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The Elektron Group of Magnesium Alloys

Physical Properties—Applications—Machining, Casting, Rolling, and Welding

Physical Properties and Characteristics

Elektron is a light alloy consisting chiefly of magnesium with variable additions of aluminium, manganese, zinc and silicon, according to the requirements. The alloys are produced by I. G. Farbenindustrie, A.-G. (Abteilung Elektronmetall), Frankfort-on-Main. The sole concessionaires in the United Kingdom are F. A. Hughes & Co., Ltd., 204/206, Great Portland Street, London, W. 1, to whom enquiries should be directed. Licensed foundries for casting Elektron are Sterling Metals, Ltd., Coventry, and the Birmingham Aluminium Casting (1903), Co., Ltd., Smethwick. Due to its lightness (specific gravity = 1.8), it has found an extensive field of application, particularly in the automobile and aircraft industries, where reduction in weight without sacrifice of strength plays an important rôle. Depending on the composition of the alloy, the tensile strength varies from 6 to 26 tons per square inch; the compressive strength from 19 to 30 tons per square inch; the elongation from 2 to 17 per cent, and the Brinell hardness from 40 to 100.

The main physical properties of the commercial elektron alloys are given in the accompanying table. Elektron alloys are characterized by a very high capacity of energy absorption in relation to elastic deformation. The endurance strength as tested under 400 million stress reversals exceeds that of duralumin by approximately 3,000 lb. per square inch. The melting point being at 1,197 deg. F. and the heat conductivity being very high, burning of the alloys is practically impossible, although the metal in the molten state is subject to rapid oxidation.

In contrast with aluminium alloys, elektron is not susceptible to alkaline solutions. When exposed to the atmosphere it is gradually coated with a layer of grey oxide, which tends to prevent further corrosion. Oxide formation may be avoided by applying suitable coatings of lacquers or by greasing or oiling the surfaces exposed to damp air and water.

Field of Application

As mentioned above, elektron alloys are used to a very large extent in the automobile and aircraft industries, on account of their high static and dynamic strengths combined with low weights and relatively high durability. Their application is not confined to such parts as chairs, housings, hoods, tanks, etc., since they are also employed for highly stressed members, such as motor pistons, connecting rods, pulleys, steering mechanism and rudder parts, wings, and fuselage.

Another important field of application is to be found in the textile machinery and machine tool industries. In these industries elektron is being used to lighten moving parts, and thus reduce the power required for acceleration and the stresses due to centrifugal forces, so that the speeds of rotary and reciprocating parts may be increased. At the same time, increased accuracy is thus obtained by relieving the working tables, beds, and guide-ways so that the resulting bending moments and other strains affecting the accuracy are lessened.

Machine Tool Applications

In the machine tool field, elektron is employed mostly in the form of castings. When particularly high stresses are to be dealt with, it may be also applied in the form of pressings or forgings. High-speed rotating parts, such as reversing pulleys, which are subject to rapid changes in direction of rotation, driving and cone pulleys of high-speed drilling and internal grinding machines, reciprocating link members of gear-cutting machines, housings of screw-cutting devices and of universal dividing apparatus, rams of spur-gear planers or shapers, can readily be lightened by the use of elektron.

A few examples from practice will be of interest. On a backing-off attachment for toolmaker's lathes to be used for backing-off hobs and similar tools, the driving motor is mounted on a bracket carried by a lever system in the form of a parallelogram. The bracket, together with the motor and the counterweight, constitute an additional load on the lathe bed, and therefore, a source of inaccuracies. By making bracket and lever system of cast elektron, not only may the counterbalance weight be reduced, but the weight of the whole attachment is only a fraction of the corresponding weight when cast iron is employed. On multi-way drilling machines the spindle housings may be made of elektron to save both in space and weight, while the production and sensitivity is increased, especially when drilling with small-diameter drills.

