle. The shape and dimensions are shown in Figure 11.

The specimens were tested for tensile strength and elongation in a five-ton Mohr and Federhaff testing machine.* These values and the locations of the ruptures are given in Table III. The tensile stress was applied, on the one hand, to the cross section of the sheet-metal strip and, on the other hand, to the elevated weld. The former stresses are of greater interest to the engineer, because he is accustomed to calculate structures with these values. By a corresponding elevation of the weld, it can almost always be planned so that the break will occur in the sheet metal instead of in the weld. The stresses applied to the raised cross sections are only intended to show how far this was successfully accomplished. The underlined numbers indicate the breaking stresses. Table III establishes the following facts.

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*No perfect determination of the elongation of the welded specimens at rupture is possible, especially when the cross section of the weld is greater than that of the rest of the specimen. The elongations here determined are expected to show simply how the elongation of welded joints can be affected by the different treatments, when test specimens of about the same dimensions are used.

1. If refined lautal sheets are welded and receive no further treatment after the welding, the welds have a strength of 23-25 kg/mm² (32,714-35,559 lb./sq.in.), or only about 60-65% of ordinary refined lautal, and the elongation has greatly decreased.

2. Through mechanical compression of the weld (hammering in the warm and cold condition) and tempering (quenching at about 500°C and 24 hours tempering at 120°C) of the welded piece, the strength of the weld can be increased to 28-33 kg/mm². The elongation is also somewhat increased.

3. If the weld is compressed cold to a somewhat greater degree by the method described in the above paragraph, it is possible to give the weld approximately the strength of ordinary refined lautal. Even the favorable elongation of refined lautal is regained in the weld.

A lautal weld can therefore be so greatly refined by suitable mechanical and thermal treatment, that there is hardly any difference between the strength of the weld and of the untreated sheet lautal. This is all the more remarkable, because such an extensive refinement of the weld is considered impossible with duralumin.* Beck says that a duralumin weld cannot be strengthened by subsequent hammering or refining, and therefore recommends the avoidance of duralumin welds.

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*Beck, "Äusserung zum Referat über die Arbeit von Knerr"; "Das Schweissen von Duralumin," Automotive Industry, May 4, 1922; Z. f. Met., 1923, p.286.

Although a subsequent mechanical and thermal treatment of welded parts is generally impossible in airplane construction, there are a few cases where it can be done without special difficulty. The writer thinks this would be feasible in the construction of fuel tanks. A round or oval tank could be made by welding together the edges of a lautal sheet as shown in Figure 12. The weld is so accessible that it can easily be heated and hammered. The cylindrical part can then be refined as a whole by heating to 500°C, quenching and annealing. By another hammering of the weld seam, it acquires the properties described in above paragraph No. 3. The ends are then inserted and welded at the edges as shown in the right-hand part of Figure 12. These welds cannot be refined. This is less important, however, because they are not so highly stressed as the longitudinal welds.

Since it has been found difficult to make the riveted seams in light-metal containers perfectly tight, welding offers noteworthy advantages, because it produces perfectly tight joints. It should also be noted that even an untreated lautal weld is fully as strong as a single-row riveted lap joint. According to the experimental results, stresses up to about 25 kg/mm² (35,559 lb./sq.in.) can be transmitted just as well by an ordinary raised lautal weld as by a single-row riveted lap joint. The former can be more easily and quickly produced than the latter and is therefore preferable in some cases. Unquestionably this is true for all the less vital parts, like the sheet-metal covering of struts and fittings, as also for the ribs, engine cowling, tail surfacing, tool chests, seats, etc.

All joints of vital importance, like those in the framework of the wings, fuselage and tail, should be riveted, since welded joints are not as reliable as riveted joints.

