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COUNTRY	USSR	REPORT	[redacted]
SUBJECT	Soviet Manual Entitled Welding in the Repair of Aircraft	DATE DISTR.	3 September 1964
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[redacted]

1. [redacted] 211-page, English-language Soviet manual entitled Welding in the Repair of Aircraft [redacted] The manual, published by the Ministry of Foreign Trade, is intended for use of technical personnel of mobile aircraft-repair shops. 50X1-HUM

2. The manual describes oxyacetylene and electric arc welding equipment and instructs in techniques of welding steel, stainless steel, aluminum, and magnesium alloys.

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(Note: Field distribution indicated by "#".)

INFORMATION REPORT INFORMATION REPORT

WELDING
IN THE REPAIR OF AIRCRAFT

**Manual for technical personnel
of mobile aircraft-repair shops of the Air Force**

Declassified in Part - Sanitized Copy Approved for Release 2014/01/09 : CIA-RDP80-00247A001300300001-2

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CHAPTER

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GENERAL INFORMATION ON THE WELDING OF METALS

§ 1. Welding of Metals

The present stage of modern technical development is characterised by a wide application of welding in the fabrication of machine parts and other articles.

Among the various metal welding techniques, electric welding has become most widely used, since, in hand with attainment of decreased manufacturing costs and speed-up of fabrication procedures, it can, in many instances, be used instead of riveting, casting and gas welding.

Outstanding fabricating and techno-economical properties of electric welding have contributed to its widespread inculcation into almost all branches of industry.

Electric welding is widely used in transport, agricultural, power and chemical machine-building, as well as in aircraft construction and shipbuilding. Electric welding is becoming a basic fabricating technique in the construction of bridges, ships, hoisting and conveying, equipment, sky-scraper frame-works, pipelines, etc.

Academician V.V.Petrov, an outstanding physicist and the first of the Russian school of electro-physicists, in 1802 discovered and investigated the phenomenon of arc discharge. By passing an electric current through two carbon rods, and later through two metal rods, he discovered that an electric arc possessing a temperature high enough to easily cause melting of any kind of metal can be set up across the ends of the rods. Describing these experiments, V.V.Petrov pointed out the possibility of utilizing electric-arc heat for the melting of various metals.

It should be pointed out here that academician V.V.Petrov discovered and described this electric-arc phenomenon several years before this was done by the British physicist Davy (in 1812). For this reason, the deep-rooted term of "Volt arc" is now replaced by the term "Petrov arc", in honour of the man who made this great discovery.

The discovery of the electric-arc discharge formed the basis for subsequent development of electric lighting engineering, electric welding of metals, and stimulated the general development of electrical engineering.

Several decades later, a Russian scientist P.N.Jablotchkov gave practical application to the discovery made by P.V.Petrov, by creating the world's first electric incandescent lamp.

In the 80-ies of the last century, Russian engineers N.G.Slavianov and N.N.Benardos used the Petrov arc for the melting and welding of metals.

§ 2. Kinds of Welding

Welding is defined as the process of inseparably joining metal articles, performed by locally heating them to a molten (liquid) or pasty condition, either without or with the application of mechanical forging effort.

At present, many kinds of welding are being used in industry.

To facilitate studies, various welding techniques are grouped together on the basis of the similarity of their methods. The classification of welding techniques is based on the condition of the metal at the point of welding, at the moment of joining of the metal, and upon the source of energy, or the method of heating the metal during welding.

As to metal condition at the point of joining, all the existing welding techniques are subdivided into two major groups:

a) fusion welding, and

b) pressure welding

Depending upon the source of energy used for heating the workpieces, the following kinds of welding are distinguished:

a) chemical welding,

b) electric welding, and

c) electro-chemical welding.

In fusion welding the edges of the pieces to be joined are heated to the melting point. No mechanical pressure is required in this case, since joining of the pieces takes place as a result of spontaneous mixing of the molten metal in a common welding puddle. When metal cools off, a welded seam results. For this reason, fusion welding is often termed "autogenous welding", that is "self-originating" welding.

<u>Note.</u> Unfortunately, the term "autogenous welding" is very often identified with the term "oxy-acetylene welding" and is used in this restricted sense, which is wrong. As can be understood from the above description, and in accordance with standard technical terminology, the term "autogenous welding" actually is synonymous to "fusion welding". Consequently, electric welding also comes under the definition of autogenous welding.

In pressure welding the edges of the parts to be joined, as a rule, are heated to a plastic (pasty) state, after which they are joined together by applying a mechanical pressure (upsetting).

Intensely high preheating temperatures are not required for pressure welding, and in some cases this kind of welding can be performed without preheating (the so-called "cold welding").

In Fig. 1. may be seen a general welding classification diagram.

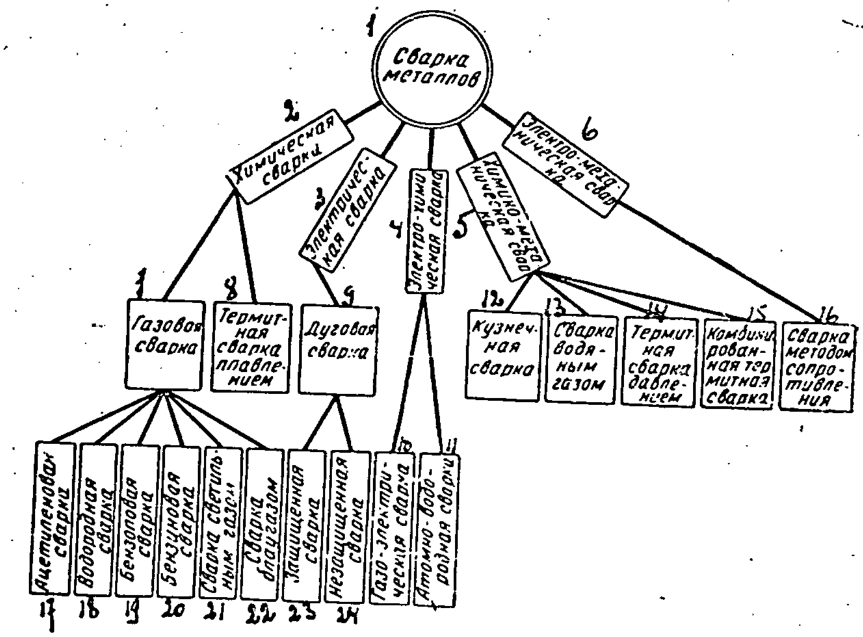

Fig. 1. Welding Classification Diagram.

1. Welding of Metals; 2. Chemical welding; 3. Electric welding; 4. Electro-chemical welding; 5. Chemico-mechanical welding; 6. Electro-mechanical welding; 7. Gas welding; 8. Thermit welding by fusion; 9. Electric-arc welding 10. Gas-electric welding 11. Atomic-hydrogen welding; 12. Forge welding 13. water-gas welding; 14. Thermit welding by pressure; 15. Combined thermit welding; 16. Resistance welding; 17. Oxy-acetylene welding; 18. Hydrogen welding; 19. Benzol welding; 21. Lighting-gas welding; 22. Blaugas welding;23. Shielded-arc welding; 24. Open-arc welding.

In aircraft repair, the most widely used kinds of welding are oxy-acetylene (gas) welding and manual electric-arc welding, all other kinds of welding, as a rule, are practically not used.

For this reason, the present book deals mainly with these two kinds of welding.

a) O X Y - a c e t y l e n e   w e l d i n g.

In oxy-acetylene welding, use is made of heat produced by the combustion of the oxy-acetylene mixture. Acetylene is fed to the torch from an acetylene generator or, sometimes, from a cylinder; the oxygen is always supplied from a cylinder. Shoun in Fig.2 is a schematic set up of an oxy-acetylene welding plant. Gaseous oxygen is fed through a hose from oxygen cylinder 1 via reducer 2 and further into torch 5. Acetylene is supplied from acetylene generator 3 through hose 4 to torch 5. Mixing of the two gases takes place inside the torch. At the torch orifice the gas mixture is ignited, thus producing an oxy-acetylene flame. The edges pieces to be welded and the filler metal are heated by the flame until melted; at this stage the molten metal fills the gap between the edges of the work pieces, and a welded joint is produced.

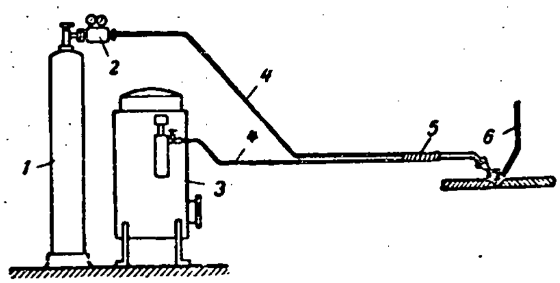

Fig. 2. Schematic Set up of an Oxy-Acetylene Welding Plant.
1-oxygen cylinder; 2-oxygen reducer; 3-acetylene generator; 4-rubber hoses; 5-torch; 6-filler metal.

b) Electric-arc welding.

In electric-arc welding the melting of the edges of the pieces to be welded and of the filler metal is achieved by the heat produced by the electric arc.

It is well known that, as a result of the breaking of an electric circuit, a spark will jump across the point where

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the circuit is broken, this phenomenon being the passage of the electric current through the air space. When the gap between two electric current terminals is kept to small enough a value, continuous sparking takes place, and an arcing discharge termed the Petrov arc is produced. The temperature of this arc is as high as 6000° absolute, which makes possible its application for the welding of metals.

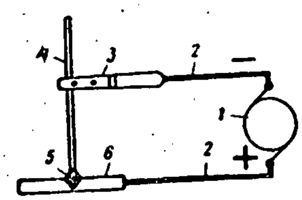


Fig. 3. Schematic Diagram of Electric-Arc Welding Circuit.

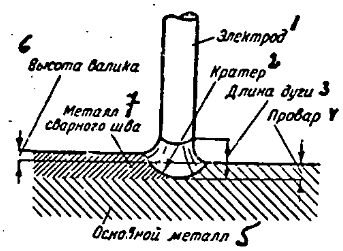


Fig. 4. Electric-Arc welding Process.

1-electric welding generator; 2-cable; 3-electrode holder; 4-metal electrode; 5-electric arc; 6-workpiece.

1) electrode; 2) crater; 3) arc length; 4) penetration; 5) base metal; 6) bead heaght; 7) welded metal.

Shown in Fig. 3 is a schematic diagram of the electric-arc welding circuit. From electric welding generator 1, current is fed through cable 2 to workpiece 6 and electrode 4. When metal electrode 4, secured in electrode holder 3, contacts the workpiece, the electric circuit closes with subsequent passage of an electric (short circuit) current through it. Should the electrode, thereafter, be moved 2 or 3 mm away from the workpiece, an arcing discharge will be set up between the workpiece and the electrode, and the Petrov electric arc will be obtained. The heat originated by the electric arc causes melting of the edges of the workpieces and the electrode; a crater is also produced in the molten metal puddle (see F 50X1). Drops of molten electrode metal are deposited in the puddle where they mix with the molten base metal. Following the electrode movement, the puddle also moves along the joint so that, as the molten metal cools, a continuous weld seam is obtained.

Since, as a result of melting, the electrode becomes ever shorter, it should be brought nearer to the workpiece so that a constant clearance of 2 to 4 mm is maintained.

Owing to the simplicity of the equipment, high efficiency and a number of other reasons, the electric-arc process has now become the most widely used industrial welding technique.

c) Atomic hydrogen welding.

In atomic hydrogen welding the pieces to be welded are heated by means of an electric arc, Contrary to electric-arc welding, here the arc flame is set up between two tungsten or carbon electrodes placed in an atmosphere of hydrogen.

During welding, the molecules of hydrogen, under the influence of the electric arc flame, are split into atoms which simultaneously absorb large quantities of heat produced by the electric arc. The atoms of hydrogen, on coming into contact with the cold surface of the workpiece again form hydrogen molecules and emit the formerly absorbed heat. This results in a rise in electric arc temperature to 3700°C. The entire welding process takes place without oxygen participation. For a schematic diagram of the atomic hydrogen welding process see Fig. 5.

The working technique of atomic hydrogen welding is as follows. A mixture of nitrogen and hydrogen or pure hydrogen is fed through two pipes into the torch; to the ends of tungsten or carbon electrodes. By contacting and separating the two electrodes at the ends, the operator draws an electric arc and under the action of the hydrogen flow pressure the arc assumes a fan-shaped form. Melting of the edges of the workpieces and of the filler metal takes place under the influence of the heat produced by the electric arc.

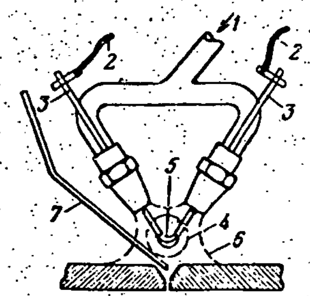


Fig. 5. Schematic Diagram of Atomic Hydrogen Welding Process.

1-hydrogen from cylinder; 2-cables to welding machine; 3-tungsten electrodes; 4-atomic hydrogen; 5-electric arc; 6-molecular hydrogen; 7-filler metal.

The advantage of this welding process lies in that the hydrogen shields the zone of the joint, protects melted weld metal against the influence of atmospheric oxygen, and thus prevents the formation of metal oxides in the welding puddle, in which case the weld strength would otherwise have been inevitably reduced and the process of welding hampered.

Owing to the high quality of the weld produced by the atomic hydrogen process, this technique is used in the fabrication of the most vital parts of machinery, irrespective of the fact that the process is relatively complicated.

In aircraft repairing, this technique is not yet widely applied, since it involves the use of intricate equipment, and, besides, no easy access can be provided for welding cracks in various corner joints of aircraft elements and parts.

d) Argon-arc welding.

Argon-arc welding has recently acquired wide application in the fabrication of thin-walled structures of stainless and heat-resisting steels.

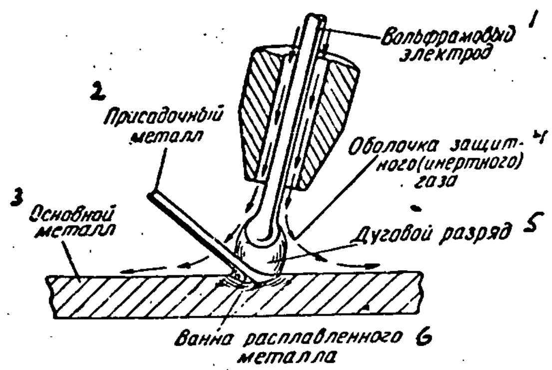


Fig 6. Schematic Diagram of Argon-Arc Welding Process:
1)tungsten electrode; 2)filler metal; 3)base metal; 4)shielding gas (inert gas) atmosphere; 5)electric arc; 6)melted metal puddle.

This new welding process, developed by Soviet engineers, allows for the avoidance of defects which could not be avoided when welding thin-walled structures by standard oxy-acetylene or electric-arc techniques, namely: the through-burning, intensive warping of weldments and burning-out of alloying additions; besides this, the argon-arc process makes the use of flux or electrode coatings unnecessary, speeds up welding procedure and produces welds of high mechanical strength and corrosion resistance.

The principles of argon-arc welding will be understood from Fig.6. An electric arc is drawn between the tungsten electrode and the workpiece. The filler metal is introduced into the puddle in the same way as in oxy-acetylene welding. The electrode, arc, filler metal and the molten puddle are shielded by the atmosphere of argon which as an inert gas. This envelope of gas protects the molten metal against the noxious influence of atmospheric air.

Argon-arc welding is carried out with standard d.c. or a.c. welding machines.

CHAPTER II

TYPES OF WELDED JOINTS AND KINDS OF WELDS

§ 3. Types of Welded joints

The choice of a type of welded joint depends upon the design of the part to be welded, the value and direction of the stresses applied, convenience of performing the welding, the type of welding process being used, and a number of other factors.

At present, the following principal types of welded joints are used: butt joint, lap joint, T-joint, corner joint, side joint, flanged joint, etc. Each of the above types is characterized by several specific features.

Fig.7. Square butt joint

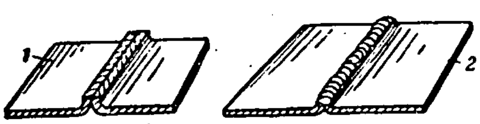


Fig.8. Double-flanged butt joint and welded seam:

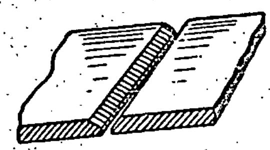
1-double-flanged butt joint; 2-seam welded on double-flanged butt joint.

T h e b u t t j o i n t s are subdivided into:

1) square butt joints (Fig7) used for welding elements o.8 to 2.5 mm thick;

2) single-flanged or double-flanged joints (Fig.8) used for welding elements up to 2 mm thick. No filler metal is used in welding these joints;

3) single-V butt joints (Fig.9) used in welding thick metal. The angle formed by the bevelled edges is from 60 to 90°,



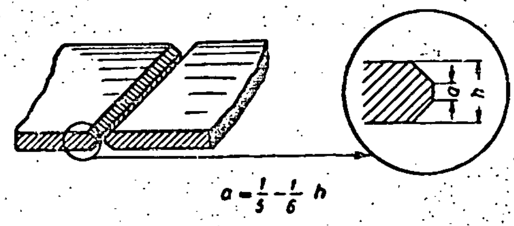


Fig.9. - Single - V butt joint Fig. 10. - X - butt joint

depending upon the thickness of the metal and the method of welding.

The blunt face, i.e. the height of the edge surface left unbevelled, should equal 1/4 or 1/5 of total metal thickness;

4) X-butt joints with double-bevelled edges (Fig. 10) are used in welding pieces over 12 mm in thickness, provided there is free access to the workpiece from both sides. As in the case of single-V butt joints, the angle between the bevelled edges should range from 60 to 90°. The height of the blunt face should equal 1/5 to 1/6 of total metal thickness.

When making a choise between the V-joint and the X-joint, it should be borne in mind that the preparation of an X-joint is more complicated, while in welding V-joints time requirements and filler-metal consumption are twice the corresponding values for X-joints. Besides this, the X-joint, being strictly symmetrical, provides for smaller shrinkage strain and warping, as compared to V-joints.

T h e l a p j o i n t s (Fig. 11) are used in various welding processes. The width of sheet overlap should be taken 3 to 5 times sheet thickness. The advantage of this type of weld joint as compared to butt joints is that no preliminary machining of the edges to be welded is required. Strap joints

(Fig. 12) are a modification of lap joints.

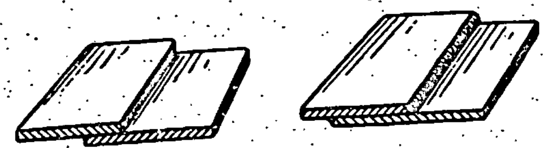


Fig. 11. - Single lap joint and welded seam.

1) single lap joint; 2) welded seam.

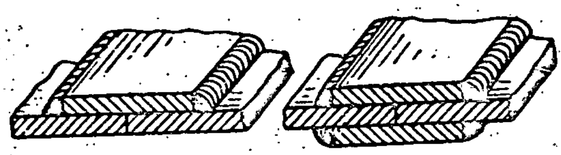


Fig. 12. - Strap butt joints and welded seams:

1)single strap butt joint; 2)double strap butt joint.

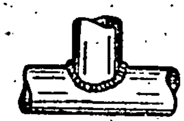


Fig. 13. - Tube T - joint

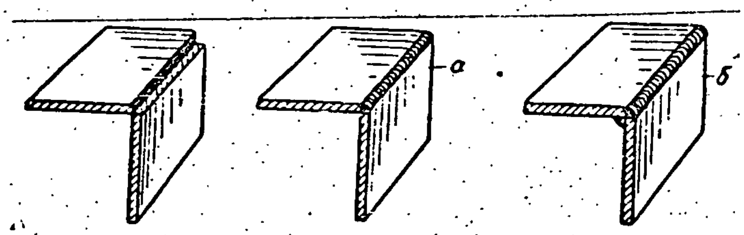


Fig. 14 - Corner joints and welded seams:

1)corner joint; 2)corner seams.

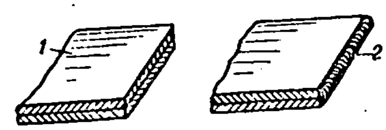


Fig. 15. - Side joint (1) and welded seam (2)

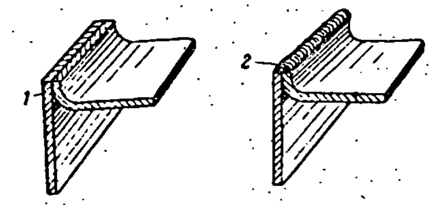


Fig. 16. - Flanged joint (1) and welded seam (2)

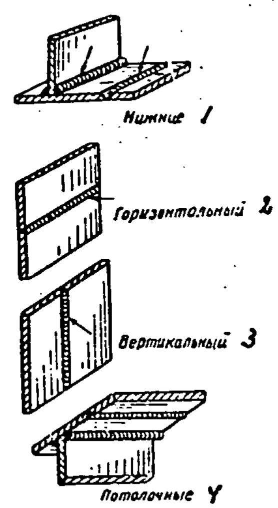


Fig. 17. - Classification of welds according to their position in space

1) downhand; 2) horizontal; 3) vertical; 4) overhead

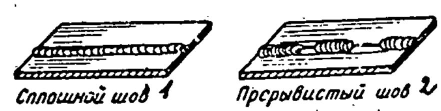


Fig. 18. - Continuous and interrupted welds 1) continuous weld 2) interrupted weld

T h e T - j o i n t s (Fig. 13) are very widely used in aircraft building, for joining steel tubular elements by welding.

T h e c o r n e r j o i n t s (Fig. 14) may be with single-side (a) and double-side (b) welded seams.

T h e s i d e j o i n t s (Fig. 15) are used in manufacturing parts or assemblies by gas welding. A modification of this joint type is the flanged joint (Fig. 16).

§ 4. Kinds of Welds

The welded seams (or welds) may be subdivided into several kinds on the basis of the following features: the number of passes, position in space, length, shape of cross section, and the arrangement of the weld seam relative to the working stress.

a) Single-pass and multi-pass welds.

Single-pass welds are used in gas-welding pieces 4 or 5-mm thick, and, in electric-arc welding, pieces 6 to 8-mm thick. Thicker elements are welded by multi-pass technique.

b) As to position in space, the welds are classified as downhand, horizontal, vertical and overhead (Fig. 17).

The seams welded in vertical and overhead positions by even the most experienced welders are characterized by comparatively poor quality. If the strength of a horizontal weld is taken as equal to 100 per cent, the strength of the vertical weld is considered to be only 95 per cent, the overhead weld-only 80 per cent. This is the reason why welding should preferably be performed in the downhand position.

c) As to their length, the welds are divided into continuous and interrupted welds (Fig. 18). Interrupted welds are used in those cases when a continuous weld is not required to provide for a design strength of a particular part or assembly. An interrupted weld normally consists of 50 to 100 mm sections of welds spaced at 75 to 200-mm intervals.

d) As to shape of the cross-section, the weld seams (Fig. 19) are classified as concave (or weakened), normal, and convex (or reinforced). Normal weld seam thikkness amounts to 25 per cent of workpiece thickness.

e) As to weld arrangement relative to working stress, welds are classified as flank, frontal, combined and oblique seams

(Fig.20).

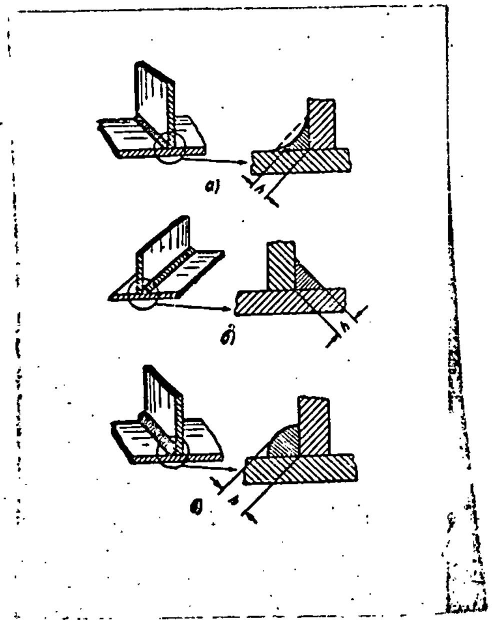


Fig. 19. - Classification of welds according to shape of bead cross-section.

a-concave; b-normal; c-convex.

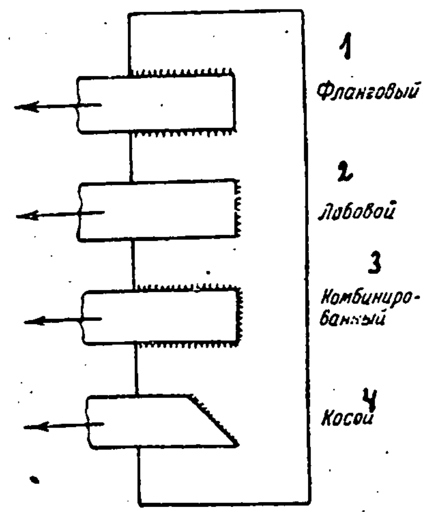


Fig.20 - Classification of welds according to direction of applied working effort.