Another interesting example is that of a multi-spindle drilling machine of the single-purpose type for machining typewriter parts. The drilling spindles are arranged on a horizontally indexing carrier disc, the respective groups of spindles being coupled to the main driver mounted at the

PHYSICAL PROPERTIES OF ELEKTRON ALLOYS

Alloy Symbol	Condition	Supplied as	Tensile Strength tons per sq. in.	Elongation per cent	Compr. Strength tons per sq. in.	Brinell Hardness	Shear Strength tons per sq. in.	Remarks
AZF	Sand-cast	Castings of every description	11–13	4–6	20	45–50	9	Used for castings.
,,	Chill-cast		11–14	6–9	23	45–60	9	,, ,,
AZG	Sand-cast		9–11	3–5	23	45–60	9–10	,, ,,
,,	Chill-cast		13–15	6–10	24	50–60	9–10	Suitable for castings in large quantity production.
VI	Die-cast		9–12	2–4	24	65–70	9	
AZ31	Sand-cast		11–13	6–9	19	35–45	6–7	Used for brake shoes.
V1	Extruded	For forgings, rods, bars, tubes, and profiles	21–24	6–8	23–25	70–75	12	For high stressed parts requiring special hardness.
V1*w*	Extruded quenched		21–24	8–10	26–28	65–70	12	
V1*h*	Extruded aged		22–26	2–3	28–30	85–100	12	
AZM	Extruded		20–24	10–12	24–28	65–70	10	For ordinary constructional parts.
AZ31	Extruded		16–18	14–17	22–24	50–55	8	
Z3	Soft	Sheets and strips	15–16	10–12	20–22	42	8	Can be coloured in staining bath.
	Hard		17–19	2–3	—	60	8	
AM503	Soft		12–14	7–10	22–24	40	8	Can be welded and when warm easily shaped.
AZM	Soft		10–12	10–14	25–27	55	10	For light constructional parts.
	Hard		12–14	1–3	—	60	10	