TABLE III. Lautal Weld Tests

Test No.	Treatment after welding	Dimensions in mm (See Fig. 11) a	b	a'	Strip section f=ab mm²	Raised weld section f'=a'b mm²
1	No subsequent treatment	0.88	9.01	1.34	7.96	12.1
2		0.91	8.75	1.47	7.96	12.9
3		1.37	8.70	2.07	11.58	20.7
4	Hammered hot and cold and again refined	0.88	7.49	1.36	6.59	10.5
5		0.87	6.58	1.37	5.72	9.0
6		0.95	7.19	1.04	6.83	7.5
7		0.87	7.63	0.97	6.64	7.5
8		0.88	7.73	1.31	6.72	10.1
9		0.88	8.79	1.39	7.74	12.2
10	Like tests 4-9 but hammered harder cold	1.55	8.00	1.80	12.4	14.4
11		1.45	8.65	1.68	12.5	14.5
12		1.56	8.15	1.75	12.7	14.3

TABLE III. Lautal Weld Tests (Cont.)
(The underlined numbers indicate breaking stresses)

Test No.	Breaking load P kg	Tensile stress (kg/mm²) in		Elongation at rupture δ * %	Location of rupture
		strip section $\sigma = P/f$	weld section $\sigma' = P/f'$		
1	200	25.1	16.5	6.9	In weld at beginning of rise.
2	192	24.1	14.9	3.1	
3	265	23.0	14.7	–	Outside of weld.
	Mean	24.1		5.0	
4	185	28.1	17.6	3.8	Beginning of rise.
5	165	28.8	18.3	4.1	6 mm (0.24 in.) from weld seam.
6	189	27.7	25.3	4.4	
7	208	31.4	28.2	6.3	Beginning of rise.
8	224	33.3	22.1	8.8	9 mm (0.35 in.) from weld.
9	246	31.8	20.2	4.1	6 mm (0.24 in.) from weld.
	Mean	30.7		5.3	
10	444	35.8	30.8	20.3	In free portion.
11	382	(30.6)	(26.3)	(6.3)	In weld seam.
12	450	35.4	31.5	20.0	In free portion.
	Mean	35.6		20.2	

*Referred to measured length $11.3\sqrt{f}$.

Translation by Dwight M. Miner,
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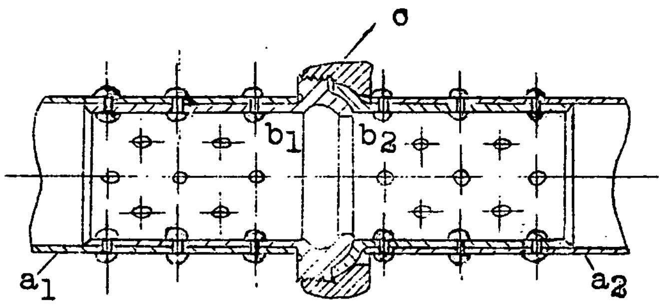


Fig. 1 Tube coupling on Junkers airplanes.
a_1 and a_2 are duralumin tubes.
b_1 and b_2 are junction pieces.
c is the threaded coupling sleeve.