1)flank; 2)frontal; 3)combined; 4)oblique.

The weld strength depends upon its sectional area, quality of welding and weld arrangement relative to the direction of the working stress. Frontal welds are subjected to compression or tensile stresses, flank welds - to shearing stresses.

When ruptured by the application of tension stresses, frontal welds are normally brittle-broken, without any noticeable flow of metal. For this particular reason, frontal welds are unsuitable for structures subjected to impact stresses. Flank welds are more plastic and are broken only after being considerably deformed. This kind of weld offers much greater resistance to impact stresses.

The oblique weld is a combination of the above two kinds of welds and is widely used in the repair of tubular aircraft elements.

CHAPTER III

GASES FOR OXY-ACETYLENE WELDINGS

§ 5. Oxygen

Oxygen is a colourless gas having no odour. It is poorly dissolved in water and is heavier than air. Oxygen has a strong affinity for most of the elements and is contained in the compounds forming the crust of the earth.

Although oxygen does not burn itself, combustible gases burn in oxygen to produce a higher temperature than in air. This property of oxygen is utilized for obtaining high temperatures in the gas welding of metals.

Atmospheric air consists, chiefly, of nitrogen and oxygen, the latter occupying 1/5 of the air by volume.

Since air is a mechanical mixture of several gases, it can be separated, this characteristic being widely made use of in the industrial production of oxygen.

Oxygen is produced by intensive cooling of air (to -195°C), with subsequent separation of oxygen from the nitrogen, the separation being based upon the difference in boiling temperatures (-183°C for oxygen and -196°C for nitrogen). Nitrogen evaporates from liquid air quicker than oxygen. On commencement of heating, the vapours will first contain more nitrogen, while the quantity of oxygen contained in the remaining liquid will steadily increase. When the temperature rises to -183°C, almost only pure oxygen will remain.

The evaporation of liquid oxygen under high pressure and filling of cylinders with gaseous oxygen is performed in thermal gas producers.

Oxygen is transported to the working site in steel cylinders at a pressure of 150 kg/cm^2.

§ 6. Acetylene

Acetylene is a chemical compound of carbon and hydrogen (C_2H_2). At normal pressure (760 mm of mercury column) and normal temperature (+15°C) acetylene is in the gaseous state; at a temperature of -81°C acetylene liquifies, and at -83°C it solidifies.

Acetylene is lighter than air. Under normal conditions 1 cu.m. of acetylene weighs only 1170 gm, as compared to 1 cu.m. of air which weighs 1290 gm. Technical acetylene used for gas welding contains certain admixtures which impart it with a sharp garlic-like odour. Acetylene is poisonous to the human organism.

Acetylene ignites at a temperature of 425°C, and under normal conditions burns without any signs of explosion. When the pressure rises above 2.0 or 2.5 kg/cm^2 gp. (where gp. stands for gauge pressure), or when the temperature is above 150 to 200°C, acetylene decomposes with a violent explosion, accompanied by intensive heat discharge.

When acetylene is dissolved in a solvent, the explosion hazard is reduced. Thus, acetylene dissolved in acetone becomes explosion-dangerous only at a pressure of over 20 kg/cm^2 g.p.

If acetylene is mixed with gases which react with it, its explosiveness increases. A mixture of acetylene and oxygen becomes explosive if the acetylene content ranges from 3 to 93 per cent; if air contains 2.8 to 65 per cent of acetylene, the mixture explodes when ignited. Due to the increased explosion hazard in connection with the employment of acetylene, special attention should be paid to welding shop ventilation. Acetylene generators are to be located in separate premises or dug-outs.

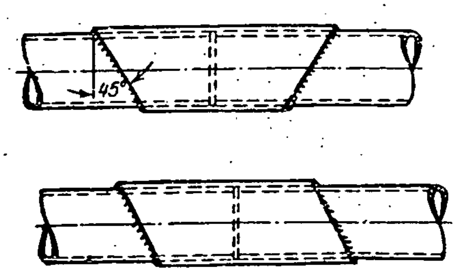


Fig.21. – Tubes connected by couplings with oblique welds.

If acetylene begins to accumulate in the welding shop atmosphere, and should its content reach 3 or more per cent, a violent explosion may occur as soon as the operator ignites the welding torch. For this reason, thoroughly check the tightness of all acetylene equipment, hoses, fittings, etc., and see that the workshop is adequately ventilated; whenever acetylene content in the air is suspected to be above normal, do not ignite welding torches or switch-in electrical equipment.

One of the characteristic properties of acetylene is its ability to react with certain metals and produce explosive combinations. Thus, acetylene in combination with copper will explode as a result of heating or even of a blow. Therefore, pure copper should not be used to manufacture fittings for acetylene, and, in particular, torch tips.

No explosive compounds are formed by acetylene with copper alloys.

Technical acetylene is obtained by decomposing calcium carbide (CaC_2) with water.

Calcium carbide (often also termed simply carbide) is a product of the fusion of quicklime and coke or anthracite in special electric furnaces.

After crushing, lumps of carbide of different size are normally obtained. Small-size granulations (2 to 15 mm) yield 230 to 260 liters of acetylene per 1 kg of carbide, while large-size lumps (20 to 120 mm) yield 270 to 300 liters per kg, as can be seen from Table 1 below.

Table 1

Carbide granulations (mm) (average dimensions)	Acetylene yield (l per kg of carbide)	
	Grade A	Grade B
2 - 4	250	230
4 - 8	260	250
8 - 15	270	250
15 - 25	275	260
25 - 50	300	270
50 - 80	300	280
80 - 120	300	280

Granulated carbide is stored and transported in air-tight drums of 100 to 120 kg capacity.

Drums should be opened with care. Heating of drums or cutting of drum covers with chisels are not to be allowed.

Theoretically, 0.56 l of water is required to dissociate 1 kg of carbide. Practically, to ensure continuous cooling of the acetylene, the process of carbide dissociation is normally performed with a surplus quantity of water, i.e. 5 to 20 liters per kg of carbide. Provisions should be made for the immediate removal of generated acetylene, to prevent abrupt rises in pressure.

CHAPTER IV

OXY-ACETYLENE WELDING EQUIPMENT

§ 7. Acetylene Generators

The apparatuses used to produce acetylene are termed acetylene generators, of which several types exist.

1) on the basis of operational principles, acetylene generators are subdivided into three groups:

a) "water-to carbide" generator, in which water is poured in small quantities on carbide;

b) "carbide-to-water" generator, in which carbide is added in small quantities to a large volume of water;

c) "contact" generators, in which periodic contact between carbide and water takes place.

Schematic diagrams of the above generators are shown in Fig. 22.

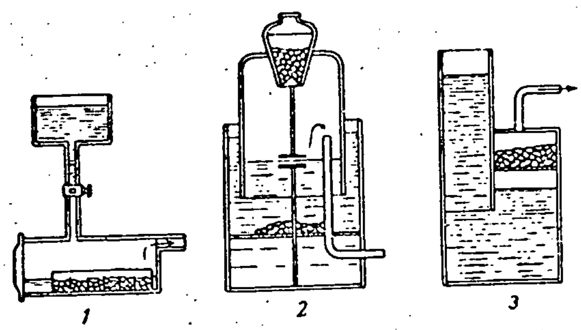


Fig. 22. - Schematic Diagram of Acetylene Generators

1 - "water-to-carbide"; 2 - "carbide-to-water"; 3 - contact type.

2) As to acetylene pressure, generators may be subdivided into three groups:

a) low-pressure generators, with pressures up to 500 mm w.c.;

b) medium-pressure generators, with pressures of 500 to 5,000 mm W.c.; and

c) high-pressure generators, with pressures of 5,000 to 15,000 mm W.c., or 0.5 to 1.5 kg/cm^2 g.p.

3) As to acetylene yield, generators are classified as:

a) low-yield generators, producing up to 3 cu.m. of acetylene per hour;

b) medium-yield generators, producing up to 30 cu.m. of acetylene per hour; and

c) high-yield generators, producing over 30 cu.m. of acetylene per hour.

Low-yield generators are normally manufactured in portable designs, while the other two types are for stationary installations.

"Record" Acetylene Generator-Design and Operating Instructions.

The "Record generators belong to the "water-to-carbide" type and are low-pressure apparatus (Fig.23). They are manufactured both portable and stationary, and may have a capacity of 1,000 to 10,000 liters of acetylene per hour. Normally small-capacity "Record" generators are used in mobile repair shops.

Specifications of "Record" generators.

Rated yield- 1,000 l/hr; weight of carbide charge 2 kg; generator efficiency under normal operating conditions - 90 to 92 per cent; efficiency under overloads - 75 per cent; water consumption per 1 kg of carbide - 3 to 4 liters; gas pressure - 130 to 140 mm w.c.

Generator design.

Dome 2 floats inside generator housing 1 filled with water;

gas pressure depends upon the dome weight and sectional area. Located in the housing bottom part are two retorts 3 accommodating carbide feed boxes 4 which are charged with carbide. Each box is divided by several partitions into a number of sections. Each retort is equipped with gas discharge pipe 14 capped at the top end by hood 15. Acetylene as it is generated inside the retorts is discharged under the dome through pipe 14. Water is fed into the retorts by the operation of three-way cock 12. The dome is provided with safety pipe 9, ensuring discharge of acetylene into the atmosphere, should excessive quantities of acetylene be generated or should a water shortage occur. The end of the safety pipe is arranged 35 mm above the bottom edge of the dome, this ensuring discharge of acetylene only through pipe 9, i.e. the safety pipe. Welded to pipe 9 is nipple 8 with rubber hose 10 by aid of which water is fed from the generator housing through the cock into the retorts. Owing to acetylene pressure, the dome is lifted and nipple 8 is pulled out of the water, thus cutting off water supply to the retort. Acetylene from under the dome is fed through pipe 16 into purifier 5 and further into water seal 6. When the dome begins to drop back into its lower position, water begins again to flow into the retort through nipple 8.

The acetylene supply hose is connected to water seal nipple 20, the opposite end being coupled to the torch.

Gas pipe hood 15 directs the acetylene along the annular passage formed between the gas discharge pipe and the hood, and further - downward into the water. Only after this, is the acetylene admitted into the dome. Thus adequate scrubbing of the acetylene is achieved; this arrangement, in addition, prevents acetylene leakage into the atmosphere during recharging of the retorts, since the gas under the dome cannot enter pipe 14 from under hood 15 whose bottom edge is always submerged in the water.

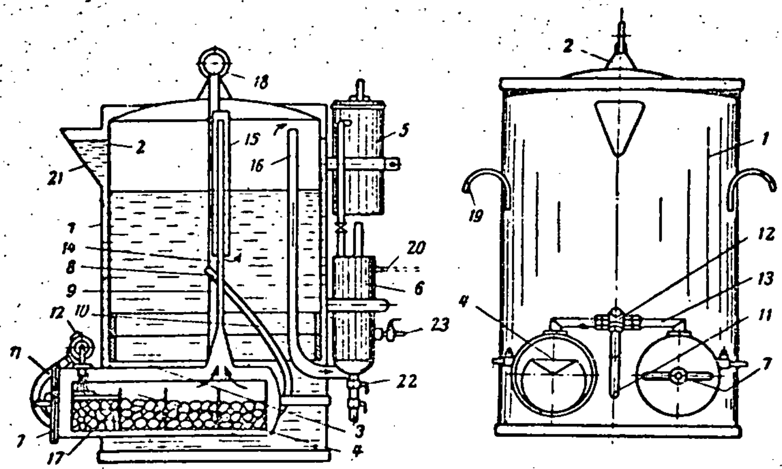


Fig. 23. - "Record" Acetylene Generator.

1-generator shell; 2-dome; 3-retort; 4-carbide feedbox; 5-purifier; 6-water seal; 7-retort cover; 8-feed water nipple; 9-dome safety pipe; 10-feed waterrubber hose; 11-water supply pipe to three-way cock; 12-three-way cock; 13-water supply pipe to retort; 14-gas pipe; 15-gas pipe hood; 16-acetylene take-off pipe; 17-carbide feed box partition; 18-dome lifting ring; 19-handles for generator carrying; 20-take-off nipple for connection of acetylene-feed hose; 21-water filler funnel; 22-drain cock; 23-water-level try cock.

Technical acetylene contains a number of admixtures which impair the quality of the weld. Acetylene is cleaned of hydrogen sulfide and ammonia by dissolving these gases in water, while phosphine is removed in chemical purifiers of the type shown in Fig. 24.

Acetylene is fed into the purifier from the generator through pipe 5, passes through purifying material 8 and after being purified leaves the apparatus via pipe 6. Thin cotton-wool layer 7 prevents gas feed pipe 5 and drain cock 4 from being obstructed by the purifying material. As a purifying material, "geratol" is used (a yellow-coloured powder impregnated with sulphuric and chromic acids).

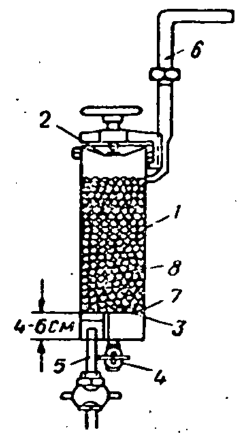


Fig.24. - Chemical purifier.

1-shell; 2-cover; 3-grate; 4-drain cock; 5-gas feed pipe; 6-gas discharge pipe; 7-cotton wool layer; 8-charcoal or coke covered with purifying material.

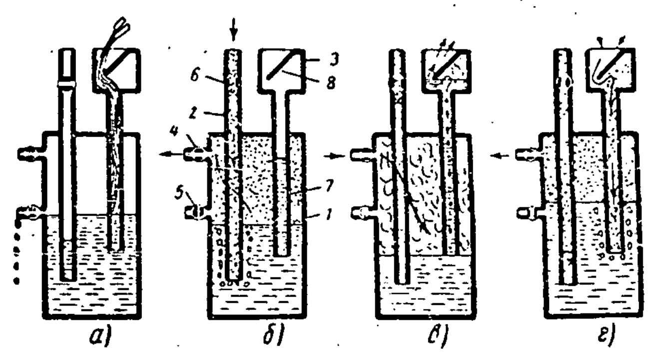


Fig.25. Schematic diagram of low pressure water seal arrangement and operation.

a) water seal being filled with water; b) water seal in normal operation; c) back-fire; d) air inflow when generator contains insufficient volume of acetylene;
1-water seal shell; 2-gas feed pipe; 3-funnel; 4-cock with nipple for rubber hose connection; 5-water-level try cock; 6-gas feed cock; 7-safety pipe; 8-protective visor.

It should be pointed out that the carbide produced in modern industrial plants contains but an insignificant percentage of harmful admixtures. For this reason, even in the welding the most vital of aircraft el ments, the use of a chemical purifier is optional.

Each acetylene generator is provided with a safety water seal designed to prevent generator explosions.

An acetylene generator explosion may be caused by:

a) a sucked-in inflow of atmospheric air or oxygen into the generator when there is but a small volume of acetylane present;

b) pentration of the welding flame into the generator housing through the acetylene supply pipe as a result of a back-fire.

The water seal shown in Fig.25 is a vessel with two pipes, i.e. gas feed pipe 2 and safety pipe 7. Funnel 3 serves for filling the seal with water, while protective visor 8 prevents throw-out of water from the seal housing as a result of back-fire. Pipe 2 is provided with cock 6, for admitting gas into the water seal. Cock 4 is furnished to discharge acetylene from the seal, while try cock 5 is used to check the water level inside the seal.

The water seal works as follows. Water is first poured in through funnel 3, until its level in the seal rises to reach the level of water try cock 5. Pipes 2 and 7 are submerged in the water to different depths; the gas feed pipe being at least 25 mm deeper than the safety pipe.

When gas is admitted into the water seal housing, it passes throuth the layer of water and accumulates above it. Gradually acetylene pressure inside the water seal increases, and the water level drops. Acetylene can now be fed to the torch through cock 4.

As a result of back-fire and consequent pressure rise, water begins to fill pipes 2 and 7 so that the water level drops as low as the end of the safety pipe. This allows the explosive mixture to enter safety pipe 7 and pass through it to the atmosphere; the pressure then drops, water from the pipes flows back into the seal housing, and the initial working state is restored. Should the quantity of water in the seal be too small, with the safety pipe 7 not submerged in the water, acetylene discharge into the air occurs. To prevent this, the welder is required to check the water level inside the water seal housing before commencing work.

S t a r t i n g t h e G e n e r a t o r. To charge the generator with carbide, open retort covers 7 (see Fig. 23), pull out the carbide feed boxes, clean them of slime and fill each box section with carbide to one half of its height; then replace the boxes in their working positions and tightly close the covers.

Prior to starting the generator, pour water into water seal 6, so that the water level reaches the level of try cock 23 (see Fig. 23). Then place a layer of cotton wool on the screen of purifier 5, spread enough purifying material ("geratol") over the cotton wool to reach the discharge nipple level, and tightly close the purifier with its cover. Geratol should be filled in freely, without any packing, and should be replaced after every twenty carbide charges. See that three-way cock 12 is closed, and through funnel 21 fill the generator with water to the funnel bottom edge.

Open the three-way cock, admit water into one of the boxes and for some length of time open the blow-off cock of this particular box in order to bleed the air mixed with the first portions of acetylene.

The discharge cock of the generator should also be opened for some time, to exhaust the first portions of acetylene mixed with air from under the dome.

To discontinue generator operation, close the three-way and discharge cocks.

The rules given below should be strictly adhered to during generator operation:

1. A generator, if it is not located in a special room, etc., should be placed at least 10 m away from the welder's post, as well as from open flames, sources of sparks, or heated articles.

2. On no account should carbide dust be charged into acetylene generators.

Carbide dust in contact with water decomposes with such extreme intensivity that the dust particles become quickly enveloped by gas bubbles and rise to the surface of the water. Here the dust particles form a damp crust. Subsequent batches of carbide dust which gather upon this crust begin to decompose under unfavourable conditions, which may lead to ignition of the acetylene.

3. Prior to starting the generator, the water level inside the water seal housing should be checked. A check should be repeated at least every 2 or 3 hours during generator operation. Should the quantity of water be insufficient, add more water, until water seeps from the water-level try cock 23 (see Fig. 23). Should water flow from this cock be intensive, allow the surplus water to drain off.

Do NOT OPERATE acetylene generators without a water seal. DO NOT CONNECT two torches to the same water seal.

After water is admitted into the retort, the air-acetylene mixture should be discharged from it. This is done by bleeding the mixture into the atmosphere through the blow-off cock, until a flow of pure acetylene appears.

4. Before igniting a torch, allow acetylene to pass through the hose and the torch, so that the air-acetylene mixture is completely expelled from them.

During generator operation, see that there is no gas leakage. Should gas leakage be detected, discontinue generator operation, tighten all the connections, etc., and eliminate gas leakage.

Prior to discharging slime from the retorts, open the try cock (see Fig.23), bring down the pressure, and make sure that the chamber is completely filled with water.

5. When operating the acetylene generator in winter in cold premises or in the open, drain the generator and the water seal of water., if welding is to be discontinued for a considerable period of time. If necessary, the water seal may be filled with a saturated solution of common solt to prevent its freezing.

6. Should freezing of the water occur in the generator or water seal, for warming up use only hot water or steam. On no account should an open flame be used for melting ice inside the generator, or the removal of ice be resorted to by means of a metallic object.

Generator repairs involving its heating when cutting, welding and soldering, as well as other working techniques where sparking may occur, should be performed only after the generator has been cleaned of acetylene and carbide, and after subsequent repeated and thorough washing of the generator parts with water. During washing, the water should fill the entire inner space of the generator.

Generator cleaning, disassembling and washing should be carried out in special premises.

T r o u b l e T r a c i n g. For the principal troubles which may be encountered during generator operation, and for their remedies see Table 2 below.

Table 2

Trouble	Possible Cause	Remedy
1. Failure of automatic water feed.	a) Rubber hose is not air-tight.	a) Check rubber hose and its joints and connections for air-tightness.
	b) Water feed cock or pipe are obstructed.	b) Clear water feed cock and piping.
2. Acetylene leakage through retort during recharging.	a) Hood is not slipped over acetylene dis charge pipe.	a) Check for presence of hood and slip it over discharge pipe end.
	b) Water level inside generator is below required height.	b) Add water to generator to required level.
3. Acetylene leak through retort co-ver.	a) Rubber packing ring of retort cover is torn or badly worn.	a) Repair or replace rubber ring.
	b) Retort cover screw is not tightened.	b) Tighten retort cover screw.
4. Water is thrown from water seal.	a) Foreign load has been placed upon dome.	a) Remove foreign load from dome.
	b) Water seal is over-	b) Drain off

Trouble	Possible Cause	Remedy
	filled with water.	surplus water.
5. Jamming of dome inside generator shell.	b) Dome or generator shell is bent.	b) Straighten dome or generator shell or both.
6. Water inflow into retort through acetylene discharge.	a) Excessive quantity of water has been poured into generator.	a) Check water level and drain surplus water.
7. Acetylene discharge pipes filled with slime.	a) Surplus charging of carbide inside generator.	a) Make sure that there is no surplus carbide feed boxes; see that carbide occupies not over one half of box volume.

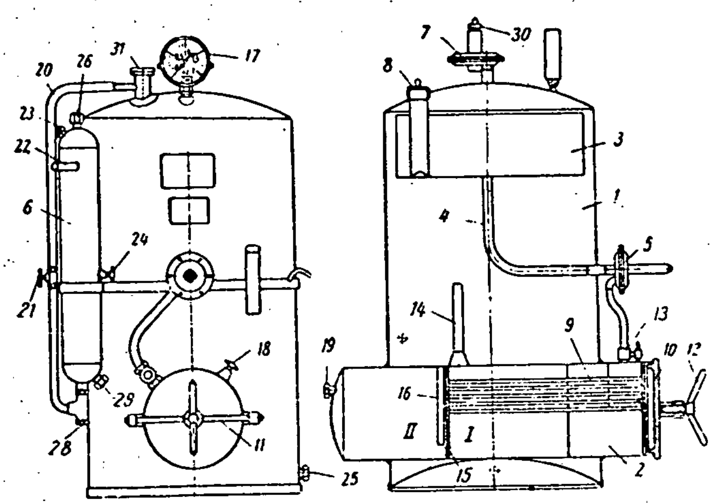


Fig. 26 - Model ГВР-1.25 Acetylene Generator:

1-generator shell; 2-retort; 3-active water tank; 4-pipe; 5-feed water governor; 6-water seal; 7-safety valve; 8-throat; 9-basket; 10-retort cover; 11-cross-piece; 12-screw; 13-cock; 14-acetylene discharge pipe; 15-opening; 16-partition; 17-pressure gauge; 18-try cock; 19-plug; 20-hose; 21-cock;

22-nipple; 23-throat; 24-try cock; 25-drain plug; 26-diaphragm; 27-28-drain plugs; 30-adjusting nut; 31-safety diaphragm.

Model ГВР-1.25 Acetylene Generator - Design and Operating Instructions

The Model ГВР-1.25 acetylene generator (Fig.26) is a single-torch portable generator of the batch-action type. The generator has one retort and operates on a combined principle of contact and "water-to-carbide" systems.

Generator Basic Specifications

Rated acetylene yield	1.25 m^3/hr
Acetylene working pressure, depending upon operational conditions	0.15 to 030 kg/cm^2 g.p.
Maximum pressure inside housing	0.7 kg/cm^2 g.p.
Generator height	935 mm
Generator shell diameter	480 mm
Total sheel capacity	130 l
including of:	
active water tank capacity	24 l
volume of space filled with cooling water	38 l
Generator weight (less water and carbide)	46 kg
Weight of carbide charge	4 kg
Water consumption per charge of carbide	17 l
Size of granulated carbide	25x50 and 50x80 mm
Generator efficiency, at rated output .	86 %

Generator Design.

Welded into the bottom end of generator shell 1 is retort 2. Active water tank 3 is mounted in the top end of the shell. This tank is connected by means of pipe 4 to the feed water regulator which controls water feed to retort 5.

The generator is filled with water through throat 8. Water first fills tank 3 and then overflows its edges and fills up the bottom part of the generator. Water is fed to the generator until the water level in the generator shell rises to the level of try cock 24.

Basket 9 is charged with carbide and placed in retort 2 which is closed with cover 10. Then cock 13 is opened and the process of carbide decomposition by water begins. Acetylene produced as a result of this process passes from the retort via acetylene discharge pipe 14 into the gas manifold.

When the acetylene pressure in the gas manifold rises to 0.18 or 0.20 kg/cm^2 g.p., diaphragm 1 of the feed water regulator (Fig.27) is shifted to the right to close valve 3. In this position water feed is fully cut off.