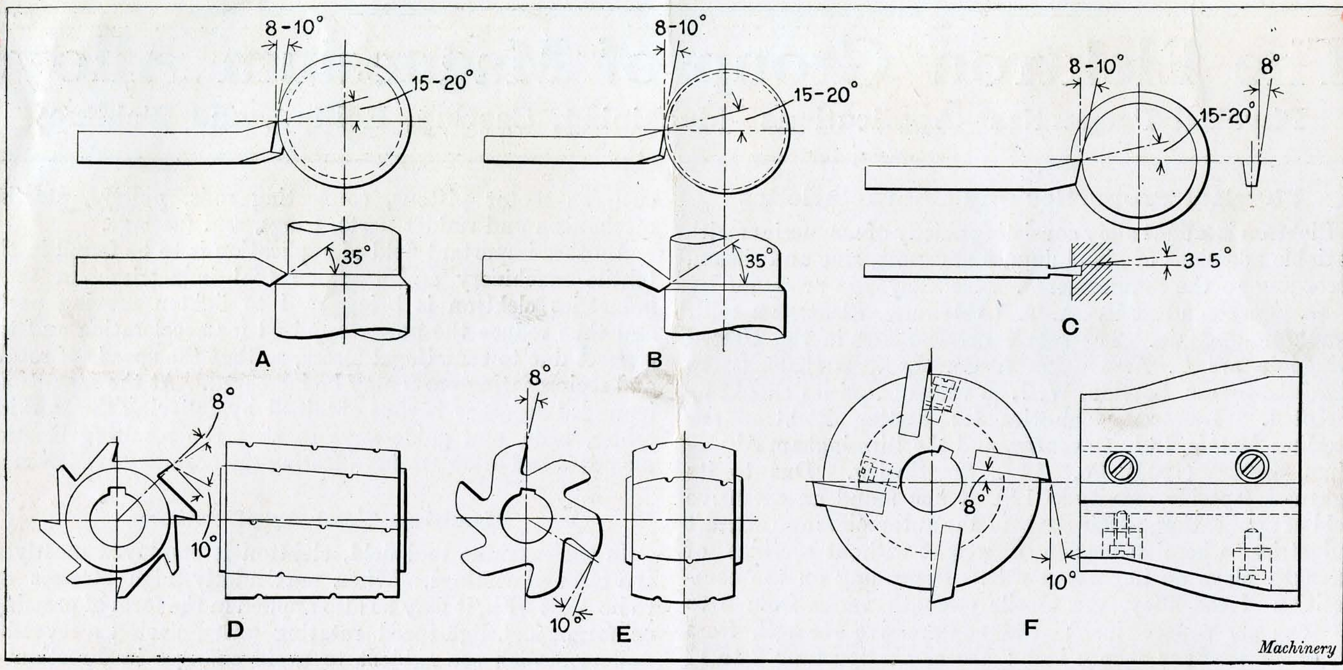

Fig. 1. Examples of Turning, Milling, and Drilling Tools for Elektron Alloys. *A*—**Rough Turning Tool.** *B*—**Finish Turning Tool.** *C*—**Grooving Tool.** *D*—**Face Milling Cutter with Notched Teeth.** *E*—**Form Cutter with Backed-off Teeth.** *F*—**Inserted Tooth Milling Cutter**

outer end of a lever system and driven from a central power source. The work piece is clamped in an indexing fixture on the work table. By indexing the fixture and the spindle carrier disc the respective spindle groups are successively brought into the working positions. The horizontal disc having an outside diameter of 4 feet 7 inches, the swinging-lever system transmitting power to the driver and the vertically adjustable work table are made of elektron, so that the moving parts are quick and easy to actuate, and the non-productive indexing times are shortened without imposing any increased strain on the operator.

It may be mentioned that the sliding faces of the table which contact with the cast-iron ways of the machine column are provided with cast-brass strips to avoid excessive wear. Whenever employing elektron machine tool parts, consideration should be given to the different coefficients of expansion of elektron and cast iron, so that any adverse effects on the accuracy of machining operations may be avoided.

Such elektron parts as are in permanent contact with coolant supply while the machine is in service should be cleaned and oiled.

Portable machine tools may be provided with elektron housings, bearings, pistons, connecting rods, etc.

In the case of cigarette manufacturing machinery, use may be made of elektron to replace all cast-iron quick-moving parts subject to high stresses, when a marked increase of production is obtainable. This is especially the case with cutting devices the swinging or oscillating cutter carriers of which are made of elektron in place of aluminium, with the result that the machine output in many instances can be increased by at least 60 per cent when compared with cast iron, and by 30 per cent when compared with aluminium cutting devices. In addition, the durability or life of the devices is improved, due to the fact that elektron is distinguished by a very high endurance strength when subject to high-frequency alternating stresses.

Machining Elektron Alloys

The price per unit of weight of raw elektron alloys is higher than that of other materials, but when making comparisons as to the prices of raw materials to be applied to a given job, the ratio of specific gravities must be considered. In any case, the higher prices of elektron are usually more than compensated for by the ease with which the alloys are machined, in which respect they are superior to all other known metals or alloys. Speeds, feeds, and tools used for aluminium are suitable, but in order to take full advantage of the high cutting speeds at which elektron may be machined, it has been necessary to develop new designs of machine tools allowing spindle speeds up to 5,000 r.p.m., so that elektron parts may be machined at speeds of 4,550 feet per minute. Apart from the high cutting speeds possible, the power required for machining is less than with any other metal.

Generally, elektron is machined without employing coolants. Turning, boring and drilling, milling and screw-cutting operations require no lubricants, and only in some exceptional cases, as drilling deep holes, cutting small screw threads, finish-turning and grinding operations, suitable cooling media, such as ordinary water, thin oil or crude kerosene, is required, the latter being used exclusively for grinding. When using water, the work pieces must be thoroughly washed in kerosene. Where the stock is removed in the form of very fine chips or powder, thin oil is recommended to prevent the chips from flying about and igniting.