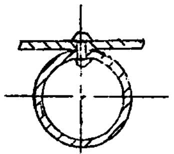


Fig.2 Riveting metal sheet to tube

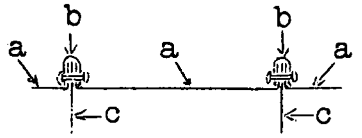


Fig.3 Riveting wing covering to frame work

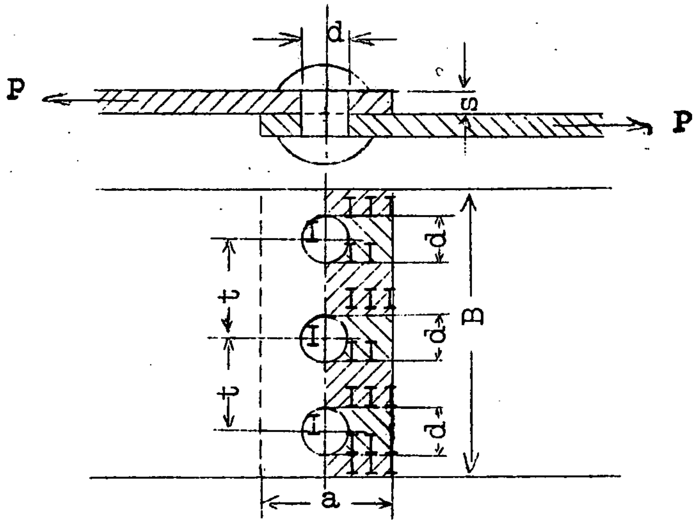


Fig.4 Single row riveted lap joint

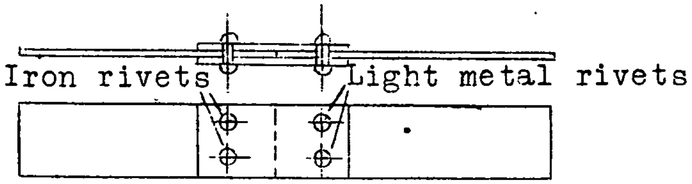


Fig.5 Testing the shearing strength of light metals

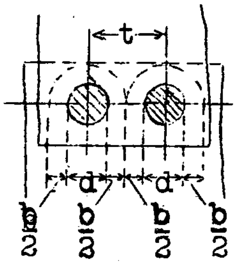


Fig.6 Rivet spacing

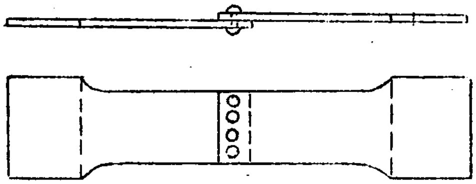


Fig.7 Riveted joint for strength test

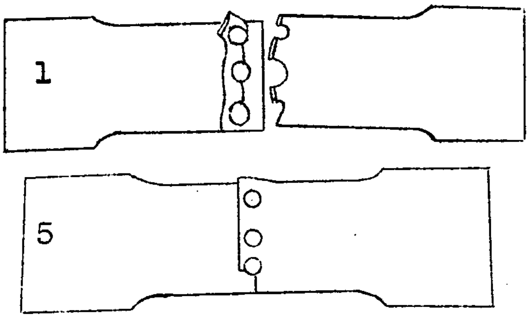


Fig.8 Specimans after tensile tests

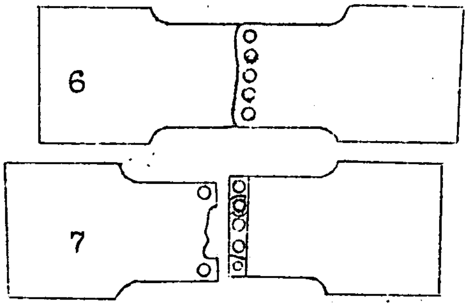


Fig.9 Specimens after tensile tests

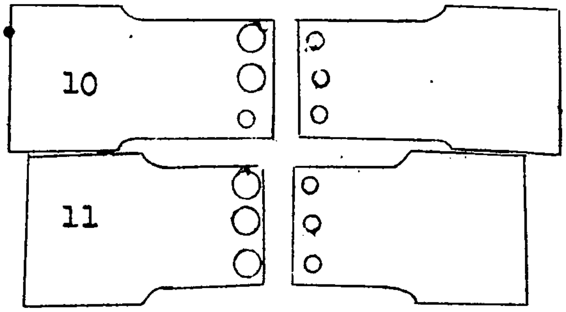
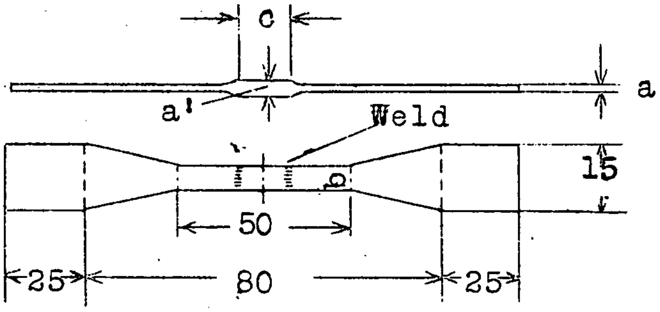


Fig.10 **Specimens** after tensile tests



Fig' 11 Specimens for testing welds

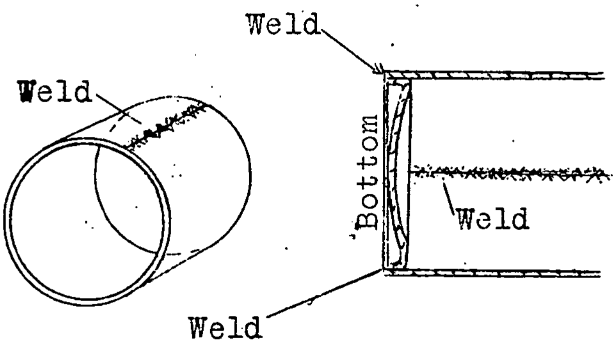


Fig. 12 Welding a lautal tank