To ensure normal generator performance, the feed water regulator is so adjusted that water flow into the retort is interrupted as soon as the acetylene pressure in the gas manifold reaches 0.18 to 0.20 kg/cm^2 g.p., and is recommenced as soon as the acetylene pressure in the gas manifold drops again to 0.16 or 0.18 kg/cm^2 g.p. Consequently, the maximum allowable difference in pressure required to cut off and to recommence feed water flow to the retort is 0.02 kg/cm^2 g.p.

Acetylene pressure is adjusted by means of screw 7.

In the course of acetylene generation, due to the reaction between the carbide and the water, the pressure of the acetylene in the gas manifold and inside the retort gradually rises; this results in expulsion of water from the right-hand retort chamber (marked I in Fig.26) to the left-hand chamber (II), through hole 15 in partition 16 (see Fig.26).

Pending water expulsion from chamber I into chamber II, further acetylene generation becomes limited and pressure rise inside the gas manifold is slowed down.

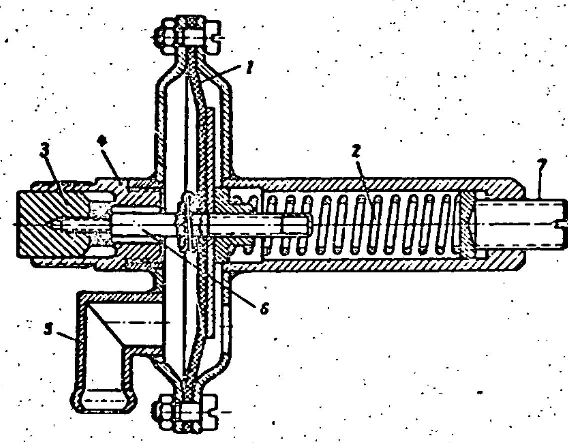


Fig. 27 - Model ГВР-1.25 generator feed water governor.

1-diaphragm; 2-spring; 3-valve; 4-seat; 5-pipe; 6-rod; 7-pressure screw.

When some of the acetylene is taken from the gas manifold (i.e. consumed by the torch), the acetylene pressure in the gas manifold again drops, causing water to leave chamber II and to reestablish contact with the carbide, thus recommencing acetylene generation.

When the gas pressure in the generator drops to 0.16 or 0.18 kg/cm^2 g.p., simultaneously with the flow of water back from chamber II additional water is admitted in the retort through feed water regulator 5; this water supply is discontinued as soon as the acetylene pressure in the gas manifold rises above 0.18 or 0.20 kg/cm^2 g.p.

The generator is equipped with pressure gauge 17 to indicate the acetylene pressure inside the shell. The 0.7 kg/cm^2 point is marked on the pressure-gauge dial by a red line.

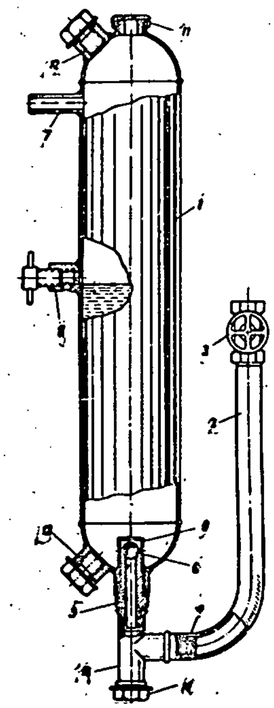


Fig.28 - Model ГВР-1.25 generator water seal.

1-shell; 2-pipe; 3-valve; 4-filter screen; 5-valve; 6-ball; 7-nipple; 8-try cock; 9-cap; 10-drain plug; 11-coupling nut; 12-water filling throat; 13-water drain outlet; 14-tee-piece.

Try cock 18 serves to control retort performance. The retort is drained after washing through plug 19.

Acetylene is supplied from the generator through hose 20, valve 21, water seal 6 and nipple 22 (see Fig.26).

The water seal (Fig.28) of the Model ГВР-1.25 generator consists of shell 1 with a check valve screwed into the bottom. This valve has the shape of pipe-connection 5 whose bore is closed by ball 6 provided with a thin rubber coating. Ball lift is restricted by means of cap 9 provided with side ports.

Screwed on to the pipe-connection bottom end is tee 14. Pipe 2, designed to pass acetylene from the generator to the water seal through valve 3, is screwed into the side opening of the tee.

The bottom end of the tee is closed with a plug serving for the draining of water from the acetylene-feed pipe and the pipe-connector fitting.

Screen 4 detains carbide slime particles and protects the check valve against clogging.

The bottom end of the shell is provided with water drain nozzle 13; the top end-with filler throat 12 through which water is poured into the seal shell.

To ensure greater tightness, the plugs are provided with rubber gaskets.

Located in the water seal top end is a rupturing-type diaphragm made of tin, aluminium or some other foil. By means of coupling nut 11 the foil diaphragm is secured between two rubber gaskets.

Nipple 7 designed for take off of acetylene through the hose and for torch supply is located in the upper section of the shell side wall; try cock 8 being arranged in the middle section.

Prior to starting the generator, water is poured through throat 12 into the water seal shell, until the water level rises flush with try cock 8, after which the latter is closed.

The operational principle of the water seal is as follows. After valve 3 is opened, acetylene passes through pipe 2 and filter 4, then it lifts valve 5 and on having passed through the water layer inside the seal, leaves the seal shell through nipple 7 to enter the hose leading to the welding torch.

In cases of oxy-acetylene flame back-fire, the acetylene pressure in the water seal shell rises and is transmitted by the water to the ball which is pressed against the seat, thus preventing an abrupt rise in pressure in pipe 2 and the generator.

Simultaneously, as a result of the abrupt rise in acetylene pressure in the generator shell, the foil diaphragm is ruptured by the explosion pressure, and surplus acetylene is discharged into the air.

Operating the Generator. The diaphragm for the water seal should be made of a piece of foil that has been previously tested. The diaphragm is then placed between two rubber or ebonite gaskets and secured by coupling nut 11 (see Fig. 28). Nut 11 should be screwed on carefully, to prevent rumpling or scratching of the diaphragm.

The diaphragm should be free of defects, such as dents, scratches, folds, etc.

Diaphragms may be manufactured of tin, aluminium or lead foil. Copper foil is not to be used.

If the diaphragm working diameter is 12 mm, and when gas pressure rises gradually, the diaphragm should normally break at a pressure of 2 to 3 kg/cm^2 g.p.; at a static pressure of 0.7 kg/cm^2 g.p. the diaphragm should retain its gas-tightness for a period of one hour and should not undergo a deformation of over 4 mm.

The diaphragms are checked for the above characteristics after they have been kept in water for a minimum period of two hours.

In addition to diaphragm checking, the air-tightness of the entire water-seal assembly is checked. This is done by plugging the acetylene take off nipple and by pumping gas in through pipe 2, until a pressure of 1.5 kg/cm^2 g.p. is obtained inside the water seal. All the joints are covered with soap foam and are then examined for soap-bubbles which should not appear during the first two minutes of the test, if the joints are tight.

Prior to starting the generator, check the following items:

a) See that the seals on the safaty valve and feed water regulator are intact.

b) See that diaphragm 26 of the water seal and diaphragm 31 in the generator cover are intact.

c) See that pressure-gauge seal is intact.

To prepare the generator for starting, proceed as follows:

a) fill the water seal with water until its level rises as high as try cock 24;

b) open try cock 27 located on the generator shell wall, and then charge water through filler throat 8 into the top tank and the shell, until it begins to flow from cock 27;

c) open cock 13 and make sure that water is fed to the retort;

d) close try cocks 24 and 27, cock 13 and throat 8.

Prior to each initial starting of the generator, it should be blown off. Proceed as follows. Charge basket 9 with about 1 kg of carbide, place the basket in position inside retort 2 and tightly close the retort with cover 10.

Open cock 13, admit water into the retort and use the acetylene that has now been produced, to blow off the generator, the acetylene to be discharged through the water seal.

The above blowing-off should be performed whenever intervals between discharging and charging of the generator are in excess of 30 minutes, with the retort cover open.

To recharge the retort, proceed as follows:

a) open try cock 18, to discharge water and gas;

b) open the retort cover, remove the basket, clean the retort of slime, wash the basket and dry it without using an open flame;

c) add water to water tank 3 (see Fig.26).

Do not open the retort cover until the water and gas have been discharged from cock 18.

A maximum 4-kg charge of 25 x 50 or 50 x 80 -mm granulated carbide should be placed into basket 9, the carbide level reaching the level of the basket top rods.

To start the generator, open cock 13 and admit water into the retort.

During acetylene take off, see that the cooling water temperature does not rise above 60°C (which temperature can be felt by hand), and that the gas pressure inside generator shell is not in excess of 0.7 kg/cm^2 g.p.

When the carbide charge is consumed, water will appear as soon as try cock 18 is opened. To recharge the generator, close cock 13, to cut off water feed to the retort, and then proceed with the actual recharging.

After the consumption of each individual carbide charge, add some more water to tank 3. To do so, open try cock 27 and through the filler throat pour water into tank 3, until water flows from cock 27. Then close plug 8 and cock 27. Keep in mind, that plug 8 should not be opened with the view of pouring water into the generator, until the pressure is reduced by discharging gas through cock 18 of the retort; otherwise water will be pressure-forced through the filler pipe-union and air will penetrate into the generator shell (Fig.26).

Should, after several successive rechargings, the temperature of the cooling water rise above 60°C , the cooling water should be replaced. To do so, first continue generator operation until the last charge of carbide is consumed, and then remove the slime from the retort; further, through plug 25 drain the generator of cooling water and, after having closed plug 25, refill the generator with fresh cooling water.

Prior to restarting generator operation, blow it off with acetylene, as instructed above.

Check water level in the water seal at least three times during a working shift and after each back-fire, if it occurs.

If necessary, add water to the water seal through throat 23, until it rises to the level of try cock 24.

In winter, if the generator is stored in unheated premises, it should be drained of water to prevent freezing. Water is drained:

a) from the generator shell, through plug 25;

b) from tank 3, through cock 18 and retort 2;

c) from the water seal, through drain plugs 28 and 29.

At least once every two weeks screw out the check valve of the water seal, clean it and check its tightness by water.

Prior to each recharge of carbide, wash the retort and the charge basker with water.

In the course of generator repairs or preventive maintenance which should be performed at least once every three months, thoroughly check generator fittings and eliminate gas leaks in the joints, try cocks and other cocks. It is recommended that the cocks be greased with technical vaseline.

To check and adjust the feed water regulator, proceed as follows (see Fig.26).

a) fill top tank 3 with water (see Fig.26);

b) tightly close the generator retort with its cover;

c) using a hose, connect the generator retort through try cock 18 to a cylinder with compressed air. The compressed air should be supplied to the retort through a reducer which allows the air pressure to be adjusted between 0 and 0.5 kg/cm^2 g.p.;

d) set up an air pressure of 0.15 kg/cm^2 g.p. inside the retort (as registered by pressure gauge 17, Fig.26);

e) by turning cock 13 admit water into the retort; then slowly screw in regulator screw 7 (see Fig.27) and watch for the beginning of feed water flow, judging it by the sound of flowing water;

f) slowly increase the air pressure in the retort. At a pressure of 0.18 to 0.20 kg/cm^2 g.p. the flow of feed water into the retort is to be discontinued (as judged by the sound). Should feed water flow be discontinued at a pressure above 0.20 kg/cm^2 g.p., slightly turn out screw 7, reduce the air pressure inside the retort and perform the entire check once more.

A regulator which is in a good condition, if adjusted to cut off water supply at pressures of 0.18 to 0.20 kg/cm^2 g.p. ensures resumption of water supply as soon as the pressure drops to 0.16 or 0.18 kg/cm^2 g.p.

After this adjustment is completed, proceed as follows:

a) close cock 13, drain water from the retort and close it, raise the pressure in the retort up to 0.10 kg/cm^2 g.p. and open cock 13 for one or two minutes. Close cock 13, reduce the pressure, and open the retort; see that the retort containes water;

b) drain the water from the retort, close it, raise the pressure to 0.20 kg/cm^2 g.p., open cock 13 for one or two minutes, then close it again, reduce the pressure and open the retort; see that there is no water in the retort.

Should the above checks give positive results, seal the feed water regulator.

The feed water regulator should be adjusted only after all faults in the regulator itself have been eliminated, and the adjustment work should be supervised by the head of the shop or a foreman.

The diaphragm safety valve should be adjusted only after repairs, or in cases of slackening of the spring. The safety valve should guarantee full air-tightness at a pressure of 0.69 kg/cm^2 g.p., and the discharge of acetylene at 0.70 kg/cm^2 g.p., thus preventing a pressure rise inside the generator shell. When gas pressure in the shell drops, the valve discontinues gas discharge, the minimum discharge pressure being 0.65 kg/cm^2 g.p.

To adjust the valve, proceed as follows:

a) Remove the seal from the valve;

b) Raise the pressure in the generator shell and, by turning adjusting nut 30, adjust the valve for the commencement of air discharge at 0.70 kg/cm^2 g.p. (See Fig.26);

c) with gradual consumption of acetylene from the generator, make sure that the valve discontinues gas discharge at a minimum pressure of o.65 kg/cm^2 g.p.;

d) seal the safety valve again.

For principal troubles which may be encountered during generator operation, and for their remedies see Table 3 below.

Table 3

Trouble	Possible Cause	Remedy
1. Failure of water feed into retort.	a) Water feed pipe at feedwater regulator is obstructed.	a) Remove hose from water feed nipple and clear pipe leading

Trouble	Possible Cause	Remedy
		to retort.
	b) Screen filter located in pipe leading to feed water regulator is obstructed.	b) Carefully remove the regulator, without impairing its adjustment, remove filter, rinse it and place it in position.
	c) Feed water regulator is obstructed.	c)Remove and rinse feed water regulator, taking special case not to impair its adjustment.
2 After starting, pressure inside generator rises to 0.7 kg/cm^2 g.p. and acetylene discharge through safety valve begins.	a)Plug of retort chamber II is not tight and permits gas to leak, and too much water has flown into chamber II.	a)Tightly screw plug into pipe connector and consume carbide charge without opening retort.
	b)Hole connecting chambers I & II is plugged with slime.	b) Irrespective of gas losses, consume carbide charge without opening retort. During subsequent retort recharge clear hole connecting chambers I & II.
3-When acetylene consumption is discontinued, pressure inside generator rises	a)Carbide possessing acetylene yield of below 250 1/kg has been used.	a)Consume the carbide charge and for subsequent charges use carbide of minimum 250-1/kg

TRouble	Possible Cause	Remedy
to 0.7 kg/cm^2 g.p. in less than 10 min., resulting in acetylene discharge through safety valve.		acetylene yield.
	b)Carbide granulation in sizes below 25x50mm have been used.	b)Consume the carbide charge and for subsequent charges use carbide of 25x50 and 50x80mm granulation.
	c)Water supply cut off has been adjusted for a pressure above 0.2 kg/cm^2 g.p.	c)Readjust water supply cut off.
4. When acetylene is being consumed, pressure inside generator shell remains below 0.1 kg/cm^2 g.p.	a)Water supply cut off has been adjusted for a pressure below 0.18 kg/cm^2 g.p.	a)Readjust water supply cut off as required.

§ 8. Cylinders, valves and Reducers

Oxygen is transported and stored in cylinders (Fig.29) which are manufactured of seamless steel tubes.

A 40-liter cylinder contains 6,000 liters of oxygen at a pressure of 150 kg/cm^2. The thickness of the cylinder walls is 8,0 mm, cylinder weight is 67 kg.

Oxygen cylinders are painted blue, with the word "Oxygen" marked in black letters.

Acetylene is simetimes delivered to the working site also in cylinders (Fig.30).

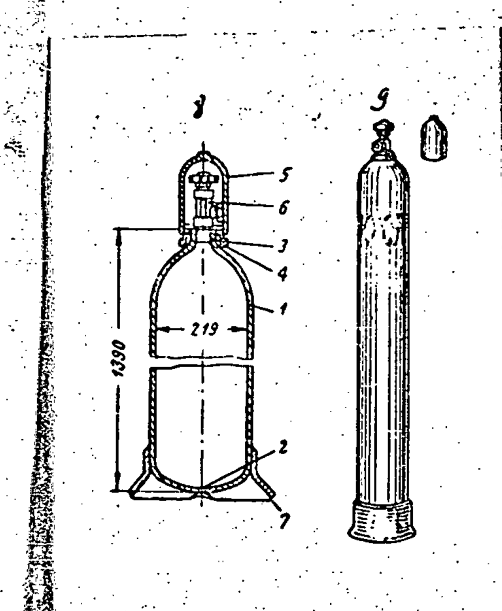


Fig.29. - 40-liter oxygen cylinder.

1-cylinder; 2-bottom; 3-throat; 4-ring; 5-cap; 6-valve; 7-shoe; 8)longitudinal section; 9)external view.

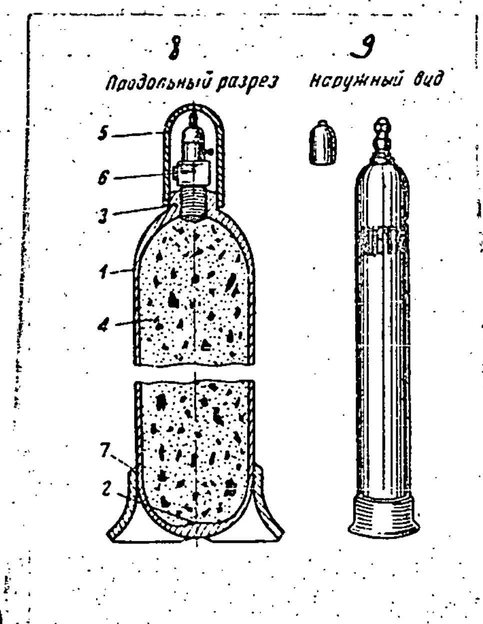


Fig.30. - 40-liter acetylene cylinder.

1-cylinder; 2-bottom; 3-throat; 4-porous filling; 5-cap; 6-valve; 7-shoe; 8)Longitudinal section; 9)External view.

An acetylene cylinder is filled with a porous material (МГ-100) consisting of activated charcoal impregnated with acetone.

Then an acetylene valve is screwed into the cylinder throat and the porous material is impregnated with acetylene.

Shown in Fig.30 is the longitudinal section of an acetylene calinder filled with the porous material and equipped with a stop valve.

During transportation, the valve is protected by cap screwed down over the throat of the cylinder.

Once in three years acetylene cylinders, as well as oxygen cylinders, are subjected to a test in the works where they are charged with gas.

After each test, the test data and the date of the next obligatory test are stamped on the cylinder wall.

Thus, if a cylinder has been tested on December, 10, 1953, stamped on its wall will be the date of the next test-December, 10, 1956.

Until this date, the cylinder may be repeatedly filled with gas and used as prescribed.

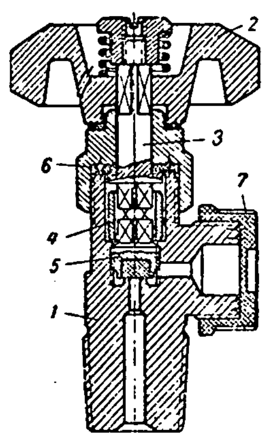


Fig. 31. Oxygen valve.

1-body; 2-hand wheel; 3-stem; 4-intermediate coupling; 5-valve proper; 6-packing gasket; 7-closing cap.

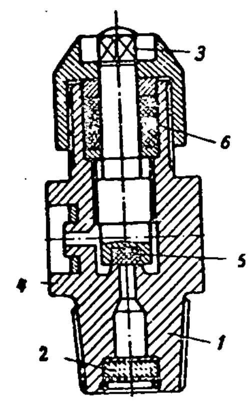


Fig. 32 Acetylene valve.

1-body; 2-filler; 3-spindle; 4-outlet; 5-valve proper; 6-packing gland.

After the said date, the cylinder should on no account be used and should be sent to the works, for retesting. Acetylene cylinders are painted white.

The valves (Figs. 31 & 32) are designed to facilitate cylinder filling and discharge of gas during welding. The valves are manufactured of brass and are screwed into the cylinder throats.

According to the gas used in the cylinders, the valves are classified as oxygen and acetylene valves.

Before starting work, the valves should be thoroughly inspected and blown off.

During blowing off, the operator should stand to one side of the valve outlet, because, otherwise, he may be wounded by fine metal particles being blown from the cylinder.

To check the valve, it should be opened without using any tools, by a short turn of the hand wheel. If the valve is out of repair, it will fail to open, and the gas will not be discharged from the cylinder.

On no account should such a valve be disassembled at the site of work. A cylinder with a defective valve should be sent back to the works for repairs.

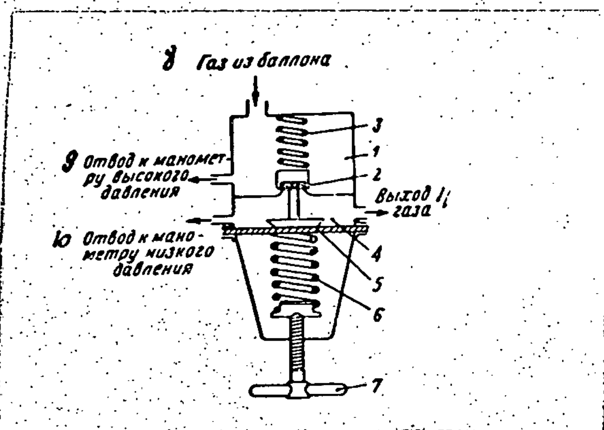


Fig.33. - Schematic diagram of reducer:

1-high-pressure chamber; 2-reducing valve; 3-closing spring; 4-low pressure chamber; 5-diaphragm; 6-pressure spring; 7-adjusting screw; 8) Gas from cylinder; 9) H.P. pressure gauge connection; 10) L.P. pressure gauge connection; 11)Gas outlet.

Reducers (Fig.33) are designed to ensure low constant pressures of the welding gas.

The reducer comprises high-pressure chamber 4 and low-pressure chamber 1. The opening through which the two chambers communicate is closed by reducing valve 2 which is pressed against the edges of the opening by closing spring 3. Chamber 4 is closed by diaphragm 5 connected to valve 2. Located on the opposite side of the diaphragm are pressure spring 6 and adjusting screw 7.

When the reducer is not in action, pressure spring 6 is released; closing sprinf 3 tightly presses valve 2 against the opening, thus preventing the gas from flowing into chamber 4. When adjusting screw 7 is screwed in, spring 6 is compressed and presses against diaphragm 5 which forces valve 2 to shift and open for passage of the gas into chamber 4.

Should the rate of gas supply and gas consumption in the reducer be equal, the working pressure remains constant, and diaphragm 5 also remains in a constant position. Should gas consumption become greater, the pressure in chamber 4 begins to drop. This results in valve 2 being opened to allow increased gas feed into the low-pressure chamber.

A decrease in gas consumption in the course of welding causes a pressure rise in chamber 4 of the reducer. Since the force applied to diaphragm 5 increases, the diaphragm deforms in the opposite direction, thus allowing closing spring 3 to press valve 2 against the opening. When gas consumption from the reducer is discontinued, valve 2 automatically closes.

The gas pressures in chambers 1 and 4 are indicated by pressure gauges.

The above description covers the performance of the so called single-stage (or single-chamber) reducers (Fig. 34). However, single-stage reducers have an important weak point when used as acetylene reducers.

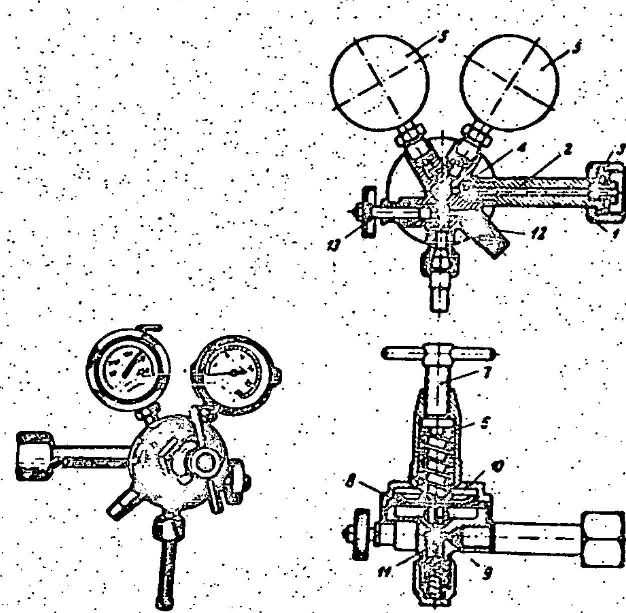


Fig. 34. - Model PK-39 single-chamber oxygen reducer.

1-coupling nut; 2-connection pipe; 3-filter; 4-heat absorber; 5-pressure-gauges; 6-pressing spring; 7-adjusting screw;

8-diaphragm; 9-stud; 10-intermediate sprindle; 11-reducing valve; 12-safety valve, for measuring working pressure; 13-stop valve.

When oxygen pressure is reduced from 150 kg/cm^2 to the working pressure of 3 kg/cm^2, an intensive temperature drop occurs, which results in the freezing of valves and reducers, since gaseous oxygen contains a certain percentage of moisture.