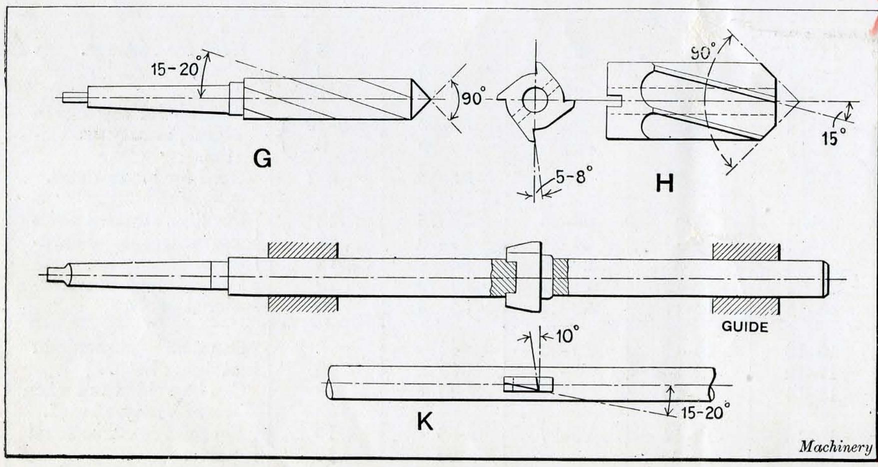

Fig. 1A. Examples of Turning, Milling, and Drilling Tools for Elektron Alloys. *G*—**Drill.** *H*—**Shell Drill.** *K*—**Counterbore**

Forms of Cutting Tools

The accompanying Fig. 1 and 1A show some of the tool shapes which have proved to be suitable for machining elektron. Ordinary high-speed steel tools are quite suitable. During turning operations the degree of heating depends on the rate of feed, the heat developed being conducted away better with larger feeds than with smaller ones. For drilling operations, flat drills are most suitable, and in place of counterbores, boring-bar cutters are employed up to 1 inch in diameter. A further advantage of the use of boring bars is the improved chip removal, although, with deeper bores, it is desirable to apply compressed air both for cooling and removing chips. When face milling housings and similar surfaces, the necessary high cutting speeds are obtained by increasing the diameter of the milling cutter heads. For first-reaming operations, the use of single-or 2-edged reamers of the inserted tooth type is recommended, the length of the cutting edge having a special influence both on the absorption of generated heat and wear of the edge. For grinding purposes, grains 60 to 80 and grades K, L, M give the best results without any loading or glazing of the wheels taking place. Finish grinding and polishing may be done by glass or flint paper, while emery paper (carborundum, etc.) should be avoided. Grinding solutions are either composed of crude kerosene or of a 4 per cent aqueous solution of fluoric sodium.

Casting Elektron Alloys

Elektron alloys are suitable for sand, die and pressure die castings. Thicknesses from 0.03-inch upwards may be readily pressure-die cast, likewise recesses and threads, both external and internal, can be produced by this method, and inserts may be cast in position. Melting of the alloy for sand and die castings is accomplished in iron crucibles by means of oil or gas burners or in coke furnaces. The charge must be well cleaned, as any sand or dirt present may form silicides which make the castings brittle. For refining and protecting the metal against oxidation, a mixture is added consisting chiefly of alkaline chlorides and fluorides and magnesium oxide. By thoroughly agitating the charge at a temperature of 1,346 to 1,418 deg. F. the molten bath is freed from oxides and other foreign substances, the metal being coated by a protecting layer of salts. After heating the bath to 1,562 deg. F., it is cooled to the required pouring temperature. The moulding of castings is similar to the moulding process for aluminium with the exception that from 3 to 10 per cent sulphur and from 0.35 to 0.75 per cent boric acid are added to the sand as used for casting aluminium, so that green sand may be employed. Similarly, green cores may be used, provided that the gases evolved are permitted to escape freely.