The two-stage (or two-chamber) reducers (Fig. 35) are free of these defects.

The specific design feature of these reducers lies in that the process of pressure reduction is subdivided into two stages. Thus an abrupt temperature drop is eliminated and, consequently, the danger of freezing is also abolished. Such a reducer is in fact a combination of two reducing valve assemblies, with two reducing valves and two reducing chambers. The two-stage reducer ensures smooth low-gradient pressure reduction, thus not only eliminating freezing but also contributing to the maintaining of a constant value of required working pressure.

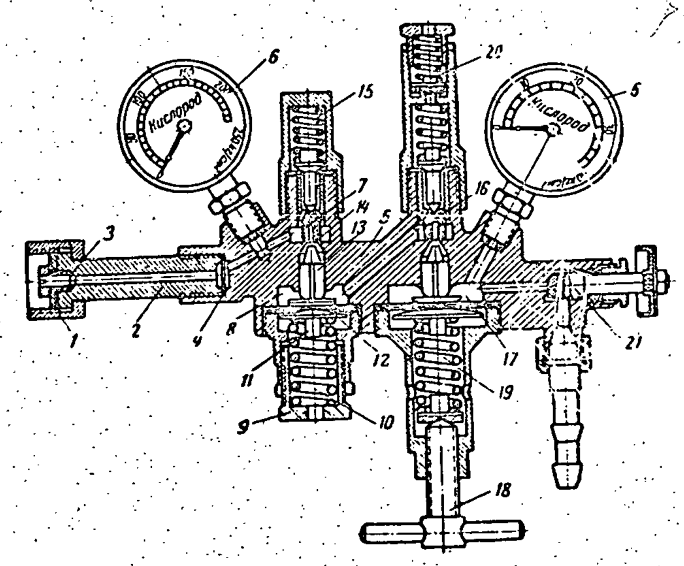


Fig. 35. - Two-chamber oxygen reducer.

1-coupling nut; 2-connection pipe; 3-filter; 4-heat absorber; 5-body; 6-pressure gauges; 7-1-st stage reducing valve; 8-1-st reducing chamber; 9-adjusting nut; 10-main pressing spring; 11-pressing disc; 12-diaphragm; 13-intermediate disc; 14-stud; 15-closing spring; 16-2-nd stage reducing valve; 17-2-nd stage reducing chamber; 18-adjusting screw; 19-2-nd stage pressing spring; 20-safety valve; 21-reducer stop valve.

According to the gas they are intended for, reducers are painted in different colours and are provided with different appliances for securing them to corresponding gas cylinders.

For reducer distinctive colours and methods of securing see Table 4.

Table 4

Working gas	Oxygen	Hydrogen	Acetylene
Reducer colour	Light blue	Khaki	White
Method of securing	Coupling nut, with 3/4-in. R.H. thread	Coupling nut, with 21.8-mm dia. L.H. pipe thread	Clamp with pressing screw (See Fig.36)

The 21.8-mm diameter thread is used for the valves and reducers of all cylinders intended for the storage of inflammable gases under a pressure of 150 kg/cm^2.

The Model PK-39 single-stage oxygen reducer (Fig. 34) is connected to the valve assembly by means of coupling nut 1. Gas flows along the bore of connection pipe 2, passes through filler 3 and heat absorber 4, and enters the high-pressure chamber of the reducer. When pressing spring 6 is compressed by means of adjusting screw 7, to make diaphragm 8 bulge so that stud 9 of intermediate spindle 10 is pressed against reducing valve 11, and the opening for gas flow into the low-pressure chamber is freed. Gas, on entering the low-pressure chamber, expands and reaches the required working pressure which is maintained approximately constant in the process of work. The low-pressure chamber is provided with spring-type safety valve 12 which bleeds gas into the atmosphere, should the gas pressure rise as high as 20 to 25 kg/cm^2 g.p. Stop valve 13 provided on the reducer permits discontinuation of gas consumtion whenever necessary. The single-chamber reducer is subjected to freezing at high rates of gas consumption, and especially in winter.

The acetylene reducer shown in Fig. 36 differs from the oxygen reducer only in the method .

of attachment to the cylinder, i.e. a clamp being used instead of the coupling nut employed on the oxygen reducer.

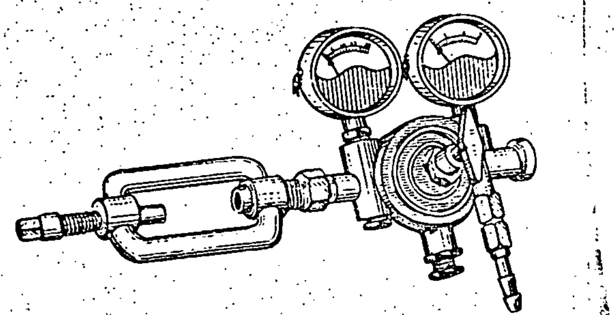


Fig. 36. Acetylene reducer

The two-stage oxygen reducer (Fig. 35) has high - mean, and low-pressure chambers. Gradual, successive expansion of the gas takes place in the mean- and low-pressure chambers. Oxygen passes through filter 3, heat absorber 4 and enters the high-pressure chamber, where the gas pressure is equal to that inside the cylinder. Further, through reducing valve 7 gas enters the first reducing chamber 8 and expands here to a pressure of 35 kg/cm^2 g.p. The pressure value in the intermediate chamber is adjusted by means of pressing spring 10. This spring, acting through disc 11, diaphragm 12 and stud 14, lifts valve 7. Valve 7 is moved back into its initial position by means of closing spring 15.

Having passed through the second reducing valve 16, oxygen enters the second reducing chamber 17, where it expands until its pressure drops to the normal working value. This value may be set for pressures within a range of from 1 to 15 kg/cm^2 g.p. by means of adjusting screw 18. Pressures are indicated by pressure-gauges 6.

The following rules should be adhered to when using a reducer:

1. Prior to connecting an oxygen reducer to the cylinder valve, make sure that there are no signs of oil or grease on the reducer coupling nut; if detected, thoroughly wash the reducer with aircraft-engine gasoline and then dry it. Remember that compressed oxygen on coming into contact with oil may cause an explosion.

2. Blow off the cylinder valve in order to remove dirt, shavings, scale and other mechanical admixtures that may cause damage to the reducer.

3. Prior to connecting the reducer, make sure that the adjusting screw is fully turned back.

4. After the reducer is connected, slowly open the cylinder valve. Then, by turning the adjusting screw clockwise, adjust the pressure gauge for the required working pressure. Normal oxygen welding pressure is 1.5 to 3.5 kg/cm^2 g.p.

5. On completion of work, close the cylinder valve, discharge gas that has been left in the reducer, and release the spring by turning the adjusting screw counter-clockwise.

6. For short periods of standstill, it is sufficient to close the cylinder valve.

7. In cases of freezing of the reducer, use only hot water or steam for defreezing; DO NOT USE an open flame for this purpose.

Principal reducer troubles and their elimination

1. Leaky joints. During reducer operation leaks may develop at certain points, thus increasing gas losses. In order to detect leaky joints, attach the reducer to the cylinder, close its stop valve, open the cylinder valve, adjust the working

pressure and coat the reducer with soapy water. Soap-bubbles will appear at points of gas leak. Now remove the reducer from the cylinder and eliminate detected leaks as described below.

1) Leak under connection pipe coupling nut should be eliminated by tightening the nut with a wrench or by replacing the fibre gasket.

2) To eliminate leaks from under pressure -gauge unions, tighten the pressure gauge nut with a spanner or replace the fibre gasket.

3) Should the pressure-gauge case prove to be leaky, this means that the pressure-gauge spring pipe is not air-tight, and the defective pressure-gauge should be replaced.

4) If reducer caps are not tight enough, tighten them up with a spanner or replace the fibre gaskets laid under the caps.

5) Should leaks occur under the reducer covers or through the cover holes, tighten the covers with a spanner or replace the gasket; if this brings no improvement, replace the rubber diaphragm.

6) To eliminate leaks in the safety valve, discontinue gas flow through the reducing valve.

7) If the packing gland of the reducer stop valve proves to be leaky, tighten the packing gland nut; should gas continue to leak, replace the packing gland gaskets.

2. <u>Spontaneous gas flow.</u> The usual causes of spontaneous gas flow are:

1) foreign metal articles, such as shavings, scale, etc., which get under the valves;

2) valve seat surfaces which have become rough and uneven;

3) ebonite gasket surface, which is uneven and porous;

4) sagging of an ebonite gasket or steel pin inside the seat;

5) damaged or slack closing springs;

6) jamming of a valve in its valve guide.

To eliminate spontaneous gas flow, disassemble and thoroughly examine the reducer. Should foreign matter be present under the valve, clean the seat and the valve proper and grind them in with Nos. 140 or 170 emery paper. Prior to installing the valve in position, thoroughly blow off the reducer, in order to remove metal particles and shavings which might have left in the reducer passages. If the valve packing has lost elasticity, or the steel pin has sunk, the valve should be replaced.

3. Obstructed reducer. The reducer filter has gradually become clogged with the particles of rust, scale, dirt, etc. discharged from the cylinder or piping and detained by it with resultant hampering of gas flow into the reducer.

For the above reason, the filter should be thoroughly cleaned of dirt and then rinsed. This is to be done at regular intervals of time by turning the nipple out of the high-pressure chamber and cleaning the filter located under this nipple. Should the metal screen of the filter happen to be torn, the screen should be replaced.

4. Drop in working pressure. If the adjusting screw is screwed in as far as it will go, and the working pressure still remains comperatively low, this shows that the reducer is out of order. The cause may lie in the breaking or slackening of the pressing spring, or the bending of the steel pin of the intermediate disc. Such defective parts should be replaced.

5. Freezing. Sometimes, during reducer operation the working pressure begins to drop or fluctuate sharply, irrespective of the fact that the cylinder still contains a considerable quantity of gas. This indicates that the reducer has frozen. Such being the case, close the cylinder valve and warm the

reducer by the use of hot water or steam. After warming, the reducer should be blown off, and only after this the work may be resumed.

§ 9. Welding Torches and Operator's Tools

The mixing of acetylene and oxygen and the producing of the welding flame is performed by the welding torches.

According to their principle of operation, the welding torches are divided into two groups, i.e. low-pressure (injector-type) torches and high-pressure (non-injector-type) torches.

An injector torch can be operated at an acetylene inlet pressure of o.02 to 0.08 kg/cm^2 g.p. and an oxygen pressure of about 3.0 to 3.5 kg/cm^2 g.p., irrespective of the tip being used. In high-pressure torches the oxygen and acetylene are admitted at an equal pressure of 0.5 to 0.7 kg/cm^2 g.p.

In aircraft repair, the commonly used torches are those of the low-pressure injector type, i.e. Models СГМ-47, СУ and "Liliput".

The welding torch (see Fig. 37) consists, in the main, of the body tip and end piece.

The body is that part of the torch which contains passages for the acetylene and oxygen. The body is provided with two nipples for connection to the flexible rubber hoses. The body serves simultaneously as the torch handle.

The torch tip comprises the injector and the mixing chamber. Each torch is furnished with a complete set of tips . By changing the tips, a flame of required intensely can be obtained.

The end part of the tip through which the stream of working mixture is discharged is termed the end piece. The end pieces may be of an interchangeable type, or may be made integral with the tip.

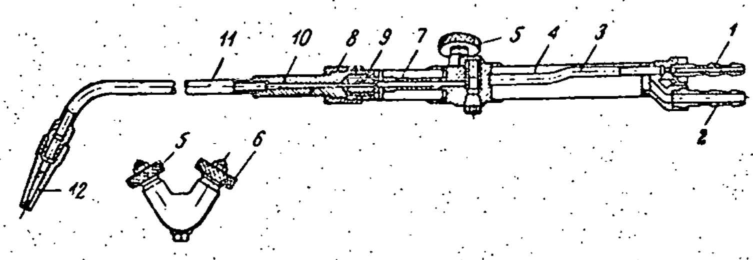


Fig.37 - Model CУ Welding Torch.

1-oxygen nipple; 2-acetylene nipple; 3-pipe; 4-handle; 5 & 6-valves; 7-intermediate pipe; 8-coupling nut; 9-injector; 10-mixing chamber; 11-pipe; 12-end piece.

The Model CУ universal welding torch (see Fig.37) is designed for the oxy-acetylene welding of metals of o.5 to 30-mm thickness. The torch is provided with a set of interchangeable tips and a cutter, all these tools being made of brass or red copper. The torch is termed universal since it is suitable for welding metals of different sections, as well as for gas cutting.

In this torch oxygen admitted into the torch through the rubber hose attached to nipple 1 passes further via pipe 3 into the central opening of injector 9. The acetylene fed through the hose via nipple 2 and hollow handle 4 enters the intermediate pipe torch from which it flows into the circular passage of the injector. Oxygen, on leaving the injector nozzle bore at a high velocity, creates a vacuum inside the circular injector passage and thus sucks in the acetylene. The quantities of gases admitted into the injector are controlled by means of valves 5 (oxygen valve) and 6 (acetylene valve). The tip is attached to the torch body by means of coupling nut 8, which is screwed down on the threaded length of intermediate pipe 7.

Stamped on each tip is a figure indicating the acetylene consumption (l/hr) for which the particular tip is designed.

The "Liliput" torches differ from Model СУ torches both in weight and intensity of the welding flame.

For the principal Specifications of the injector torches manufactured in the USSR, see Table 5.

Table 5

Torch Model	СУ	"Liliput"	СГМ-47	СТБ	СТМ	СУ-48	СГ
Maximum thickness of metals welded	0.5 to 30.0	0.2 to 4.0	0.5 to 6.0	2.0 to 20.0	0.2 to 4.0	2.0 to 20.0	0.2 to 4.0
Number of tips	8	–	4	2	–	4	4
End pieces, numbers	1 to 7	00 to 2	0 to 3	2, 3, 5 & 6	00 to 2	2, 3, 5 & 6	00 to 2

The gas welder is required to wear goggles with blue or dark glasses when working. On the work site he should be provided with hoses for gas supply, a wedge-pointed hammer for chipping scale from the welds, steel brushes for weld cleaning, a chiesel-type hammer for cutting away solidified drops of deposited metal, pliers for handling light workpieces during welding, a piece of chalk used for plotting or marking, and a box for storing filler rods and studs.

CHAPTER V

OXY-ACETYLENE WELDING TECHNIQUES AND PRACTICES

§ 10. Gas Flame, and Practical Methods of Operating the Torch

During welding, complete combustion of acetylene in the atmosphere of oxygen takes place in two stages, namely: partial combustion of the acetylene by the oxygen fed from the torch which takes place according to the reaction:

$$C_2H_2 + O_2 = 2CO + H_2,$$

and combustion of the acetylene by the aid of atmospheric oxygen, according to the reaction:

$$4CO + 2H_2 + 3O_2 = 4CO_2 + 2H_2O$$

In order to obtain a neutral flame, taking into consideration that a certain quantity of H_2O is also produced during the first stage of combustion, about 1.15 volumes of oxygen are introduced into the torch per volume of acetylene.

To ignite the gas mixture discharged from the torch tip, proceed as follows:

1) take the torch by the left hand;

2) by the right hand first turn the oxygen valve 1/3 of a full turn, and then the acetylene valve, 3/4 of a full turn;

3) quickly strike a match and ignite the oxy-acetylene mixture;

4) adjust the flame.

Immediately after the torch is ignited, its flame may be of three different kinds (Fig. 38), depending upon the proportion of the gases, namely: 1) a neutral flame, 2) a carbonizing flame (with acetylene surplus), and 3) an oxidizing flame (with oxygen surplus). Ferrous metals are, as a rule, welded with a neutral flame. Non-ferrous metals and alloys are normally welded with a flame containing a small acetylene surplus. The use of an oxidizing flame for the purposes of welding is not allowed.

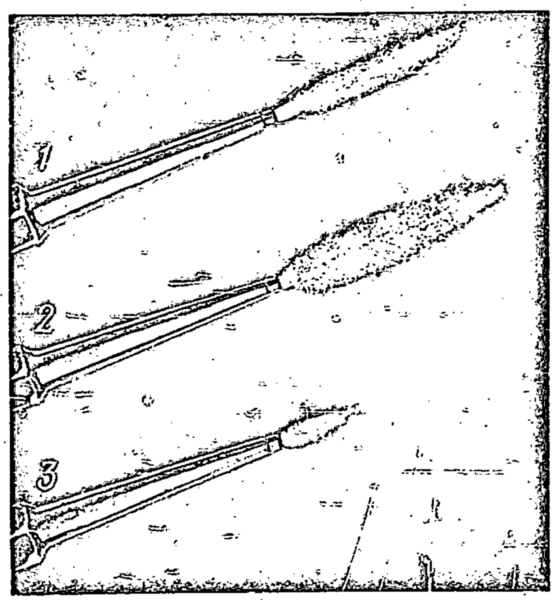


Fig. 38 - Kinds of acetylene flames.

1-neutral flame; 2-reducing flame; 3-oxidizing flame.

The flame is adjusted on the basis of its external appearance. In order to be able to adjust the welding flame, one should be familiar with its composition and shape.

The neutral flame consists of three zones, a central dazzling white nucleus of round-nose shape, a middle or reducing zone, and the outer enveloping zone of full combustion in the form of yellow-red flame.

The carbonizing flame is produced when a surplus of acetylene exists. It is longer than the neutral flame. A thin layer of free carbon having the shape of a tongue can be seen to separate from the central nucleus of the carbonizing flame. Should the acetylene surplus increase still more, the flame becomes noticeably extended. The central nucleus merges with the flame and has an orange-red colour. The oxidizing flame is obtained when the proportion of the gases is $\frac{O_2}{C_2H_2} > 1.2$. The oxidizing flame is shorter than the neutral flame. The central nucleus is somewhat shortened and has the form of a sharp cone. The oxidizing flame is of a violet colour.

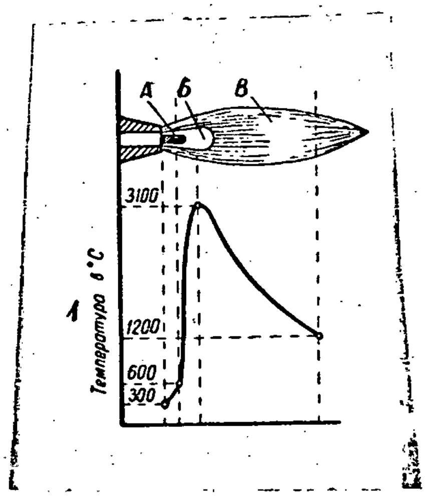


Fig. 39. - Temperature zones of an acetylene flame.
A-central nucleus; B- middle reducing zone; C - full combustion zone; 1) Temperature, deg.C.

The temperature of the neutral flame alters along its length as shown ba the curve in Fig.39.

The highest temperature, approaching 3100°C, is produced in the centre of the middle reducing zone of the flame, at a distance of 2 or 3 mm from the edge of the central nucleus.

To ensure obtaining of a neutral flame, at the beginning of welding, adjust for a small surplus of acetylene in the flame, bearing in mind that in the process of work, owing to the heating of the torch, the proportion of the gases being admitted may alter so that the percentage of oxygen will increase.

It should also be remembered that, when the flame is adjusted as required, the acetylene valve should not be fully opened, as otherwise there will be no possibility to eliminate a surplus of oxygen resulting from heating of the torch.

To adjust welding flame, proceed as follows:

1. Take the torch in the left hand.

2. By the right hand open the acetylene valve so that a definitely carbonizing flame is produced.

3. Gradually open the oxygen valve until the flame nucleus becomes sharply distinguishable and dazzling white in colour.

Operating the Oxy-Acetylene Torch

Prior to starting work, check the condition of the torch. Proceed as follows. Slip the oxygen-hose on the oxygen nipple. Having adjusted oxygen pressure in the reducer, open the oxygen valve of the torch.

A deep vacuum should be produced in the acetylene side of the torch, which can be easily detected by pressing the finger to the acetylene nipple. After making sure that the required vacuum exists in the torch bore, connect the acetylene hose to the corresponding nipple and start work.

Should there be no vacuum inside the torch, or should the vacuum be too weak, remove the tip and inspect the torch.

The following reasons may account for the absence of vacuum:

1) The joint between the injector and the nozzle on to which the injector is fitted when the tip is placed in position is not sufficiently air-tight. To eliminate this defect, clean the injector and the nozzle, and grindthem in, if necessary.

2) The end piece, injector or mixing chamber are obstructed, which hampers oxygen discharge. To eliminate this defect, clear the corresponding bore inside the torch.

3) The joint between the acetylene and oxygen passages is not air-tight. To detect the leak, close both adjusting valves of the torch and apply pressure through the oxygen nipple. Should gas bleed through the acetylene nipple, it shows that the oxygen pipe is leaky. In this case the torch should be turned over for repairs.

Should shot-like cracking occur when the torch is ignited, or when no surplus of acetylene is attained when the acetylene valve is fully opened, tighten the coupling nut of the tip, or raise oxygen pressure.

The torch should be ignited as quickly as possible, as otherwise a considerable quantity of the inframmable gas mixture, which can explode on ignition, will accumulate around the end piece.

To extinguish the torch, first close the acetylene, and then the oxygen valves of the torch.

If, though the valve has been closed, gas continues to hiss in the hoses, without loosing a second, bend the hoses as far from the torch as possible, or, still better, close, if possible, the reducer valve and the acetylene cock on the water seal.

Do not dip a torch with open or untightly closed valves into water, since this is dangerous as an explosion may occur.

If back-fires occur repeatedly and often, extinquish the torch and cool the end piece in water.

After cooling, clear the torch end piece with a brass or copper needle. Should the end piece happen to be badly obstructed, remove it from the torch and carefully clear it with a needle from the inside.

§ 11. Fluxes and Filler Metal

All matals are covered with an oxide film. When a piece of metal is heated in the process of welding, the oxide film becomes heavier. As a general rule, the oxides are less fusible than the base metal, and therefore prevent its welding. For instance, the melting point of aluminium is 650°C, while that of aluminium oxide (Al_2O_3) is 2050°C.

To produce high-quality welded joints, it is necessary, in the first place, to dectroy and remove the oxide film from the surface of the base and filler metals, and, in the second place, to protect the surface of the molten metal against the formation of new oxides. This can be achieved by using special powders or pastes which are introduced during welding into the weld and are termed fluxes.

The oxides may be removed from molten metal by two different methods, i.e. by dissolving them or by forming easily melted chemical compounds.

To the group of solvent fluxes belong sodium and potassium chlorides, with a 10 -per cent addition of sodium and potassium fluorides and a small quantity of sodium bisulfate.

The main disadvantage in using these fluxes consists in their hydroscopicity, i.e. the ability to activety absorb water.

The solvent fluxes are mainly used in the welding of aluminium parts.

Most widely used in the welding of various metals are the fluxes which form easily melted compounds with the oxides of the corresponding metals, and which do not dissolve in the molten metal and rise to the surface of the molten puddle.

According to their chemical properties and composition, these fluxes are subdivided into acid and basic fluxes.

To the group of acid fluxes belong those which, in reacting with oxides, possess the properties of acids. Silicon oxide, boric anhydride, ortho-boric acid and borax are in this group. These fluxes are used in cases where the oxides formed during welding are basic in nature, that is, are such that on reacting with acids they form salts. Almost all the metal oxides belong to the basic oxides.

The action of an acid flux can be best understood from the following example. Let the surface of a zinc article be covered with an oxide film (zno), to remove which an acid flux, and namely - boric acid (H_3BO_3) should be used. The reaction results in the formation of borate zno . B_2O_3 ,

$$ZnO \div 2H_3 - ZnB_2O_3 \div 3H_2O.$$

The action of silicon oxide SiO_2 used in the capacity of an acid flux can be seen from the following reaction.

$$FeO \div SiO_2 = FeO . SiO_2,$$

where FeO . SiO_2 is a slag which easily rises to the surface of the liquid metal.

To the group of basic fluxes belong those which possess the properties of bases on reaction with oxides. Used in the capacity of basic fluxes are sodium carbonate Na_2CO_3 and potash K_2CO_3. The basic fluxes are used chiefly in the welding of cast-iron.

The composition and methods of application of different fluxes vary with the type of metal and will be described below.

In a high-quality weld the mechanical properties of the deposited metal should be identical to those of the base metal. To meet this requirement, the filler metal should be selected on the grounds of the following considerations.

1. The filler metal should have a definite chemical com-

position corresponding to that of the base metal.

2. Filler wire or filler rod diameters should correspond to the thickness of the parts to be welded.

3. The filler wire surface should be clean and smooth, free of scale, rust, cuts and dents.

4. During melting the filler metal should not spatter, or boil, or evolve gases.

5. The melting points of the base and filler metals should be the same.

6. The deposited metal should possess good machinability.

To improve the mechanical properties of the weld, filler metal with an increased content (as compared to that in the base metal) of manganese, chromium, silicon and other elements is sometimes used in the welding of steel. Besides this, an increased manganese content reduces spattering during welding. In addition to the above, additional properties are required of the filler metal, depending upon the characteristics of the base metal.