Cores which are highly stressed and enclosed by metal on all sides are made of quartz. The pouring temperature is between 1,328 and 1,418 deg. F., depending on the composition of the alloy. Before pouring, the protective skin is removed, and while the metal is flowing, it is protected against oxidation by applying powdered sulphur. Trimming, cleaning, and chipping of castings are performed in the same way as with aluminium. The castings are then pickled in a nitric acid bath or provided with a protecting coat consisting of a chromate combination produced by the reaction of nitric acid and bichromate. We may note that foundry processes in connection with elektron alloys are patented.

Forging and Pressing

The physical properties of elektron metals may be improved by forging and pressing operations. The latter are performed on hydraulic presses at temperatures between 608 and 752 deg. F., depending on the kind of alloys and the desired shapes. With this method, bars, wires, pipes, or tubes and many profiles may be extruded which, otherwise, cannot be produced by rolling. The working speeds are lower, and the applied pressures higher than when extruding brass parts. Bars are made with a tolerance of $\pm$ 2.5 per cent (at least $\pm$ 0.01-inch). If greater accuracy is required, the bars may be re-drawn. For special purposes, flat and round bars may be made within limits of 0.004-inch in lengths up to 10 feet. Hollow parts, such as tubing and pistons, may be also made by the extrusion process.

Rolling and Drawing

Rolled elektron sheets can be supplied in standard thicknesses from 0.012 to 0.4-inch, and in standard lengths and widths, the rolling tolerance varying from $\pm$ 0.0012 to 0.008-inch, depending on the thickness. Hard-rolled sheets are softened by annealing them for one hour at a temperature of 572 deg. F. and cooling them either in the furnace or in the open air. Finish-pressed pipes and tubes can be supplied with standard inner diameters from 3/8-inch to 3 9/16 inches, and wall thicknesses from 1/16-inch upwards. Pipes can be bent by heating them to about 482 deg. F. and filling them with sand or a similar loading material.

Rolling and drawing elektron sheets is carried out in the hot state, the most suitable temperatures being between 518 and 662 deg. F. Only very thin gauge sheets may be handled cold. It is very important to maintain the prescribed temperature range, the sheets being heated in a muffle furnace which should be located close to the rolling mill or drawing bench, respectively. Such tools, as chucks, drawing dies, beading rolls, etc., should be pre-heated to at least 572 deg. F. With regard to the resulting heat expansion, a clearance of approximately 0.008-inch should be provided when making the dies.

Complicated profiles made from extruded strips should be drawn in several stages. Two of the stages may be combined in one operation by employing two dies arranged in tandem and rigidly connected together. It is not advisable to combine more than two dies, since otherwise the resistance becomes greater than is permitted by the tensile strength of the material in the hot state. Drawing profiles from strip material is limited to sheets having thicknesses up to approximately 0.088-inch, while larger thicknesses must be profiled under the edging machine or power press.

During the drawing process a high flash point lubricant should be applied, such as a mixture of two-thirds machine oil and one-third cylinder oil suitable for superheated steam cylinders, or a mixture of equal parts of beeswax and tallow. The drawing speed varies with the thickness of material, being from 13 to 17 feet per minute for thicknesses up to 0.08 inch, and from 7 to 10 feet per minute for greater thicknesses. For deep-drawing operations, elektron is claimed to be equivalent to aluminium alloys. The tools and dies, for these operations, must be pre-heated to at least the temperature of the blank. Hot fluid cocoa-nut butter is used as a lubricant, and is squirted on to the tools at a temperature of about 392 deg. F., after the work has been placed into the drawing blocks. The deep-drawing speed should be kept low so that it does not exceed 0.08-inch per second. The drawing power is very small because of the light plasticity of the material.