Filler wire is notmally stored in coils. Prior to welding, filler wire of up to 1.5-mm diameter is wound in coils, each of 25 to 30 meter length. Filler wire thicker than 1.5 mm is cut into rods, each approximately 1 meter long. Each lot of filler wire is tested for its melting properties. No flux is used during these tests. If in the course of depositing of the welded bead, the wire melts quietly, without noticeable slag formation and spattering, and the welded bead after cooling has a uniform sealy structure, free of overflows and porosity, the quality of the particular lot of wire is considered satisfactory.

Filler metal grades used in gas welding are given in Table 6 below.

Table 6

Grade of Base Metal	Filler metal Grade	Grade of steel used for wire manufacture
10A, 20A, 10Г2A, 10Г2A, 25XГCA, 30XГCA, with tensile strength of up to 90 kg/mm^2	1 A	10 A
25XГCA, 30XГCA, with tensile strength of over 90 kg/mm^2	IV or V	20XГCA or 20XMA

Good results are obtained when wire made of Grade ЭИ400, ЭИ403 and ЭИ934 steel is used as filler metal. In this case it becomes possible to avoid the formation of cracks during welding.

When different grades of steel are joined by welding, for example, Grade 10A and Grade 30XГCA steel, to increase the strength of the weld, filler wire Grades IV and should be used.

§ 12. Techniques and Methods of Gas Welding

The process of gas welding consists in the melting of the edges to be joined and of the filler metal by means of the oxy-acetylene flame, in the subsequent thorough intermixing of the molten metal and the formation, after cooling, of the weld seam (Fig. 40).

The melting of the base and filler metal results in the creation of a liquid metal puddle. The size of the puddle and, consequently, the size of the future weld seam depends upon the amount of filler metal added to the puddle. After a puddle of a sufficient size is formed, the torch flame and the filler rod are slowly moved further along the welded joint, to that each newly formed molten metal puddle overlaps the formerly produced neighbouring puddle at least to 1/3 of its length.

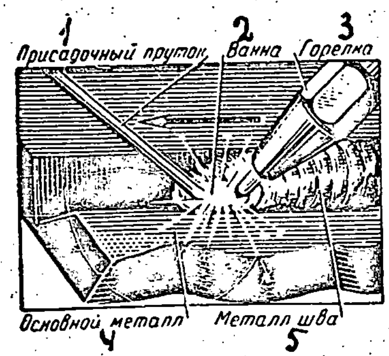


Fig. 40 - Schematic view of oxy-acetylene welding process. 1) Filler rod; 2) Molten puddle; 3) Torch; 4) Base metal; 5) Weld metal.

When depositing a weld, the operator holds the torch in his right hand, and the filler rod in his left hand. The torch may be moved either from right to left (the right-to-left method) or from left to right (the left-to-right method).

In the right-to-left method of welding (Fig. 41) the welding flame follows the filler rod and is directed on the unmolten edges. As the torch is moved on, the molten metal remains unshielded against the noxious influence of atmospheric oxygen and, in addition, cools too quickly. Irrespective of these drawbacks, the common prectice is to weld parts of 5-mm maximum thickness by the right-to-left method, which should be considered as wrong.

In the left-to-right method (Fig. 42) the torch flame moves ahead of the filler wire and is directed towards the molten metal puddle, as well as towards the newly formed weld. In this case the molten metal of the weld remains shielded by the reducing zone of the flame, and the newly formed weld cools slowly. These conditions are more favourable for the obtaining of a better-quality weld. In addition, the left-to-right method ensures higher productivity and involves smaller acetylene consumption as compared to the right-to-left method. The operators should aim at mastering this more efficient method of gas welding.

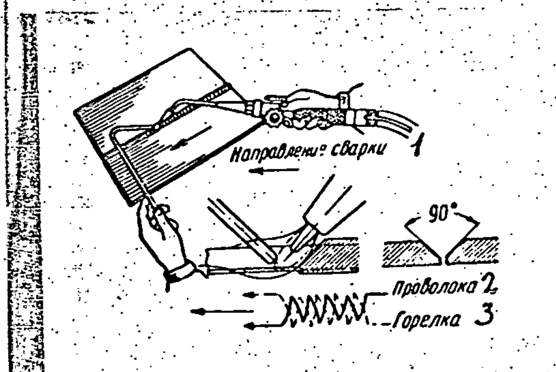


Fig.41. - Right-to-left welding method

1) Direction of welding; 2) Filler wire; 3) Torch.

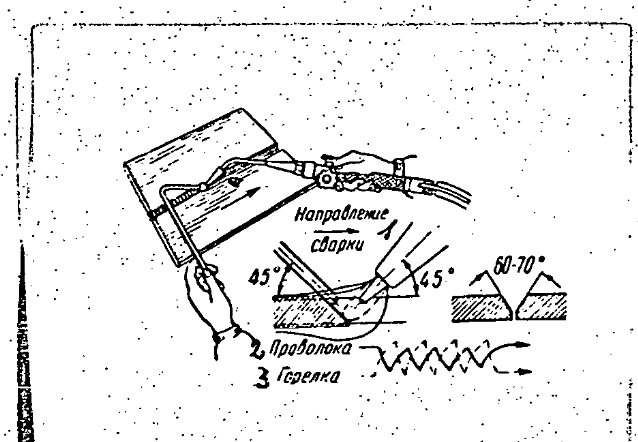


Fig.42. - Left-to-right welding method

Direction of welding; 2) Filler wire; 3) Torch.

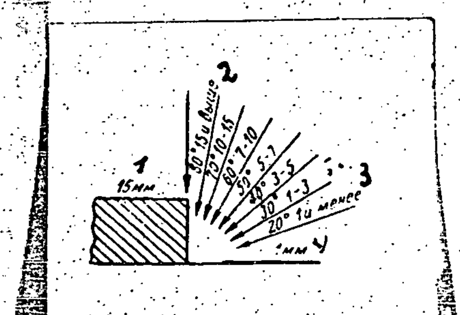


Fig.43. - Angle of torch incline in dependence upon metal thickness.

1) 15mm; 2) 80° 15mm & over; 3) 20°, 1mm under; 4) 1mm; 5) 30°; 1 to 3mm.

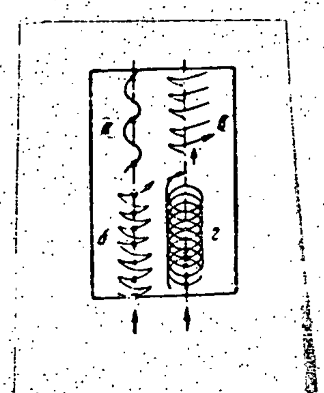


Fig.44. - Patterns of torch movement during welding.

In gas welding, the angle of torch incline increases from 20 to 80° (Fig.43). with the increase in metal thickness.

The angle of incline of the filler wire should, in all cases, be between 40 to 50°.

To obtain a high-quality weld, the position of the flame relatively to the molten metal, as well as the direction of movement of the torch and filler rod should be strictly uniform and should remain constant until the depositing of the weld is completed. There are several different methods of moving the torch in the process of depositing a weld (Fig. 44). The selection of a particular pattern of torch movement depends upon the thickness of the pieces to be welded, type of joint and method of welding. When metal sheets with flanged adges are being welded, the torch moves along a straight line or with but minor fluctuations to both sides(Fig. 44-a). When welding butt joints of perts of over 2-mm thickness, zigzag movement of the torch is preferable (Fig. 44-b). When thin-metal parts are being welded, the pattern shown in Fig. 44-c is commonly made use of; however, here the flame is moved to one side of the joint, thus allowing the molten metal of the weld to come in contact with the atmospheric oxygen and to become oxidized. Consequently, this method should be avoided.

In welding thick-metal perts (over 5 mm), good-quality welds are obtained when the torch describes a spiral (Fig. 44-d)

The following rules should be adhered to when using gas welding for joining machine parts.

1. Welding condition specifications (i.e. tip number, pressure of oxygen and filler wire diameter) are selected from Table 7.

2. Welding should be performed by the reducing zone of a neutral flame. The flame nucleus should be held at a distance of 2 or 3 mm from the molten metal (Fig. 45).

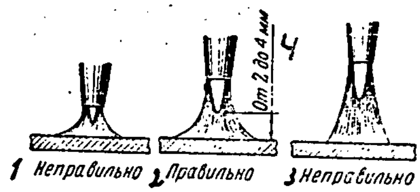


Fig.45. - Distances from flame nucleus edge to workpiece.
1) Wrong; 2) Correct; 3) Wrong; 4) 2 to 4 mm

3. The intensity of the flame and the speed of welding should be accurately coordinated. Insufficient flame intensity and excessive welding speed result in lack of penetration, while in the opposite case burning-through occurs.

4. To avoid lack of penetration and the formation of cracks, the zone about the joint should be preheated.

5. The selection of a correct angle of torch incline and of filler-rod incline is of major importance.

6. The base metal should melt without spattering and evenly over the entire surface. The filler metal should melt in the mass of the molten base metal.

Due to the movements of the filler rod and the torch, a more intensive mixing of the base and filler metal is secured. Early melting of filler metal results in lack of penetration.

7. When parts of different thickness are being welded, the flame of the torch should be directed on the thicker of the two parts.

8. During welding, the flame of the torch should not be moved away from the molten metal. When welding is completed or temporarily discontinued, the torch should be slowly moved

upwards, with obligatory heating of the surrounding metal.

9. Avoid a second heating of the weld by the flame of the torch, as this may result in the formation of cracks.

10. The welding of horizontal, vertical and overhead joints is complicated ba the fact that the molten metal of the weld flows downwards due to its own weight. To obtain a normal weld in these positions, follow rules given below.

a) Use a torch tip one size (one number) smaller than that used in welding a similar joint in the downhand position.

b) The joint should be made by the welding of short sections (15 to 20 mm).

c) When welding horizontal joints, first heat the bottom edge, and then direct the torch flame towards the top edge.

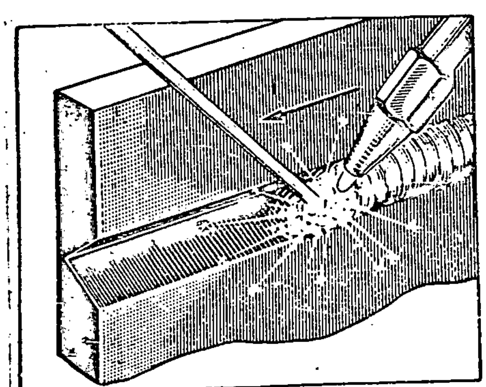


Fig. 46. - Welding of a horizontal joint.

The torch should be held slightly inclined towards the top edge (Fig. 46), so that the pressure of the gas stream acts to prevent the molten metal from flowing downward.

d) Vertical joints are to be welded by the right-to-left method, from below upwards (Fig. 47). To weld thick-metal parts, two or more passes are required, each layer of the weld on completion being forged.

e) Overhead joints (Fig. 48) are welded at reduced gas pressure, in thin layers, with subsequent forging of each layer

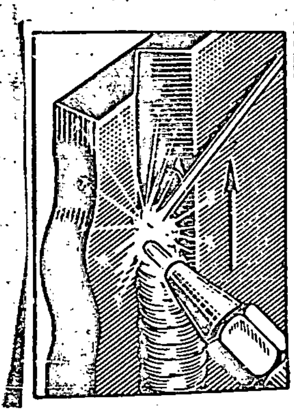


Fig.47 - Welding of a vertical joint.

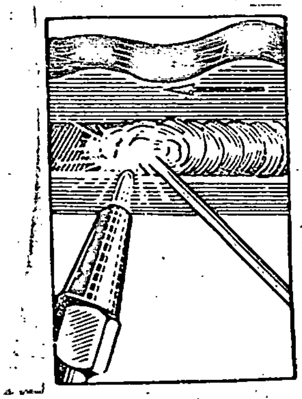


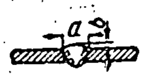
Fig.48. - Welding of an overhead joint.

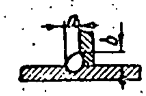
When welding carbon steels by oxy-acetylene flame, to forge the weld, use a peening hammer and deliver first light and then ever increasingly strong blows.

Forging of welds should be performed when the metal is heated to a light-red colour. The forging of metal which has already cooled to a dark-red colour is not allowable, as the metal will then be subject to cold-hardening and lose its ductility. To meet this requirement, welding is performed over comparatively short sections. When the length of a section of a joint has been completely filled with deposited metal, it is heated by the torch flame and forged.

Low-Carbon Steel Oxy-Acetylene Welding and Tacking

Specifications

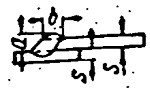
Butt joints: 

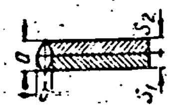
Tee joints: 

Metal thickness (mm)	Type of Joint: Butt joints — Tip No.	Butt joints — Oxygen pressure (kg/cm^2 g.p.)	Butt joints — Filler wire dia. mm	Tee joints — Tip No.	Tee joints — Oxygen pressure (kg/cm^2 g.p.)	Tee joints — Filler wire dia. mm
	1	2	3	1	2	3
0.5÷0.5	00	1.5	1	00	1.5	1
0.5÷1	00	1.5	1	0	1.5	1
0.8÷0.8	0	1.5	1	0	1.5	1
0.8÷1.5	0	1.5	1-1	0	1.5	1-1.5
1÷1	0	1.5	1-1.5	0	1.5	1.5
1÷2	0-1	1.5	1.5	0-1	1.5	1.5
1÷3	1	2	1.5	1	2.0	1.5
1.5÷1.5	1	2	1.5	1	2	1.5
1.5÷3	1-2	2.5	2	1-2	2.5	2
2÷2	1-2	2.5	2	1-2	2.5	2
2÷3	2	2.5	2	2	2.5	2
2÷4	2	2.5	2	2	3	2.5
2.5÷2.5	2	2.5	2	2	3	2.5
2.5÷5	2	3	2.5	2-3	3	2.5
3÷3	2	3	2.5	2-3	3	2.5
3÷5	3	3	3	3	3.5	3
4÷4	3	3	3	3	3.5	3

...ing
...nt
Filler wire dia. mm
3
1
1
1
1–1.5
1.5
1.5
1.5
1.5
2
2
2
2.5
2.5
2.5
2.5
3
3

Table 7





Metal thickness (mm)	Lap joints			Side joints		
	Tip No.	Oxygen pressure (kg/cm^2 g.p.)	Filler wire dia. mm	Tip No.	Oxygen pressure (kg/cm^2 g.p.)	Filler wire dia. mm
	1	2	3	1	2	3
0.5÷0.5	00	1.5	1	00	1.5	1
0.5÷1	0	1.5	1	00	1.5	1
0.8÷0.8	0	1.5	1	00–0	1.5	1
0.8÷1.5	0	1.5	1	0	1.5	1
1÷1	0	1.5	1–1.5	0	1.5	1
1÷2	0–1	1.5	1.5	0	1.5	1
1÷3	1	2	1.5	1	2	1.5
1.5÷1.5	1	2	1.5	1	2	1.5
1.5÷3	1–2	2.5	2	1	2	2
2÷2	1–2	2.5	2	1	2	2
2÷3	2	2.5	2	1–2	2.5	2
2÷4	2	3	2	2	2.5	2
2.5÷2.5	2	3	2	2	2.5	2
2.5÷5	2	3	2.5	2	3	2.5
3÷3	2	3	2.5	2	3	2.5
3÷5	3	3.5	3	3	3	3
4÷4	3	3.5	3	3	3	3

CHAPTER VI

ELECTRIC-ARC WELDING EQUIPMENT

During welding, current is supplied for the electric arc by aspecial source of electric power. Both direct and alternating current may be used to produce the arc. For welding with direct current, welding generators are used, and for welding with alternating current - welding transformers.

§ 13. Welding Generators

Welding generators should meet the following requirements.

1. Idling or no-load voltages should be high enough to ensure arc striking, but should not exceed 80 v.

2. Generators should automatically maintain the arc and restrict the short-circuit current.

3. Generators should quickly alter the arc voltage in accordance with the arc length. They should possess a drooping external characteristic, that is current increase should result in voltage decrease.

4. Generators should have a power capacity sufficient for supply of the arc.

5. Generators should provide a means for continous regulation of the welding current.

Direct current welding generators are classified as single-post or single-operator units (designed to supply current for one welder) and multi-post units (designed to supply current to several welders).

For welding generator specifications see Table 8 below.

The CMΓ -1 welding generator unit Fig.49) consists of a d.c. welding generator and an electric motor, both mounted on a common base frame. The generator shaft is connected to the

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Table 8

Characteristics	Welding Generator Model				
	СМГ-1	СМГ-2а	СМГ-2б	СУГ-2а	СУГ-2б
1. Generator					
a) rated voltage, v	25	40	25	40	25
b) rated current under continuous load, a	150	250	250	250	250
c) range of current adjustment, a	40-250	75-400	75-400	75-400	75-400
2. Three-phase electric drive motor					
a) voltage, v	220/380	220/380	220/380	220/380	220/380
b) power rating, kw	6.82 or 10	14.5 or 16.5	14.5 or 16.5	11.6	11.6
c) speed, r.p.m.	1430	1430	1430	1430	1430
d) average power factor	0.6-0.8	0.6-0.85	0.6-0.85	0.6-0.85	0.6-085
3. Assembled unit					
a) average efficiency	0.3-0.5	0.35-0.63	0.35-0.63	0.4-0.65	04-065
b) overall dimensions, mm:					
length	1565	1780	1540	1270	1270
width	710	690	575	664	664
height	705	710	880	900	900
c) total weight, kg	570	750	750	550	550

electric motor shaft by means of a coupling.

Fig. 50 shows the circuit diagram of the СМГ-1 generator. This generator is of a double-pole type, since the poles of the same sign are arranged close to one another, and the unit is therefore termed a "split-pole generator".

The working current is adjusted by moving brushes on the collector by means of a handle. To decrease the current, the brushes should be moved in the direction of armature rotation, to increase the current in the reverse direction.

In other words, to adjust the working current, proceed as follows:

a) to increase the current, rotate the handle clockwise;

b) to decrease the current, rotate the handle counter-clockwise.

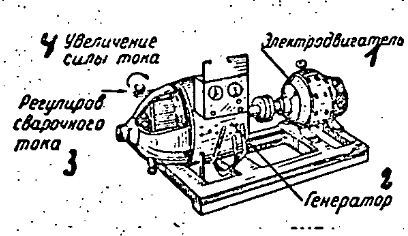

Fig. 49. - <u>СМГ-1 welding generator unit.</u>

1) electric motor; 2) generator;
3) welding current adjustment;
4) to increase current.

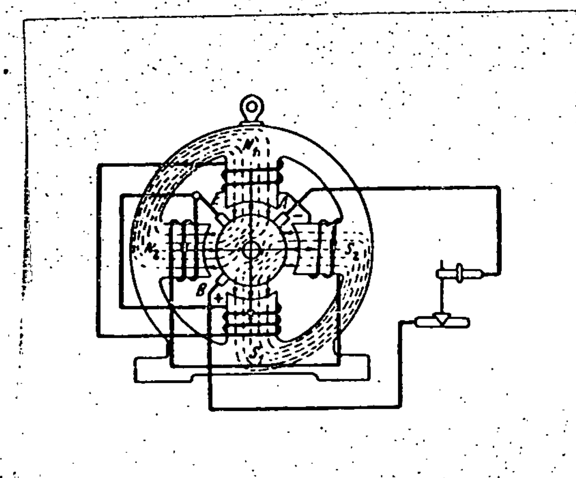

Fig. 50.- <u>СМГ-1 generator circuit diagram.</u>

To obtain currents under 90 <u>a</u> from the СМГ-1 generator, a ballast rheostat should be included in the circuit.

The СМГ-2 welding generator unit differs from the СМГ-1 unit in that the former is provided with an additional exciting winding which increases the slope of the drooping external characteristic.

In the СМГ-2 generator current adjustment is performed by two methods: coarse adjustment is by shifting of the brushes, and fine adjustment - by means of the rheostat located on the top of the generator.

To increase the current, the rheostat hand-wheel should be rotated clockwise; to decrease the current - counter-clockwise.

The CMГ-2 generator units are manufactured in two modifications:

The CMГ-2a generator - for a working voltage of 40 v, and the CMГ-2б generator - for a working voltage of 25 V.

The CУГ-2 welding unit (Fig.51) is a portable welding set equipped with a d.c. generator having the circuit of the CMГ-2 generator. The CУГ-2 welding unit is available in two modifications, that is, with the CMГ-2a and the CMГ-2б generators.

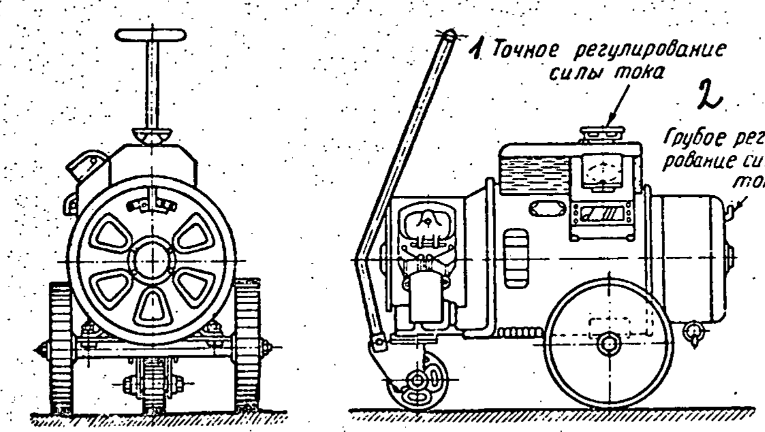

Fig.51. - CУГ-2 welding unit.

1) fine adjustment of current; 2) coarse adjustment of current

Adjustment of the welding current in the CУГ-2 welding unit is achieved both by shifting of the brushes and by means of the rheostat. The brushes may be fixed in three alternative positions on the commutator, namely:

extreme left position (from the generator side) - to deliver currents of 70 to 100 a;

intermediate position - to deliver currents of 115 to 230 a;

extreme right position - to deliver currents of 200 to 360 a

Fine current adjustments are made with the rheostat. The rheostat hand wheel is brought out on the hood of the welding unit and is provided with a pointer. When the hand wheel is rotated, the pointer moves over a dial marked with figures indicating the values of the current.

The CAK-2 welding unit (Fig.52) consists of the CMГ-2б generator and an internal combustion engine (kerosene engine).

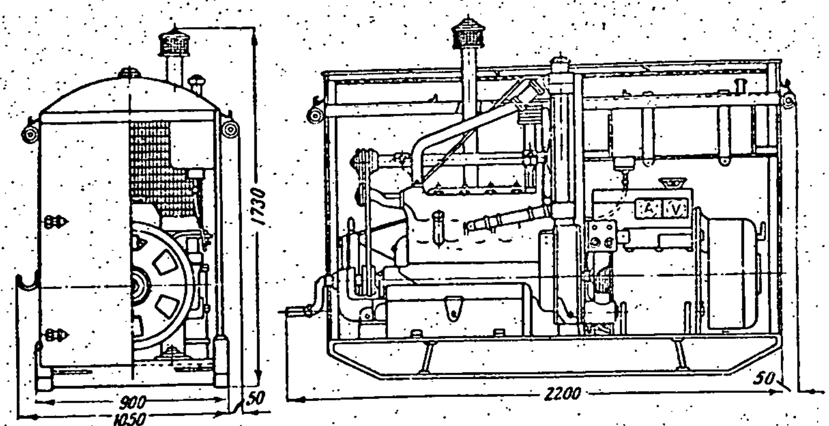

Fig.52.- CAK-2 welding unit

The engine is equipped with a speed governor allowing the speed to be maintained in a range of 1880 to 1510 r.p.m. during welding.

An advantage of this welding unit is that it requires no industrial power supply.

Proper operation of welding units ensures their reliable and long service life. The welders should be required to adher to the following rules of welding unit operation and maintenance.

1) clean the unit of dust and dirt;

2) wash the bearings with kerosene;

3) refill the bearings with clean oil;

4) check the condition of the commutators and the brushes,

5) check connections and contacts,

6) check smoothness of armature rotation by manually turning it into both directions.

After the unit has been prepared for its first start, it is required that it be started by an electrician well aquainted with this type of equipment and possessing the necessary knowledge and experience enabling him to make the star or delta connections of the electric drive motor winding in accordance with the voltage of the power supply source.

During welding, the generator should not be overloaded in excess of rated value of current given on the name plate. In cases of sparking of the commutator, switch off the unit and eliminate the defects. Do not operate the unit if the bearings are out of repair, which can be judged by the presence of axial play, knocking and noise.

Two or three times a day wipe the generator commutator off with dry rags. Prior to starting and after the day's work-with rags slightly moistened in gasoline. At the start of each day's work, blow off the generator with dry compressed air. This is of a special importance in operating the welding unit under field conditions.

At least once a month the commutator should be given a polishing.

If a welding unit has been stored for a considerable length of time in damp premises or in the open in wet weather, it should be dried in a warm dry room or with a stream of warm air.

§ 14. Welding Transformers

Welding posts are supplied with alternating current by welding transformers. To adjust the welding current and to increase are stability, a regulator or a reactor is series-connected in the welding circuit.

A voltage of 220 or 380 v is fed from the supply system into the primary winding of the welding transformer (Fig.53).

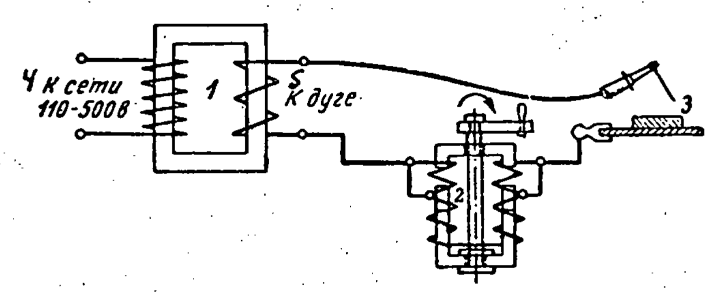

Fig.53- - Elementary circuit of an a.c. welding device

1-welding transformer; 2-chocke coil (reactor);
3-Petrov arc.

A voltage of 55 to 65 v is produced in the secondary winding.

From the transformer secondary winding one cable is lead directly to the electrode, the other to the current regulator (reactor). The second terminal of the reactor is connected by a cable to the workpiece through the worktable.

The current regulator (reactor) consists of an iron core with a moving armature (yoke) and a choke coil.

Current is adjusted by altering the air gap between the core and the armature. Current increases with increase in this gap.

The single-post welding transformers are manufactured in two modifications, i.e. with a separate reactor and with the reactor contained in a common housing (Fig.54). The transformers of the first type are designed as CTЭ-24 and CTЭ-34 (Fig.55), and have PCTЭ-34 regulators (reactors). They are simple in design and convenient in operation. The value of the welding current is adjusted by rotating the regulator handle either clockwise, to increase the current, or counterclockwise, to reduce the current.

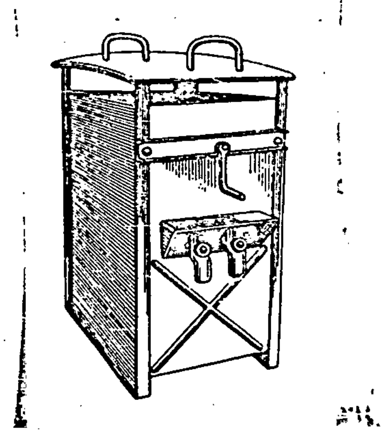

Fig.54. - CTH-500 welding transformer.

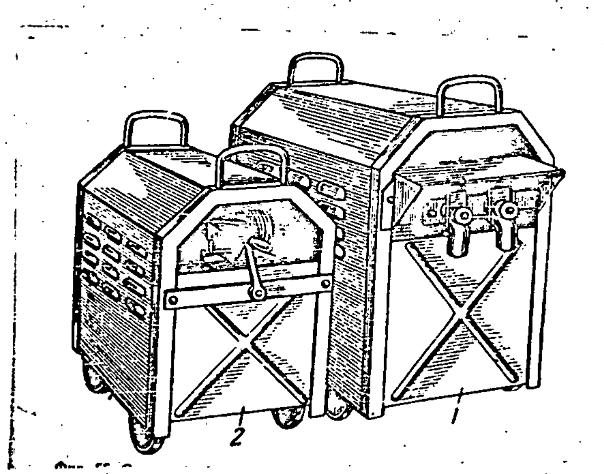

Fig.55. - CTЭ -34 welding transformer and PCTЭ -34 regulator (reactor).

1-transformer; 2-reactor.

Prior to connecting the transformer to a power circuit, its housing should be grounded by a wire of 10 to 16-sq-mm cross section.

For specifications of single-post welding transformers see Table 9.

When a welding transformer is available, Model AП airfield lighting station units may be used, if they are connected to the 10-kW terminals. During welding, all electric current consumption should be cut off, except the local lighting load. A voltage of 55 to 65 v should be adjusted for by means of a rheostat.

To adjust the current, a water rheostat may be used, which is in effect a barrel of three-to-five-pail capacity filled with salt water, in which metal plates are suspended. The adjustment of the welding current is achieved by lifting or lowering the plates.

When using a water rheostat, wear rubber gloves and rubber footgear, since the voltage in the circuit presents a dangerous shock hazard. If a water rheostat is stationed in closed premises, adequate ventilation should be provided for.

The maintenance of welding transformers consists in observing the following rules.

1. See that the cables of the primary and secondary circuits are securely connected to the corresponding terminals by means of soldered-on connecting lugs.

2. See that the welding transformer is not stationed close to a source of heat.

3. Protect the transformer and the regulator against moisture, especially when working in the open.

4. See that all the screws and nuts are kept properly tightened.

5. To move the transformer and its reactor to a new po-

Table 9

Welding Transformers

Type	Primary voltage (v)	Specifications: Consumed power (kva)	Duty factor (per cent)	No-load voltage (v)	Maximum value of welding current (a)	Overall Dimensions: Width	Length	Height	Weight (kg)
СТЭ-24	220 or 380	27.4	65	65	350	316 320	transformer, 625 regulator, 594	650 560	140 90
СТАН-0	220 or 380	8.7	65	63-80	135	420	698	485	80
СТЭ-34	220 or 280	37.0	65	63-80	500	370 320	transformer, 690 regulator, 609	660 545	195 125
СТАН-1	220 or 380	21	65	65-70	330	520	870	800	185
СА-2	220 or 380	38	65	70	600				270
САМ-2	220 or 380	40	70	70	700				360

sition, use the handles, but do not by tugging the cables.

Should a welding unit fail to switch on, or should it fail to answer to adjustments, as well as in cases of overheating, switch it off and send for an electrician.

§ 15. ПС-100 Welding Unit and Welder's Tools

The ПС-100 welding-unit is designed for the electric-rc welding of thin elements, with the use of electrodes of .0-mm maximum diameter and at currents from 20 to 115 a (Fig. 56).

The ПС-100 unit is a portable set consisting of a СП-10 single-phase increased-frequency generator and a type ДЭ-4-1/2 three-phase asynchronous motor rated for 220/380 v f supply, both the generator and the electric motor being

Table 9

Welding Transformers

Type	Primary voltage (v)	Specifications: Consumed power (kva)	Duty factor (per cent)	No-load voltage (v)	Maximum value of welding current (a)	Overall Dimensions: Width	Length	Height	Weight (kg)
CTЭ-24	220 or 380	27.4	65	65	350	316 320	transformer, 625 regulator, 594	650 560	140 90
CTAH-0	220 or 380	8.7	65	63-80	135	420	698	485	80
CTЭ-34	220 or 280	37.0	65	63-80	500	370 320	transformer, 690 regulator, 609	660 545	195 125
CTAH-1	220 or 380	21	65	65-70	330	520	870	800	185
CA-2	220 or 380	38	65	70	600				270
CAM-2	220 or 380	40	70	70	700				360

...sition, use the handles, but do not by tugging the cables.

Should a welding unit fail to switch on, or should it fail to answer to adjustments, as well as in cases of overheating, switch it off and send for an electrician.

§ 15. ПС-100 Welding Unit and Welder's Tools

The ПС-100 welding-unit is designed for the electric-arc welding of thin elements, with the use of electrodes of 4.0-mm maximum diameter and at currents from 20 to 115 a (Fig. 56).

The ПС-100 unit is a portable set consisting of a ГСП-10 single-phase increased-frequency generator and a type АД -4-1/2 three-phase asynchronous motor rated for 220/380 v arranged on a common frame. The generator and electric motor rotors are assembled on a common shaft.

Smooth adjustment of the welding current is accomplished by means of a special Model PT-100 regulator. The unit is started and stopped by turning the handle of the rotary switch.

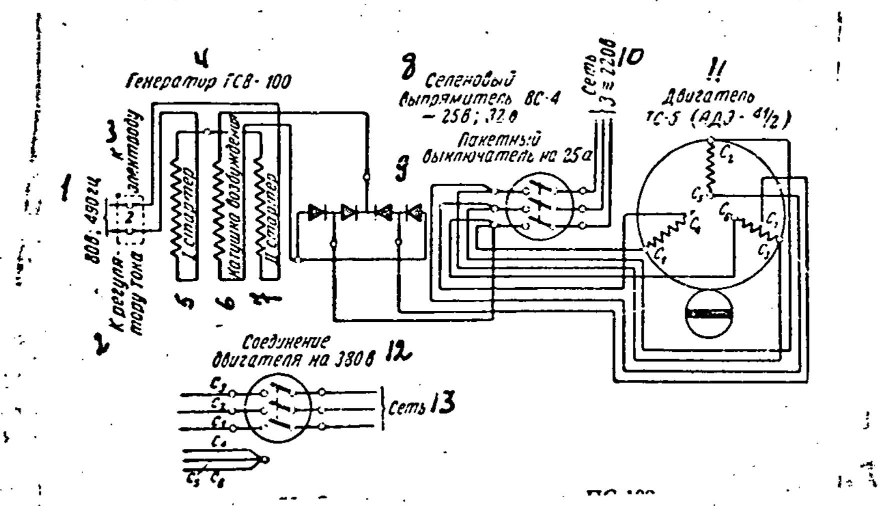

Fig.56. – ПС-100 welding unit circuit diagram:

1) 80 v, 490 c.p.s.; 2) to current regulator; 3) to electrode; 4) ГСВ-100 generator; 5) 1-st starter; 6) exciting coil; 7) 2-nd starter; 8) ВС-4 selenium rectifier – 25 v; 32 v.; 9) 25-a rotary switch; 10) 3-wire supply circuit ≈ 220 v; 11) ТС-5 (АДЭ -4 1/2) electric motor; 12) Electric motor connections, for 380-v supply; 13) Supply circuit.

ПС-100 Welding unit Specifications

a) Generator;

No-load voltage	80 v
Current at a duty factor of 100 per cent	80 a
" " " " " 75 " "	92 a
" " " " " 50 " "	115 a
Frequency	490 c.p.s.
Speed	2900 r.p.m.

b) Electric motor.

Rating . . . . 4 kW
Voltage . . . . 220/380 v
Current . . . . 13. 5/7 .8 a
Speed . . . . 2900 r.p.m.
Frequency . . . . 50 c.p.s.

The PT-100 current regulator has the form of a choke coil or reactor. Its core consists of a stationary and a moving part. The moving part is shifted by means of the hand wheel. The reactor winding consists of two coils. The regulator allows for switching in of either both coils in series - for low-duty currents, or only one coil-for medium-duty currents, or for complete cut out of both coils - for heavy-duty currents.

The low- and medium-duty current values can be adjusted with a greater degree of accuracy by changes in the air gap, as a result of hand wheel operation. To increase the current, the hand wheel should be turned clockwise. Secured to the regulator housing is a fixed linear scale along which the pointer rigidly connected to the moving core travels to indicate core position on the scale of the ruler. The scale is graduated in values of welding current. Actually, the scale has two ranges corresponding to the two switchpositions, allowing current to be adjusted by means of the core.

The unit is to be started with the welding circuit open, therefore, prior to starting the unit, make sure that a short circuit does not exist. To start the unit after it has been connected to the electric supply circuit, turn the switch handle into the "ПУСК" position ("Start") stamped on the casing.

Since the electric motor has no protective devices, see

When the motor is started, voltage is applied to the rectifier, and, at the moment at which the rated speed of rotation is obtained, rated no-load voltage is also attained on the generator.

Whenever the electric motor is in operation, the generator is under excitation.

On having adjusted the required current by means of the regulator and hand wheel, the operator may begin welding. Should it occur that the current required for a given job lies beyond the limits of the scale, the operator should set the switch in the required position and then make final adjustments of the current by means of the hand wheel.

To stop the unit, turn the handle to the "СТОП" ("Stop") position.

For ПС-100 welding unit circuit diagram see Fig. 56.

Welding may be performed by electrodes with a chalk or special coating. For conditions for the butt welding steel elements see Table 10.

Table 10

Sheet thickness (mm)	Electrode diameter (mm)	Current (a)	Edge preparation
1	1.5	20-30	Closed butt joint
1	2	20-30	Flanged edge joint
1.5	2	30-45	Closed butt joint
2.0	2	40-60	Open butt joint, 0.5-mm gap
3.0	3-4	70-115	Open butt joint, 1 to 1.5 mm gap

thinner elements to be welded.

A particular element of welding unit maintenance is care of the bearings. In the course of time, the bearing grease solidifies and becomes dirty; therefore, to protect the bearings from possible damage, the grease should be replaced once or twice a year. Proceed as follows. Take off the packing glands, remove the old grease and thoroughly wash the housings out with gasoline, using a squirt gun, so that none of the old grease is left. Then stuff the bearings to 1/3 or 1/2 of the free volume with clean grease, wash the packing gland covers with gasoline and fit them back in position.

The insulation resistance decreases, in most cases, as a result of penetration of moisture if the unit has been stored idle in dump premises for a long time. When the insulation resistance becomes reduced, the unit may be in danger when switched on, as a breakdown of the winding insulation may occur. When the unit is to be started after a long period of standstill, first check the condition of the insulation, using an inductor or megger. The minimum allowable insulation resistance is 0.5 megohms.

Should the value of resistance be below this figure, the unit should be dried by one of the generally employed methods (i.e. removal to a warm dry room, subjecting to a jet of warm air, etc.). To prevent the insulation from being damaged during drying, watch to see that the temperature of the winding does not rise above 90° C.

Overheating of winding as a result of power overloading also deteriorates the insulation; for this reason see that the unit is not loaded to above the power rating indicated on the name plate.

Polarity. When welding with direct current, different of the heat is liberated at the positive pole (anode), 35 per cent - at the negative pole (cathode), and 20 per cent between the electrodes. Therefore, thick elements are to be welded with straight polarity, that is, the positive terminal (anode) is to be connected to the workpiece, and the negative terminal (cathode) to the electrode; on such an arrangement more heat is liberated at the workpiece, and less at the electrode. Thin elements, on the contrary, are welded with reversed polarity, i.e. with the workpiece connected to the negative terminal, and the electrode to the positive terminal.

When welding with alternating current, polarity loses its significance, since the current alters its direction with considerable frequency and the quantity of heat liberated at both poles (i.e. on the electrode and the weldment) is equal.

If no polarity signs (+ for positive, and - for negative) are to be found on the generator terminals, to establish the corresponding contacts, use one of the methods described below.

1. Lower the ends of wires connected to the generator terminals into a weak solution of sulphuric acid. As a result of sulphuric acid decomposition, intense evolution of hydrogen bubbles will take place at one of the immersed ends. This is the wire connected to the generator negative terminal.

2. Connect a metal article to one of the generator terminals, and a carbon electrode to the other terminal. Strike an electric arc between the carbon electrode and the metal article. If the electric arc is quiet, this means that the carbon electrode has been connected to the negative terminal, and the metal article to the positive one. If the arc is unstable and

sitive terminal, and the metal article to the negative terminal.

Having established the polarity of the generator terminals, mark accordingly the positive (+) and the negative (-) terminal.

Welder's tools. For use in the process of work, the welder should have the following tools available at the place of work:

1. Fitter's hammer and chisel.

2. Pliers.

3. Steel wire brush.

4. Electrode holders (Fig. 57) for holding the electrodes and feeding electric current to them.

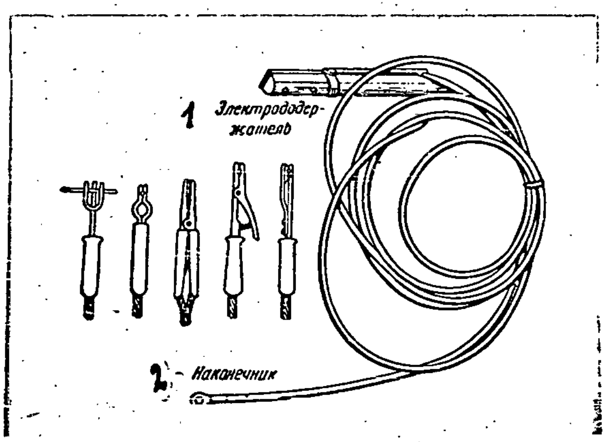

Fig. 57. - Electrode holders:

1) electrode holder; 2) cable terminal.

The handle of the electrode holder is made of some insulating material, while the clamping cheeks should provide a good electric contact with the electrode and should securely hold it.

5. The cable (or wire) for supplying welding current from the welding machine to the electrode holder should be provided with terminal lugs or connectors, to facilitate connection to welding machine terminals.

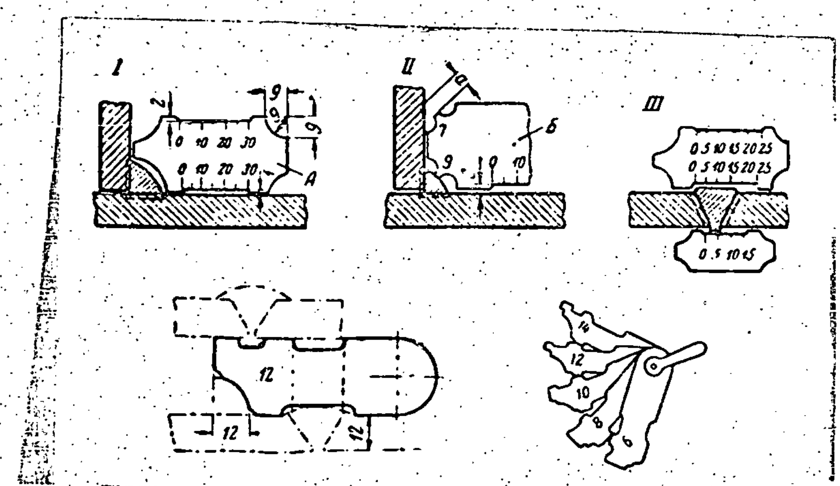

Fig.58- Gauges and templetes for checking weld size.

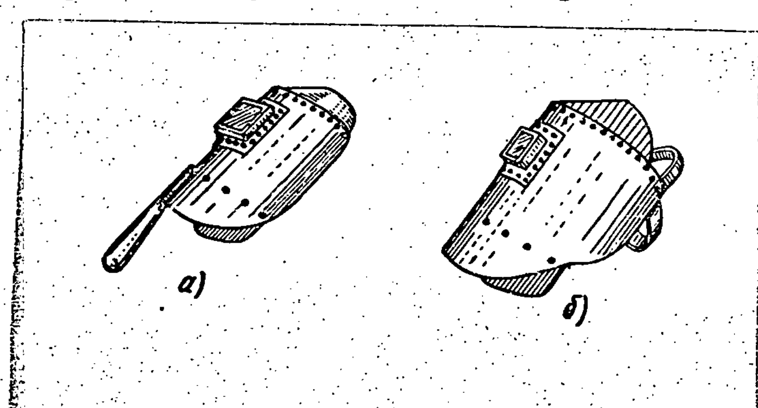

Fig.59. - Welder's shield (a) and helmet (b)

6. A magnifying glass, for weld quality control.
7. A set of templets (Fig.58), for weld size control.
8. A piece of chalk, for marking and plotting.
9. A box for electrode storage.
10. A welder's helmet or mask (Fig.59).

In working with the electric arc, the operators are to use a ТИС grade protective glass which absorbs the ultra-violet and infra-red rays which are harmful to the eyes and skin.

In arc welding, the following numbers of ТИС glass are used.

No.3 - for currents of up to 100 a.

On the helmet, at the outer side, the THC glass is protected by an ordinary white glass.

CHAPTER VII

MANUAL ELECTRIC-ARC WELDING

§ 16. Electrodes and Coatings

Electrodes used in manual electric-arc welding have the form of metal rods covered with a layer of coating.

Unimportant parts and elements may be welded by direct current, with uncoated rods which are called bare electrodes.

At present, electric-arc welding as a rule is performed by coated electrodes only. In cases when elements of minor importance are being welded, use is made of electrodes with but a very thin (ionizing) coating which facilitates arc striking and increases the stability of arc burning This coating is termed "thin" because its thickness varies between 0.05 and 0.20 mm on a side. When more important parts are to be welded, electrodes with a thicker coating (termed high-quality coating) are used. The thickness of this coating varies between 0.3 and 1.1 mm on a side of the electrode, depending upon the rod diameter (see Table 11).

Electrode Coating Thickness

Table 11

Electrode Diameter, mm	Thickness of Coating on a Side, mm	
	Thin coating	Thick coating
2	0.5 to 0.10	0.3 to 0.4
2.5	0.07 to 0.10	0.4 to 0.5
3.0	0.10 to 0.15	0.6 to 0.7
4.0	0.15 to 0.20	0.9 to 1.1

In the process of welding with thin-coated electrodes the drops of molten electrode metal and the molten metal puddle are not shielded against the influence of atmospheric air.

As a result, the metal acquires a high oxygen and nitrogen content, while carbon, silicon, manganese and other chemical elements present in the alloy are burned out. The mechanical properties of the weld are thus considerably lowered. Impact strength and ductility sharply fall in value. For the above reasons the thin-coated electrodes are used for the welding of machine parts working under static stresses.

The cheapest types of electrode coatings are made with water solutions of potash and chalk. The former is prepared in the following way.

Fill a metal vessel having a depth equal the length of the electrodes to be coated full of a 15 to 20 - per cent water solution of potash, and then stand a bunch of bare rods in it. During work, the welder picks an electrode from the vessel and, when it is still wet, inserts it into the electrode holder. These electrodes are not intended for storage since the thin layer of potash easily crumbls, and the wire, attacked by the potash, quickly rusts.

The composition of the chalk coating is as follows (by weight).

pure chalk . . . . 80 to 85 per cent
water glass . . . . 20 to 15 per cent

The chalk intended for the coating is first ground and screened through a screen having 1200 holes per one sq.cm. After screening, the chalk is mixed with water glass and diluted with water to a cream-like consistency. Further, metal rods of required length are dipped into this substance and then pulled out so that a thin layer of coating is left on the rod surface. The electrodes thus coated are then dried in the open air or inside a drying cabinet, at a temperature of 40 to 50°C.

To produce a weld having high mechanical properties, thick-coated electrodes are used. Thick coatings are sublivided into protective (slagforming and gas-generating) and alloying coatings. The main purpose of the protective coatings is to shield the molten metal against the harmful influence of the air. The purpose of alloying coatings is to replenish the molten weld metal with the chemical elements most subject to active burning out in the process of welding in order that the initial chemical composition of the metal be maintained or even improved.

<u>The slag-forming coatings</u>, in the process of electrode melting, produce a considerable amount of slag which envelopes the drops of molten metal in the form of a thin layer and also forms a heavy layer on the surface of the puddle, thus preventing the molten metal of the weld against being saturated with the oxygen and nitrogen from the ambient air. Besides this, the slag-forming coatings increase arc burning stability. In addition, the slag slows down the process of cooling of the deposited metal which also contributes to the improvement of the weld-metal structure.

The slag-forming coatings are composed of titanium ore. manganese ore, feldspar, chalk, kaolin, quartz and some other compounds.

<u>The gas-generating coatings</u>, in the process of welding, generate a considerable volume of gases which protect the molten metal against the influence of the ambient air. Many organic substances, such as starch, wood flour, cellulose, charcoal, grain flour, etc., are used to make gas-generating coatings.

<u>The alloying coatings</u>, on melting, introduce into the molten metal various alloying additions such as nickel, chromium, molybdenum, carbon, etc. The principal alloying components of these coatings are ferroalloys (ferromanganese, ferrosilicon, ferrotitanium and ferromolybdenum), or metal oxides.

Ferroalloys serve simultaneously as reducing agents used to expell oxygen from the deposited metal.

In addition to the above, each coating contains certain bonding agents which impart pastiness to the coating and make it stick to the metal rods.

By applying various coatings to electrodes, a wide range of deposited-metal properties can be attained. At present, a great number of coatings is used in the welding industry of the USSR. For the compositions of the most widely used coatings see Table 12.