When using form rollers instead of dies, the operations should be subdivided into several stages. Generally, form rollers do not stress the material as heavily as dies. It must be kept in mind, however, that the use of form rollers will be limited to full-open sections, as shown by Fig. 2, *A* and *B*, while half-open sections as at *C* can only be drawn by means of dies. When making half-open sections, form rolling and drawing operations may be combined in such a way that the first stages are performed by form rolling, while the final section is produced by die-drawing. By combining the two methods, the various stages may be arranged in progression, the tools being placed at distances of approximately 4 inches one from the other.

For round bending profiles between rolls, the smallest possible radii to be bent may be assumed to be twice the thickness of the plate provided that the thickness does not exceed 0.08-inch. When larger thicknesses are to be dealt with, the smallest radii to be bent are limited to 1.5 to 1.8 times the plate thickness. The bending rolls as well as the material to be bent should be heated by gas burners.

In the same manner, stamping, punching, edging, bulging, and crimping operations may be readily accomplished, provided always that care is taken to heat the tools while the operations are proceeding. With certain operations which are to be performed on a small number of pieces, and in cases where the tools cannot be heated, preheating the sheets to the prescribed

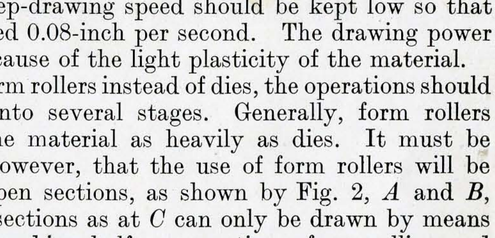

Fig. 2. Elektron Sections produced by Rolling and Drawing

temperature is considered to be sufficient, the sheets being clamped between hard wood which has a low heat conductivity, so as to prevent the heat from being transferred to the adjacent machine parts. In some case, where a relatively small number of pieces are to be dealt with dies made of cast elektron metal may be employed, which, owing to their ease of machining, are cheaper than those made from other materials.

Welding Elektron Alloys

Welding elektron alloys is readily accomplished by applying a special flux which, after welding has been completed, must be removed. To keep the welding seams free from enclosures, welding can be only carried out by the butt-welding method.

Fig. 3 shows some welding examples taken from practice with both correct and incorrect seams. Fittings to be butt-welded should be provided with welding collars. Sheets having thicknesses below 0.04-inch should be flanged at the ends by 0.08 to 0.12-inch and welded in such a way that the welded seam has the appearance of a butt weld. Edge welding is also feasible ; provision should be made, however, that the metal readily flows to the inside of the seam, thus ensuring the exclusion of the flux.

The surfaces to be welded should be cleaned, before welding them, by means of scraping tools, files or wire brushes, etc., and care should be taken to fit them accurately to avoid stresses.

The metal added in welding consists of thin strips of the same alloy as the material to be welded, and should be also thoroughly cleaned before use.

After the pieces to be welded and the metal to be added have been prepared, the flux is applied to the work as well as to the metal to be added. To facilitate proper welding, the sheets are first tacked. The autogenous oxy-acetylene process has proved to be the best method of welding elektron sheets. The nozzle of the burner should have a diameter of 0.02 to 0.04-inch, the ratio of mixture between oxygen and acetylene gases being from 2.2 to 3.6. The welding flame should be held flat, because otherwise, when directing the flame vertically towards the work, holes may be burned into the sheets. It should be so adjusted that the point of the flame is always in advance of the weld. After having tacked the seam, the work is straightened with a wooden hammer, larger deformations being rectified in the hot condition.

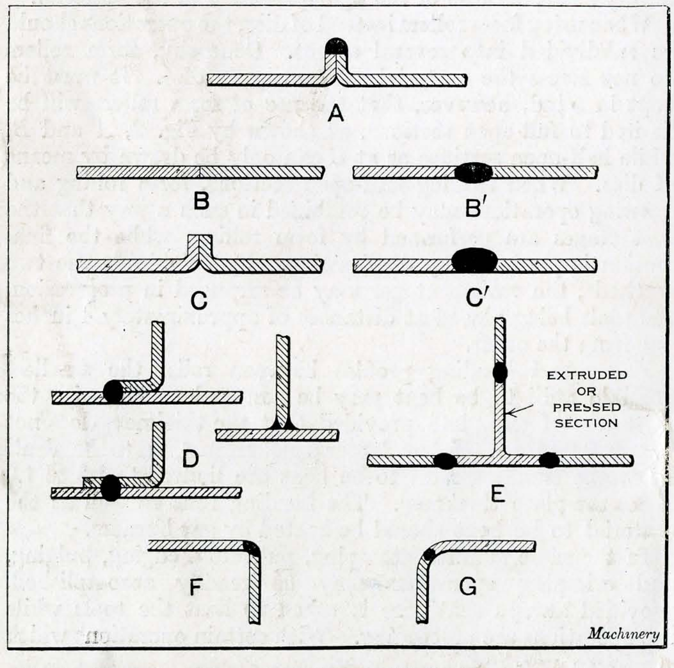

Fig. 3. Examples of Correct and Incorrect Welded Seams. *A*—**Incorrect Seam.** *B, B′*—**Correct Seam before and after Welding.** *C, C′*—**Correct Seam before and after Welding.** *D*—**Incorrect Seams.** *E, F,* **and** *G*—**Correct Seams**

Following the tack-welding, the seams are finish-welded by filling up. Distortions which may have occurred while welding should be removed by hammering. After the weld is completely finished, the flux is removed from both sides of the seam by washing with water, and scraping if necessary ; and finally, the metal is thoroughly dried, if possible, by steam heating. The welded and cleaned pieces must be pickled in a bath consisting of a chromate and nitric acid.

When welding complicated parts, such as tanks and containers having several seams to be welded successively, each welded seam should be cleaned and then pickled in an intermediate bath consisting of nitric acid (10 to 15 per cent). Before welding the next seam, the finish-welded seam must be completely dried. Pickling baths consisting of potassium bichromate, as usually applied, cannot be used in such cases, since the metal would be coated by a layer of chromium composition which would have to be removed when the next seam was started. By applying the preliminary nitric acid pickling bath, the seams may be easily inspected for welding defects, if any. When the last seam has been welded, the whole piece is pickled in a final bath of chromate and nitric acid.

The pickling process is followed by a drying process, which should be applied especially to the inside. To this end the piece should be heated until the last traces of moisture have disappeared.

With regard to the strength and elongation of welded elektron seams, these are nearly the same as those of the parent metal. By forging at a temperature of about 572 deg. F., the strength may be increased, while the relative elongation reaches 4 per cent. The welded seams may be bent, bulged, and crimped in the same manner as the original metal, when heated to 572 deg. F. With sheets having thicknesses of 0.04-inch and over, the seams may be smoothed by scraping or filing.

Whenever pieces having different volumes are to be welded, the larger component part should be pre-heated correspondingly to obtain an even flow of heat in both parts, Welded containers should be protected on the outside surfaces by coating them with a special varnish or lacquer, while the inside surfaces should be cleaned from time to time with a mixture of benzine and machine oil.

The electric spot-welding process is applicable to elektron sheets to some extent, so far as low-stressed joints are concerned.

No soldering or brazing process has been developed at present suitable for application to elektron alloys. Riveted joints may be readily produced, provided that rivets made of a special alloy are used. Rivets made of iron, copper, and aluminium alloys should be avoided.

To insulate or caulk elektron metals against contact with other materials, rubber, black japan, cemented glue, or fibre impregnated with paraffin, may be used. Other insulating materials, particularly those containing acids and chlorides, should not be used, owing to the possibility of chemical reactions which hinder the formation of a self-protecting oxide.

A large number of lacquers and enamels are available suitable for giving protective coatings in various colours. In addition, it is possible to produce rust preventive coatings penetrating into the pores of the metal and combining with the latter.

The method is based on the principle of producing an artificial oxide layer by pickling, which may be made in any desired colour, with the exception of pure white, and which may be polished, if required.