Table 12

Composition of Thick Coatings

Coating Grade	Components	Weight Content (per cent)
OMM-5	1. Manganese ore (pyrolusite)	21
	2. Ferromanganese	20
	3. Starch or wood flour	9
	4. Titanium concentrate	37
	5. Feldspar	13
		Total 100
	6. Water glass mixed with water in proportion 2:1	30 to 35 per cent of dry component weight of coating
UN-7	1. Red hematite	33
	2. Granite	32
	3. Ferromanganese	30
	4. Starch	5
		Total 100
	5. Water glass	25 to 30 per cent of dry component weight of coating

Coating Grade	Components	Weight Content (per cent)
УОНИИ-13/45	1. Marble	52
	2. Fluorite	56
	3. Quartz	7
	4. Ferromanganese	5
	5. Ferrosilicon	10
		Total 100
	6. Potassium water glass	25 to 30 per cent of dry components weight of coating

Table 13

Electrodes for Electric-Arc Welding of Steels

Electrode Grade	Required joint position	Recommended current & polarity	Grades of steel welded	Recommended voltage (V)
Electrode with chalk coating	Any position in space	D.C. (straight polarity) & a.c.	C_T.1, C_T.2, C_T.3, C_T.4, to USSR Standard ГОСТ 380-41; and steels 0.8, 10, 15, 25, to USSR Standard ГОСТ В-1050-41	15
ОММ-5	"	"	C_T.1, C_T.2, C_T.3, C_T.4 to USSR Standard ГОСТ 380-41; and steels 0.8, 10, 15, 20, 25 to USSR Standard ГОСТ В-1050-41	23
МЭЗ-04	"	"	C_T.1, C_T.2, C_T.3, C_T.4 to USSR Standard ГОСТ 380-41; and steels 0.8, 10, 15, 20, 25 to USSR Standard ГОСТ В-1050-41	23
ЦМ7С	Downhand	"	C_T.1, C_T.2, C_T.3, C_T.4, to USSR Standard ГОСТ 380-41; and steels 0.8, 10, 15, 20, 25 to USSR Standard ГОСТ В-1050-41	30
ВИ-9-6	Any position in space	D.C. (straight polarity), a.c. allowable	20А, 12Г1А, 25ХГСА and 30ХГСА	14
УОНИИ-13	"	D.C. (reverse polarity) & a.c. with oscillator	Low-and medium-carbon low-alloy steels	25
ВИ-10-6	Downhand and semi-vertical	D.C. (reverse polarity)	25ХГСА and 30ХГСА	22
ВИ-12-6	Downhand		Я1Т, ЭИ402, ЭИ403, ЭИ-417	27
ПП-2	"		Я1Т, ЭИ402, ЭИ403, ЭИ417	28

Electrode Coating

The working order in the preparation of coated electrodes is as follows:

1. Wire preparation.
2. Preparation of coating components.
3. Mix preparation.
4. Applying of coating.
5. Electrode drying.

1. Wire preparation. Clean the wire of dirt and grease and wash it with a hot 5-per cent water solution of soda ash. Then cut the wire into rods 300 to 450 mm long, depending upon its diameter, and straighten the rods. The prepared rods should be stored in a wooden box located in a dry room.

2. Preparation of coating components. The components of a coating (i.e. chalk, ferroalloys, starch, etc.) are first milled in ball mills, dried in a drying cabinet at a temperature of 120 to 150° C and then passed through a screen having 3600 to 4000 openings per sq.cm. Organic substances (for example, starch and flour) may be screened with a screen having 1000 to 1200 openings per sq.cm. Each component should be treated separately, as described above.

3. Mix preparation. Weigh out the screened components in the required proportion and thoroughly mix them in a mixer. To prepare a mix, dilute soluble water glass with water to a spesific density of 1.1 or 1.2, and then strain it through the screen.

The mixing of dry compounds and the water glass solution should be preferably performed immediately before applying the coating to the rods. Make sure that the mix has been thoroughly stirred to obtain a uniform mixture, free of lumps and air bubbles.

In the course of mixing, the ferroalloys (ferrosilicon and ferromanganese) may react with water glass. To prevent this, prior to mixing the ferroalloys subject them to heating on pans in ovens, for a period of one hour. This process is termed the possivating of the ferroalloys.

4. Applying of coating. In electrode-manufacturing works, the coating is applied on electrode wire under pressure with the aid of special machines. Under the conditions of field mobile repair-shops, the coating of the wire surface may be performed by dipping.

The prepared coating solution is poured into a deep tank into which the rods, fastened in a frame, are then dipped. After dipping, the frame, together with the rods, is carefully and slowly pulled out of the tank. If several layers of coating are to be applied, after each dipping the electrodes are dried in the air and then dipped in again. This procedure is repeated until a coating of desired thickness is obtained. See that the coating is of even thickness along the entire rod length; to achieve this, in extraction from the solution and on subsequent drying, the rods should be held strictly vertical.

5. Electrode drying. The coated electrodes should be dried. To prevent cracking of the coating, the electrodes should be preliminarily dried in the open air for a period of 2 to 4 hours, after which they should be dried in a drying oven at a temperature of 200 to 300° C for a period of one or two hours. Drying at temperatures above 300° C may cause burning-out of certain coating components. Organic components should be dried at a maximum temperature of 200° C.

Electrodes with dampened coatings should also be dried at a temperature of 180 to 200°C, for a period of one hour. Remember that electrodes with damp coatings cause unstable arc burning.

§ 17. Techniques and Working Conditions of Electric-Arc Welding

A normal welding arc is an electric discharge at atmospheric pressure of gases. Electric discharges of different character and intensity are used in welding. In the Slavianov welding method, an electric arc is drawn between a metal electrode and the metal to be welded (the base metal). This type of arc is termed a direct-action arc, since the base metal is here included in the welding circuit and plays the role of an electrode.

Striking the arc. The striking of the arc is performed by lightly contacting the base metal with the electrode and by slowly moving the electrode away to a distance equal to the arc length (2to 4 mm). This method of arc striking is known as the short-circuit method (Fig. 60).

A second method of arc striking consists in striking the electrode against the surface of the workpiece (in the way a match is struck).

When welding is performed by direct current, the welding arc has a tendency to deviate due to the influence of the magnetic field, the character of this deviation depending upon the workpiece design and the method of current supply (Fig. 61). This phenomenon is termed magnetic blow or draft.

Magnetic draft hinders the process of welding. The simplest way to eliminate magnetic draft is to alter the angle of electrode incline in the course of welding.

When welding by alternating current, such deviation of the arc does not occur.

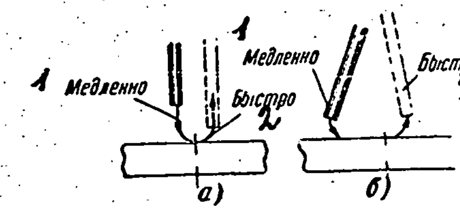

Fig. 60. - Diagram of electrode movement during arc striking: 1) slowly; 2) quickly.

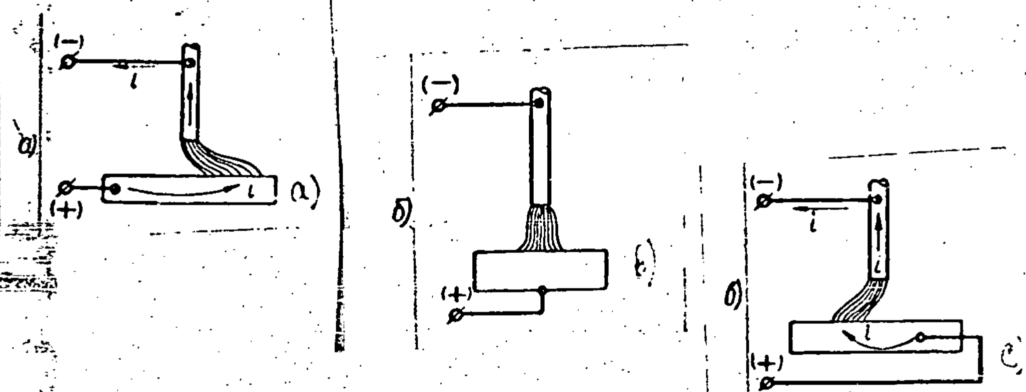

Fig. 61. - Influence of magnetic blow upon electric arc.

The arc should be extinguished only in order to replace the consumed electrode or when a seam has been completed. If a welder has not yet gained enough experience, breaking of the arc as a result of short circuiting or due to excessive arc length may occur. At the points of breaking of the arc a weakened weld is produced. In order to obtain a high-grade weld irrespective of arc breaking, the arc should be restruck on the base metal somewhat ahead of the point of breaking; then the arc should be worked backwards so that the place of breaking is welded anew, after which arc travel should be continued in the direction of welding.

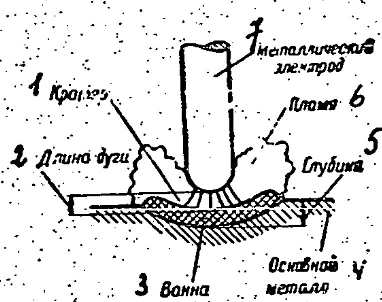

Fig.62. - Diagram of a stable welding arc between the electrode and base metal.

1) crater; 2) arc length; 3) puddle; 4) base metal; 5) depth; 6) flame; 7) metal electrode.

The base metal and the electrode under the influence of the heat developed by the burning arc are melted. The molten electrode metal, in the form of separate drops of various size, is transferred into the puddle of molten base metal.

Shown in Fig.62 is a diagram of a stabilized welding arc established between the electrode and the base metal. A molten metal puddle is formed, with a crater in its surface immediately under the electrode. The arc length is the distance between the electrode end and the bottom of the crater. The depth of the puddle or the depth of penetration is the distance from the base metal surface to the bottom of the crater.

In welding, the length of the arc and the depth of puddle should be of a definite value. When electrodes of up to 6 mm in diameter are used, arc length should not exceed 2 to 4 mm, since only under this condition can arc stability be ensured. When the arc is of such short length, the drops of molten electrode metal on their way to the puddle are influenced by the oxygen and nitrogen of the air to a lesser extent than when the arc is of greater length.

When the arc length is too great, the arc becomes unstable, deviates to the sides and often breaks; in addition, intensive spattering and oxidation take place. A formless and low-grade weld is normally produced when the arc length is excessive. Consequently, the operator should always aim at welding with a short arc.

When alternating current is used, the arc is more difficult to struck and burns with less stability as compared to a d.c. arc. To increase arc stability, the frequency and voltage of the alternating current are increased by connecting an oscillator in parallel with the welding transformer. The oscillator produces current of 250 000 c.p.s. at 3000 v. This high voltage is not hazardous to life since the frequency is very high and oscillator power is insignificant.

When the frequency is high, the interval of time during which the current drops to zero in the gap between the electrode end and the workpiece is extremely short. This period being of such short duration, the electrode is unable to cool down to considerable degree before the arc is struck again., which is as if it had not been extinguished at all.

The depth of penetration is another important factor of the welding process. To produce a high-grade weld, it is required that the molten electrode metal should fully mix with the molten base metal. Consequently, the base metal should be melted to a sufficient depth. Should the base metal be heated insufficiently, the depth of penetration is also small. In this case some of the molten electrode metal will be deposited upon the unmolten surface of the workpiece and no weld will be produced. This phenomenon is termed "lack of penetration".

To obtain a high-grade weld, the minimum depth of penetration should be 1 or 2 mm.

The depth of penetration can be estimated by the depth of the crater. By observing the crater through the protective glass, the operator can easily see the depth of melting of the base metal.

Lack of penetration may result under two conditions, namely: when the welding current is too low, or when the speed of electrode travel is excessive.

Methods of deposition. In the process of welding, the electrode, while being melted, is simultaneously moved in three directions (Fig. 63):

a) it is being constantly brought closer to the workpiece, to maintain a constant arc length;

b) it travels at constant speed along the joint;

c) it performs transverse movements of oscillatory nature.

The electrode should be inclined towards the direction of movement, forming an angle of 15 to 30 deg. to the vertical. The 15-deg. angle is used in welding with thinly coated electrodes, while the 30-deg. angle is recommended for welding with thickly coated electrodes.

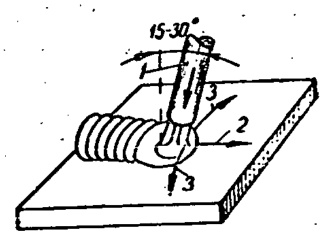

Fig. 63. - Schematic view of electrode end movement during welding:

1-electrode; 2-direction of welding; 3-transverse oscillations of electrode.

To obtain a weld of the required width, the electrode is given oscillatory movements across the joint; if not, a weld with a very narrow cross section would otherwise be produced. The oscillatory movements of the electrode increase puddle size, since a greater quantity of heat is produced by the arc per unit of weld length. This also results in the slower cooling and solidifying of the molten metal, which, in turn, serves to reduce the quantity of non-metallic inclusions and gas bubbles and decreases possibility of crack-forming in the weld.

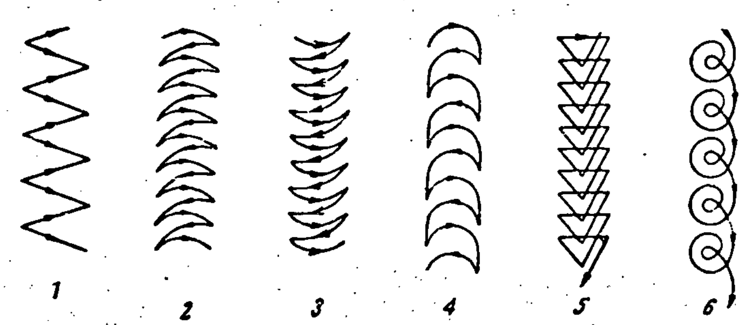

Fig. 64 - Diagram of optional patterns of electrode end movement.

1, 2, 3 - with normal heating of joint; 4, 5 - with intense heating of both joint edges; 6- with intense heating of one joint edge.

In practice, many different patterns of electrode end oscillatory movement are used, the most characteristic of them being shown in Fig. 64. None of these patterns may be recommended in preference to the others, on the grounds of alledged better weld quality.

<u>Depositing welds in different positions.</u> When a weld is deposited in the downhand position, the molten electrode metal drips into the puddle due to its own weight. The joint being welded can be conveniently observed by the operator. This is the most advantageous welding position, and the ope-

rator should always endevour to arrange the workpiece so that it may be welded in the downhand position.

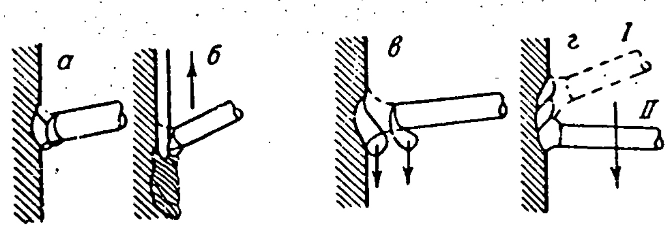

Fig. 65. - Welding of vertical joints.
a, b - correct; c, d - wrong.

It is more difficult to deposit a weld inthe vertical position (Fig. 65), since the molten metal tends to flow downward. For this reason, the vertical joints are welded from below and upwards, ba a short arc. The electrode should not be retained in a given position, but should be slowly moved aside, thus allowing the metal to solidify. This facilitates the obtaining of high-grade welds.

The welding of horizontal joints (Fig. 66) does not differ essentially from vertical joint welding.

To facilitate depositing of horizontal welds, only the top plate edge is bevelled while the bottom plate edge is left square and thus forms a kind of shelf on to which the welding metal is deposited.

Overhead joints are difficult and inconvenient to weld (Fig. 67). The molten metal strives to flow out of the puddle, and the operator must always hold it back with the electrode. Overhead welds, even when they have been made by skilled operators, as a rule are of insufficiently high quality. This is due to the inconvenience of welding and contamination of the weld by non-metallic inclusions (slag) which are lighter than the metal and therefore deeply penetrate into the molten metal (into the root of the weld).

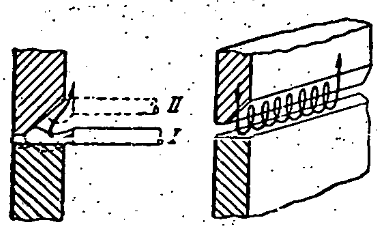

Fig. 66. - Welding of horizontal joints.

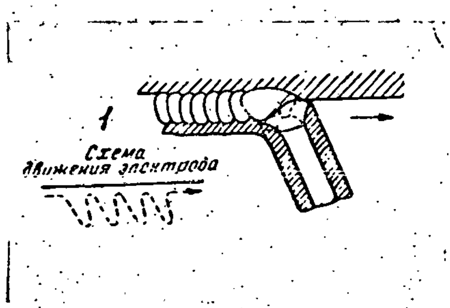

Fig. 67. - Welding of overhead joints.

1) Diagram of electrode movement.

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CHAPTER VIII

TECHNIQUES OF WELDING STEELS USED IN AIRCRAFT CONSTRUCTION

§ 18. Preparing parts for welding

Preparing parts for welding comprises the following operations:

1. Machining of the edges of joints and the removal of burrs.
2. Cleaning edge surfaces of paint, dirt and oxide films.
3. Assembling and fitting up of the parts according to templets or in jigs, etc.
4. The tacking of parts.
5. The straightening of parts after tacking and checking of gaps.

The gaps left between the edges of the parts to be welded should be of equal width along the entire joint length. For edge shapes, sizes and machining tolerances, and for gap width see Tables 14, 15, 16. When the edges of joints are to be prepared for manual welding, the values contained in the tables may be increased by 50 per cent.

Irrespective of the method of welding, the parts may be tacked both by gas and by electric-arc welding. Gas tacking is recommended for parts of 1.5-mm maximum thickness, and electric-arc tacking - for parts over 1.5 mm thick. For tacking, use Grade 10 A filler wire and Grade 10 A electrodes.

After the edges of the joint are bevelled, cleaned, fitted up and assembled, they are tacked. Tacking should be performed by short welds (10 to 15 mm) spaced at 20 to 60 mm intervals, the tacking techniques and working conditions being similar to those of welding. The maximum height of the tack weld should not exceed 70 per cent of the normal seam to be obtained as a result of the welding. The tacking of parts is performed in a definite sequence, to avoid warping. A thicker element is heated first at point of tacking. When lap joints or Tee-joints are being made, the thicker of the two elements is preheated on the reverse side of the tack pount.

Prior to tacking, the elements should be reliably secured in jigs, clamps, etc., to prevent them from shifting.

During tacking, the following rules should be adhered to:

a) tack welds should be spaced at 20 to 35 mm intervals, for metal thicknesses of 0.5 to 1.0 mm, and at 40 to 60 mm intervals, for metal thicknesses of 2mm and over. When tacking elements which are intended to be welded by the electric arc process, the spacing of tacks may be increased by one and a half times;

b) the extreme end tacks should be spaced 10 mm from the part edge, and no tacks should be made on the ends and in the corners of workpiece bends. In electric-arc welding, the tacks should be preferably located on the edges of the workpieces;

c) if a workpiece is provided with holes, the tacks should be placed at least 10 mm from the hole edges;

d) any part should be tacked from the middle towards its ends;

e) when tacking washers or tubular elements, the successive tacks should be symmetrically arranged.

f) in cases of double-side tacking, the tacks should be staggered.

Long butt joints are first tacked at the ends and in the middle, and then from the middle towards the ends, as shown in Fig.68. Stiffening ribs should be tacked in a staggered

Table 14

Edge preparation and gap tolerances for butt joints

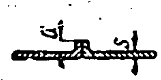
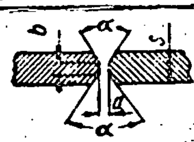
Sheet thickness S (mm)	Type & Dimensions of Joints	For gas welding a (mm)	For electric arc welding a (mm)	b (mm)	α (deg.)
0.8-1.0		1.0-1.5	-	-	-
0.8-1.5		0.5-1.0	-	-	-
1.5-2.5		1.0-1.5	0.5-1.0	-	-
2.5-6.0		-	≤ 1.0	1-2	70±10
6 - 10		-	0.5-1.5	1.5-3	70±10
6 - 10		-	0.5-1.5	1.5-3	70±10
10 - 20			1-3	2-4	70±10

Table 15

Edge preparation and gap tolerances for Tee-joints

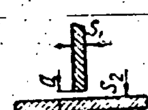
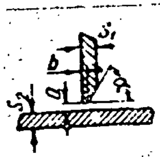
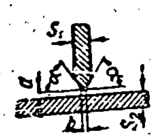
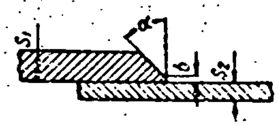
Sheet thickness (mm) S1	Sheet thickness (mm) S2	Type & Dimensions of joints	For gas welding a (mm)	For electric arc welding a (mm)	b (mm)	α (deg.)
0.5-1.5	0.5.1.5		0.5	0.5-1.0	-	-
2 - 3	0.75-3		-	0.5-1.0	-	-
3 - 6	2 - 6		-	0.5-1.0	0.75-1.5	45±10
6 -10	2 -10		-	0.5-1.0	1.5-3.0	55±10
10 -20	3 20		-	0.5-1.5	2-4	50±10
6-10	2-10		-	0.5-1.0	1.5-3.0	45±10
10-20	3-20		-	0.75-1.5	2-4	45±10

Table 16

Edge preparation and gap tolerances for lap joints

Sheet thickness (mm)		Type & Dimensions of joints	For gas & electric-arc welding	
S_1	S_2		b (mm)	α (deg.)
2-3	1-3		0.7-1.0	45
3-6	2-6		1.0-2.0	45
6-10	3-10		2.0-3.5	45
10-20	5-20		3.0-6.0	45

order (Fig. 69).

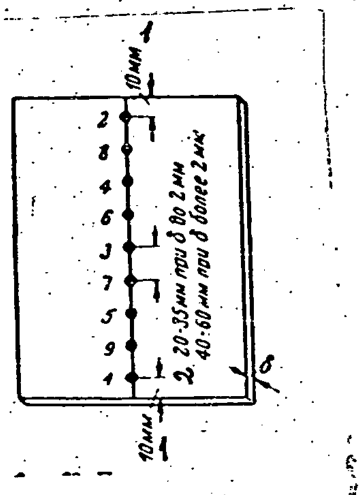


Fig. 68. - Sequence of butt joint tacking;

1) 10mm 2) 20 to 35 mm for sheet thickness below 2mm; 40 to 60 mm for sheet thickness above 2 mm.

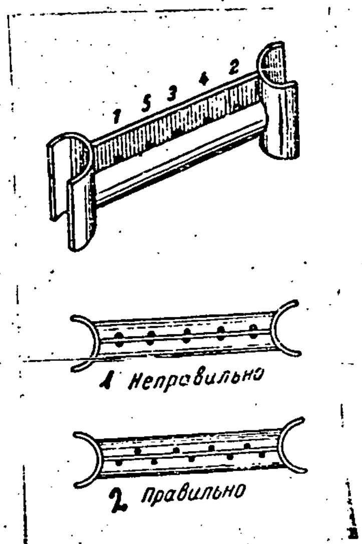


Fig. 69. - Sequence of stiffening rib tacking

1) Wrong 2) Correct

In tacking connection pipes, washers and other circular elements, proceed as shown in Fig. 70.

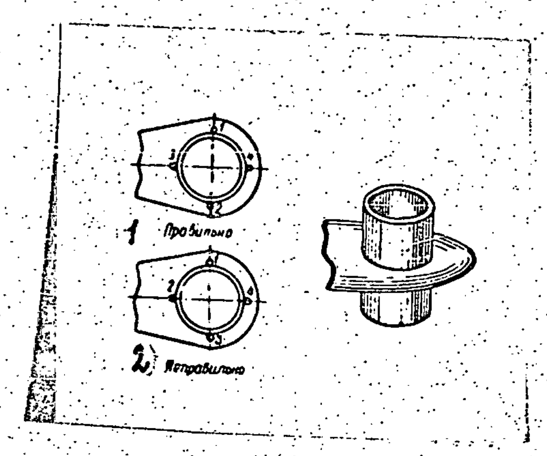


Fig. 70. - Connection pipe tacking
1) Correct 2) Wrong

§ 19. Oxy-acetylene welding of stainless chromium-nickel steels

In the course of aircraft repairs and aircraft engine repairs, a necessity often arises for joining by welding of chromium- nickel stainless steels, grades Э1 and Э1Т, containing 17 to 19 per cent of chromium and 8 to 9.5 per cent of nickel. The welding of these steels is hempered by the fact that they possess a high coefficient of linear expansion and, besides, have a tendency to form chromium carbide and high-heat oxide film. The following rules should be observed, when welding these steels.

1. The prepared edges should be clean and smooth. The gap should be even along the entire joint length, its size being:

for parts of 1.5-mm thickness . . . . 0.5 mm max.
for parts of over 1.5-mm thickness . . . . .1.0 mm max.

2. For filler metal, use thoroughly cleaned rods or strips 1.5 mm wide, cut from a sheet of Grade Э1Т steel, 1.5 thick.

3. To melt the high-heat oxides and to improve weld qua-

lity, it is advisable to cover the filler rods with a thin coating, or to apply a flux to the edges being welded.

One of the compositions given below may be used as an electrode coating (percent by weight).

No. 1 Composition

Feldspar	80
Potassium bichromate	4
Ferromanganese	10
Ferrotitanium	6

No. 2 Composition

Feldspar	40
Chalk	15
Potassium bichromate	5
Ferromanganese	15
Ferrotitanium	10
Ferrochrome	15

It should be noted that No. 2 Composition gives better results, The Grade ВИ-12-6 coating (see Table 13) is also recommended.

When the use of fluxes is desirable, the following flux composition may be recommended:

Borax	40%
Boric acid	50%
Calcium fluoride	10%

The flux should be applied to the workpiece edges 15 to 20 minutes before welding. For welding stainless steels, Grade ВИ-13-6 flux (Table 19) is recommended.

4. The torch is selected on the basis of the calculation: 75 l/hr of acetylene per millimeter of workpiece thickness. A more powerful torch will cause overheating of the metal.

5. See that the torch flame is strictly neutral; on no account should an oxidizing flame be used.

6. To facilitate removal of heat, the seam may be welded on a backing plate made of copper.

7. The angle of torch incline should be about 45 deg. to the workpiece. Both right-to-left and left-to-right welding techniques may be used. The tongue of the flame should not contact the welding puddle. The torch should be moved only along the weld, without any oscillatory motions. The filler-rod end should be kept dipped in the molten metal puddle. The welding should be performed quickly and continuously. Slow performance and frequent intervals considerably impair the quality of the weld. When long seams are being welded, a reverse-stepped welding procedure should be used.

8. On completion of the job, after the metal has cooled, the slag formed during welding should be removed by light hammering. The seam and the weld zone should then be washed with hot water and brushed.

9. After welding, the workpiece should be heat-treated by heating it to from 1050 to 1100°C and quickly cooling it in water. Steels alloyed with an addition of titanium or of carbon content below 0.06 per cent should not be heat-treated.

§ 20. Oxy-acetylene welding of chromium-molybdenum steel and chromansil steels (chromium-silicon-manganese steels)

In welding these steels, pay special attention to edge preparation. The edges should be well cleaned, and a uniform gap should be left along the entire joint length. Lack of uniformity in gap width facilitates crack formation. For filler material, use rods of Grade 10A, 20XMA and 20XГCA steels. The Grade 10A wire should be used only for parts the tensile strength of which is not over 90 kg/mm^2 after heat treatment.

The filler rods should be thoroughly cleaned of dirt. No fluxes or coatings are required. For rod diameters and other welding specifications see Table 7.

Torch size is to be selected on the basis of the following calculation: 75 to 100 l/hr of acetylene per millimeter of workpiece thickness. Maximum torch inclination is 75 deg. to the weld plane.

The torch flame should be neutral or slightly reducing.

The edge of the flame nucleus should be held at a distance of 1 mm from the molten metal.

Welding should be performed rapidly and continuously, without removing the flame from the surface of the molten metal.

During welding, the base metal is to be melted first, and then the filler rod is introduced.

To prevent crack formation during welding, the edges and the weld zone of the base metal should be preheated.

If for some reason the welding is discontinued or when a weld is completed, do not abruptly remove the torch from the joint. Move the flame slowly upwards, simultaneously heating the metal within a radius of 20 to 40 mm about the point at which weld interruption took place and reducing the temperature to a dark-red heat.

§ 21. Electric-arc welding of Grade Я1 and Я1T stainless steels

The main difficulties in welding these steels lie in their low heat conductivity and in that no overheating is allowable.

Grade Я1 steel is welded with the use of filler rods made of the same grade of steel and covered with Grade ЦЛ-2 or УОНИИ -13/н.ж. coatings (see Table 17).

Table 17

Grade ЦЛ-2 and УОНИИ -13/н.ж. Coatings
(per cent by weight)

Components	Coating Grade ЦЛ-2	Coating Grade УОНИИ -13/н.ж.
Chalk	44.0	-
Fluorite	51.0	33.5
Ferromanganese	5.0	2.5
Marble	-	57.5
Ferrosilicon	-	4.0
Ferrotitanium	-	2.5
Water glass (per cent to dry mixture weight)	35.0	25.0-30.0

Grade Я1Т steel is welded by electrodes made of the same Grade of steel and covered with Grade ЦЛ-2 or ВИ-12-6 coatings. For welding specifications of Grade Я1 and Я1Т steels see Table 18.

Table 18

Stainless Steels welding Specifications

Sheet thickness (mm)	Electrode diameter (mm)	Current (a)
3	2	50 - 70
4-5	3	90 - 100
6-8	4	120 - 150

Grade Я1 and Я1Т steels should be welded by direct current with reversed polarity. The electrode is given translatory movement only, with no transverse oscillation. To facilitate heat removal, thick copper backing plates should be placed on the reverse side of the joint.

§ 22. Electric-Arc Welding of Grade 10A, 20A, 12Г1A steels and chromansil steel

To weld these steels, electrodes are made of wire of the Grades given in Table 6. Only coated electrodes should be used.

Parts or articles of 2-mm maximum thickness are welded with thin coated electrodes, with a Grade BИ-9-6 coating. Thick parts are welded with thickly coated electrodes, with a Grade BИ-10-6 coating (Table 10).

Table 19

Composition of Coatings and Fluxes Used in Welding Steels and Light Alloys

Grade	Chemical Composition (per cent)	Application	Notes
BИ-9-6	Titanium dioxide 46	For electric-arc welding of Grade 10A, 20A, 10Г2A, 12Г2A, 25XГCA & 30XГCA steels	
	Barium carbonate 30		
	Calcium carbonate (chalk). 10		
	Manganese dioxide 8		
	Water glass (sp. gr. 1.1 to to 1.2) . . . . 1400gm per 1 kg of mixture		
BИ-10-6	Marble 52	For electric-arc welding of Grade 25XГCA, 30XГCA, 30XГCHA	
	Fluorite 14		
	Titanium dioxide 9	steels, with T.S. $\delta_B \geq 90$ kg/mm^2	
	Quartz sand 9		
	Ferrosilicon 8		
	Ferromanganese 5		
	Ferromolybdenum 3		
	Water glass (sp. gr. 1.33) 430gm		

	per 1 kg of mixture			
ВИ-12-6	Marble . . . . .60 Fluorite . . . . .29 Kaolin . . . . 5 Ferrosilicon . . . . . . 3 Ferrotitanium . . . . . 3 Water glass(sp.gr.1.3) 460 gm per 1 kg of mixture	For electric-arc welding of Grade Я1Т, ЭИ402, ЭИ403, ЭИ417 steels		
ВИ-13-6	Porcelain . . . . . 30 Marble . . . . 28 Titanium dioxide . . .20 Ferromanganese . . . .10 Ferrosilicon . . . . . 6 Ferrotitanium . . . . 6 Water glass (sp.gr.1.3 to 1.32). . . . . .650 gm per 1 kg of mixture	For gas welding of Grade ЭИ402, ЭИ403, ЭИ417, Я1Т steels	Coating is applied to reverse side of workpiece edges, and sometimes to filler rods	
Аф-44	Potassium chloride . .50 Sodium chloride . . . 28 Lithium chloride . . .14 Sodium fluoride 8	For gas welding of aluminium alloys	Use of technical salts is allowable	
	Barium fluoride . . .35.2 Calcium fluoride . . 17.4 Magnesium fluoride . 26.2 Lithium fluoride. . .21.2	For gas welding of magnesium alloys	Use of technical salts is allowable with check for absence of chlorine ions	

For welding specifications of the above grades of steel see Table 20.

When welding elements of different thickness, the electrode diameter and current should be selected according to the lower limit recommended for the thicker element.

Table 20

Grade Chromansil Steel Arc-welding Specifications

Sheet thickness (mm)	Butt Joint Electrode dia. (mm)	Butt Joint Current (a)	Lap Joint Electrode dia (mm)	Lap Joint Current (a)	Tee-Joint Electrode dia (mm)	Tee-Joint Current (a)
1	2	25-34	2	30-50	2	30-50
1.5	2	35-50	2.5	47-75	2.5	40-70
2	2.5	45-70	2.5-3	55-85	2.5-3	50-80
2.5	2.5-3	60-90	3	75-110	3	70-105
3	3	70-100	3-4	85-135	3-4	80-120
5	4	115-160	4-5	125-190	4-5	150-180
6	4-5	145-200	5-6	155-200	4-5	160-225

After welding, chromium-molybdenum steel parts are heat-treated as required for the base metal.

The chromansil steel is more difficult to weld than the chromium-molybdenum steel, since the former has a greater tendency to slag formation, and the puddle of the molten metal becomes covered with a refractory film; besides this, this grade of steel has a greater tendency for crack formation. The filler metal, order of welding, specifications and techniques adopted in the welding of the chromansil steel are similar to those adopted in the welding of the chromium-molybdenum steel.

The torch is selected of somewhat smaller size than that used in welding chromium-molybdenum steel.

Owing to the fact that the chromansil steel has a tendency towards crack formation as a result of abrupt temperature drop, when completing welding or when welding is to be discontinued slowly, move the torch away, simultaneously heating the metal with the torch flame with a radius of 20 to 40 mm around the point of welding.

In double-pass welding, to deposit the second layer of weld metal, the current should be by 10 to 15 per cent higher than that shown in Table 20.

Welding should be conducted continuously, the arc being broken only after the crater is filled. Do not break the arc at points a turning of the seam. The arc should be re-struck (after having been broken) adjacent to the crater and on the deposited weld metal.

When elements of different thickness are being welded, direct the arc towards the thicker element. The angle of electrode incline towards the weld plane should be 70 to 80 deg.

The welding should be preferably performed in the horizontal position only with a short arc. The arc length should not exceed electrode diameter.

When thin elements of chromansil steel are welded, a partial hardening of the metal in the zone of the seam takes place which requires special heat-treatment.

CHAPTER IX

TECHNIQUES OF WELDING ALUMINIUM AND MAGNESIUM ALLOYS

Aluminium-base and magnesium-base alloys are widely used in aircraft construction. The principal difficulties which arise in welding these alloys are caused mainly by their high thermal conductivity and intensive oxidation resulting in the formation of high-heat oxide films.

The specific features of the welding of parts manufactured of sheet aluminium and magnesium alloys are considered below.

§ 23. Oxy-acetylene welding of aluminium and its alloys

Parts made of aluminium and its alloys, prior to welding, should be thoroughly cleaned and washed.

To clean the edges to be welded and the filler wire, use either a steel wire brush, or employ a chemical method (degreasing and pickling).

The washing is done as follows:

a) washing in hot water (60 to 80°C);

b) washing in a 10-per cent solution of sodium hydroxide heated to 60 or 70°C;

c) second washing in hot water (60 to 80°C);

d) washing in a 10-per cent solution of nitric acid;

e) washing in hot water;

f) drying at 110 to 120°C.

When welding sheets of below 1-mm thickness, the edges should be flanged. Sheets 1 to 4 mm thick are welded without edge-bevelling, while in welding sheets over 4 mm thick single-V edge preparation with an angle of 60 to 90° is used.

Aluminium and the aluminium-magnesium alloy are welded by the right-to-left process, use being made of either a filler wire of a composition identical to that of the base metal, or of Grade AK wire. Welding conditions and wire diameters are selected from Table 21.

Table 21

Aluminium and Aluminium-Base Alloy Oxy-Acetylene Welding Specifications

Sheet thickness (mm)	Torch Tip No.	Wire Dia. (mm)	Oxygen Gauge Pressure (kg/cm²)	Acetylene Consumption (1/hr)
0.5-0.8	00	2.0	1.5	50-100
1.0-1.2	0	2.5	1.5-2.0	100-150
1.2-1.5	0-1	3.0	2.0-2.2	150-200
1.5-2.0	1-2	3.0-4.0	2.3-2.5	200-250
3.0-5.0	2-3	4.0-5.0	2.5	250-400
5.0-10.0	3-5	5.0-6.0	2.5-3.0	400-700

Welding is always conducted with the use of fluxes. A flux should be applied to both sides of the edges to be welded, and the filler wire end is to be periodically dipped into the flux in the process of welding.

For the composition of the fluxes used in the welding of aluminium and its alloys see Table 22.

The use of Grade AФ-4A flux is also recommended (see Table 19).

The torch flame should be strictly neutral. Perform the welding at a rapid speed. See that the angle of torch incline is 30°, and the angle of filler rod incline is 45° to the workpiece surface.

The filler rod end should be positioned on the puddle bottom; in addition to the translatory movement, the filler rod should be imparted a vertical up and down movement.

Table 22

Fluxes for Welding Aluminium Alloys

(per cent by weight)

Components	Flux Number				
	1	2	3	4	5
Potassium chloride	45	45	30	50	48
Sodium chloride	30	33	45	40	35
Lithium chloride	15	15	10	5.5	8
Potassium fluoride	7	7	15	3	-
Sodium fluoride	-	-	-	1.5	9
Sodium bisulfate	3	-	-	-	-

When welding long joints, use a reverse-stepped order of weld depositing. In welding thin-metal elements, use copper backing plates to facilitate weld cooling.

After welding, thoroughly clean the workpiece of the flux that remains on its surface. Proceed as follows:

a) wash the workpiece on both sides with hot water (60 to 80°C) and wipe the welded joints with a hair brush;

b) wash the workpiece with a water solution of chromium trioxide (20 gm per litre of water), at 60 to 80°C;

c) wash the workpiece with hot water for the second time;

d) dry the workpiece with compressed air until the moisture is fully dried off.

§ 24. Electric-arc welding of aluminium and its alloys

Aluminium and its alloys may be welded both with carbon and metal electrodes. Under mobile repair-shop conditions, metal and coated electrodes are normally used. Electrodes are made of pure aluminium wire or Grade AK alloy. For coatings used in the welding of aluminium and its alloys see Table 23.

Table 23

Electrode Coatings for Welding Aluminium and Its Alloys

(per cent by weight)

Components	No.1 Coating for aluminium welding	No.2 Coating for duralumin welding	No.3 Coating for silumin welding
Sodium chloride	15	27.2	12.5
Potassium chloride	50	-	50
Cryolite	35	45.5	35
Lithium chloride	-	18.2	-
Sodium sulphate	-	9.1	2.5

As a bonding agent, starch gum dextrine is used. The use of water glass for this purpose is not allowable.

No.1 coating is diluted by water, 50 cu.cm. of water per 100 gm. of the dry substance, with a subsequent drying in the open air and heating at 140 to 150°C for a period of 30 to 40 min. The thickness of Nos. 1 & 3 coatings is to be taken as 1 to 1.2 mm to a side of the electrode; the thickness of the No.2 coating is to be 0.4 to 0.5 mm.

The parts intended for electric-arc welding should be cleaned and degreased as in the case of gas welding. Sheets of up to 1.5 mm maximum thickness are butt-welded by flanging of the edges and without the use of filler metal. Sheets 2 to 5 mm thick are welded without edge bevelling, but with a gap of 1 or 2 mm. For welding sheets over 5 mm thick, single-V edge preparation at 45° is used. Welding is performed by direct current with reversed polarity. Welding conditions are selected from Table 24.

Table 24.

Aluminium Alloys Electric-Arc Welding

Specifications

Sheet thickness (mm)	Electrode diameter (mm)	Current (a)
1.5	3.0	45-55
2.0	3.0	55-65
2.5	3.0	65-75
3.0	3.0	75-85
4.0	4.0	85-100
4.5	4.0	100-125
6.0	4.0-4.5	125-175
8.0	4.5	175-225

The arc length should be maintained within 3 to 5 mm. The electrode should be moved only along the joint, with no oscillatory transverse motions. To facilitate heat removal during welding, it is recommended that copper backing plates be placed under the joint being welded; each plate being provided with a groove located directly under the weld and designed to ensure a better penetration.

After welding, the weld should be cooled slowly; to achieve this, do not take the workpieces out into the cold or subject them to draughts. Thoroughly clean the weld of slag, using a steel wire brush, wash the weld with hot water and then dry it.

§ 25. Oxy-acetylene welding of magnesium alloys

Magnesium alloys are widely used in aircraft construction. They are adequately welded by the oxy-acetylene process, provided the following rules are observed;

1. Before welding, the workpieces should be cleaned by a metal brush or by a chemical method.

2. Sheets of up to 2-mm maximum thickness are welded without edge preparation; sheets over 2 mm thick are welded with single-V edge preparation at 80 to 90°, with no gap. The minimum blunt edge should be 1.5 mm.

3. Welding is always performed with the use of flux. Filler wire is to be of the same alloy of which the part to be welded is manufactured.

In the welding of magnesium alloys use is made of the flux given in Table 19. The flux is applied to the filler rod and to both sides of the welded metal, near the edges.

The filler wire diameter is selected to suit the thickness of the sheets being welded:

for sheet thicknesses of 0.8 to 1.0 mm use wire of 1.5-mm diameter, for 1.0 to 2.0-mm sheets - 3-mm diameter wire.

4. The workpieces are only butt-welded, by the right-to-left method. The rated speed of welding is 6 to 9 metres per hour for sheets 1 to 2-mm thick, and 3 to 4 metres per hour for a sheet thickness of 5 mm and over.

The torch tip number is selected on the basis of the following acetylene consumption calculation:

for a workpiece thickness of 1 to 2 mm . . . . . 150 l/hr acetylene

for a workpiece thickness of over 5 mm . . . . 300 "

The torch flame should be strictly neutral. The edge of the flame nucleus should be located at a distance of 1.5 to 3 mm from the puddle. Do not dip the filler wire into the puddle.

5. After welding, the slag and the balance of the flux should be immediately removed, and the weld thoroughly washed

and treated with a hot solution of potassium bichromate (20 gm of potassium bichromate per liter of water) for a period of 3 to 5 minutes at a temperature of 60 to 80°C, after which the weld is washed with hot water and dried.

CHAPTER X

REPAIRS OF AIRCRAFT PARTS BY WELDING

§ 26. Preparing the parts for repairs by welding

Experience shows that on the welding of various parts, in the process of cooling certain shrinkage stresses originate in the metal of the weld which tend to cause permanent deformation (Fig. 71). As a result of the welding of two sheets, warping takes place because the welded seam during cooling contracts and produces longitudinal (along the weld length) and transversal (across the weld width) shinkage. Consequently, the welded seam deforms the parts being joined by welding in both directions. The shrinkage of welded parts may be reduced as a result of a thorough study of the importance of proper part assembly (the size of gaps), the sequence of tacking, and welding conditions, from the point of view of the amount and nature of part distortion in the process of and after welding.

On the basis of the wide experience gained by our operators, the following rules for aircraft-parts welding may be formulated.

When long sheets are welded, a gradual closing of the edges and even their overlapping at the far sheet end is normally observed. Consequently, if a gap of an equal width is left along the entire joint length, this will inevitably result in a defective weld, since the sheets will overlap and warp intensively. To avoid this, the gap between the edges should gradually increase and at the far sheet end its width should amount to 5 per cent of the joint length (Fig. 72). Thus, if the welded sheets are 1000 mm long, the gap width at the end of the joint should be $\frac{1000 \cdot 5}{100} = 50$

This procedure is followed in the welding of cylinders (Fig.73). The width of the gap is adjusted by means of a wedge which is inserted between the edges to be welded and is gradually moved along the joint.

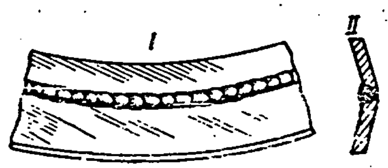


Fig.71. - Warping of steel strips during welding

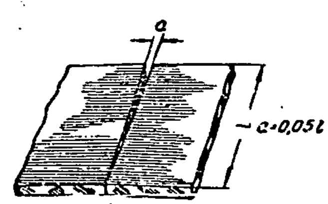


Fig.72. - Correct gap width for beginning the butt-welding of sheets

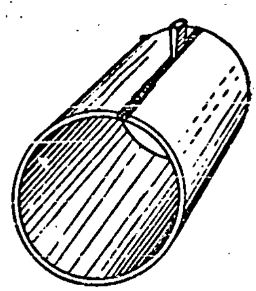


Fig.73. - Gap adjustment in the welding of a cylinder.

To ensure the required mutual arrangement of the parts and to decrease their distortion, tack them prior to welding. The sequence of tacking adopted for each type of joint has been discussed in §12 of Chapter v above, and illustrated in Figs. 68 to 70. As a rule, the parts are first tacked at the ends and then in the middle; all the other tacks being arranged to both sides of the middle tack. The tacks are spaced at 20 to 60 mm intervals; the thicker the sheets, the greater the interval. The end tacks should be located 10 mm away from the ends of the joint.

§ 27. Selection of welding process

In the repair of aircraft, needs arise for the welding of a most diverse range of structural elements made of various metals and alloys. For this reason, in the field both electric-arc and oxy-acetylene welding is used. In selecting one or the other process, it is necessary to be familiar with their specific features, advantages and disadvantages.

In electric-arc and gas welding, the weld zone and the weld metal will possess the lowest mechanical properties (as compared to the base metal).

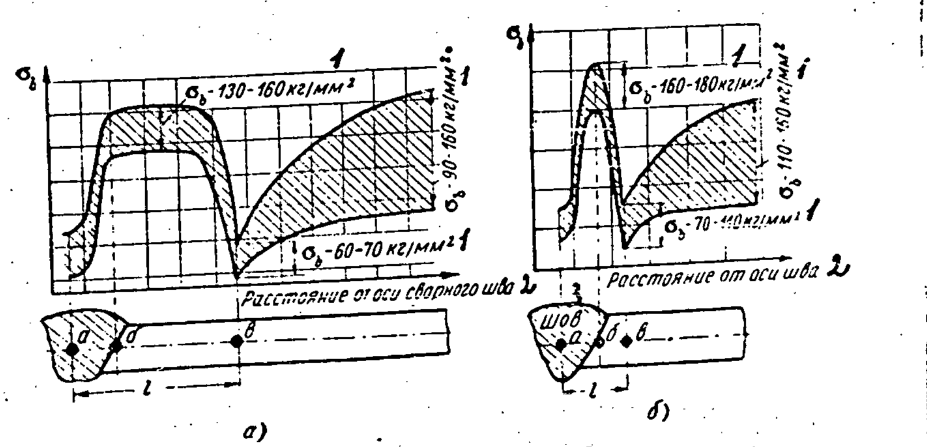


Fig. 74. - Diagram of weld metal hardness in joints made by various welding processes.

a-gas welding; b-electric-arc welding
1) kg/mm² 2) distance from weld axis 3) weld

The welded seam has a cast coarse-grained structure. As a result of the metallurgical processes taking place in the molten weld during welding (i.e. oxidization, carbonization, nitriding, etc.) the strength of the welded seam becomes somewhat lower than that of the base metal. However, when the quality of welding is high, the weld will not be a weak point because its cross section is always slightly greater than that of the base metal. For this reason, the weakest point of a welded joint is, as a rule, the base metal of the adjoining zone. This can be seen from the hardness curves for the weld cross section and the adjoining zone, drawn for the two welding processes (Fig.74).

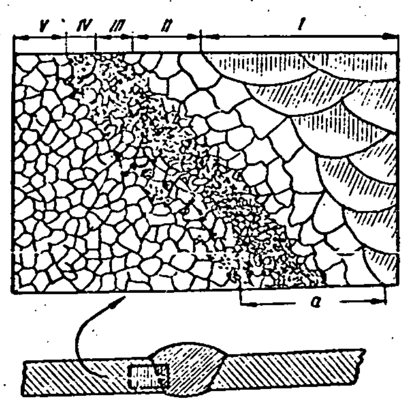


Fig.75. - Weld metal structure

In electric-arc welding the metal of the weld-adjoining zone is weakened to a lesser degree. The weld produced is also somewhat stronger than in oxy-acetylene welding.

The changes in hardness, accompanied by changes in metal strength in the zone of welding heating are due to the variable structure of the metal. The structure of the joint of a welded steel workpiece, as seen under a microscope, can be subdivided into five sectors (Fig. 75).

Sector I - The weld proper has a cast coarse-grained structure.

Sector II -(adjoining the weld) - the coarse-grained structure of intensively overheated metal which has been heated to a temperature over 1000° C.

Sector III (intermediate) - the fine-grained structure of metal which has been heated to from 800 to 1000°C.

Sector IV has but minor structural changes since it has been heated to from 700 to 800°C.

Sector V - base metal having no structural changes since it has been heated to temperatures below 700° C.

The width of the zone of thermal influence (marked "a" in Fig. 75), that is, the width of the sector in which the change in metal hardness and strength has taken place due to the thermal effect of welding (Fig. 74), is different for various welding processes. Thus, in electric-arc welding, the width of this zone is 6 to 8 mm, while in oxy-acetylene welding it is 28 to 30 mm, or 4 to 5 times greater than in electric-arc process.

Besides, in oxy-acetylene welding, when lerge volumes of metal are being heated, intensive internal stresses are originated which often become the cause for highly excessive warping and crack-formation close to the weld.

Changes in the properties of metal due to the local heating are more characteristic for parts which have high ultimate strength, since the base metal of these parts is more sensitive to thermal treatment than a metal having an ultimate strength σ_b below 100 kg/mm^2.

With due consideration to the above specific features inherent to oxy-acetylene and electric-arc welding, at present definite fields of application are set for each of the two welding methods, as regards their employment for aircraft repairs.

Oxy-acetylene welding should be used in the repairs of aircraft structures when the iltimate strength of the structural elements is not above 100 kg/mm^2. For joining parts which have been heat-treated for an ultimate strength of over 100 kg/mm^2, electric-arc welding is used. Besides, it should be kept in mind that the efficiency of oxy-acetylene welding is considerably below that of electric-arc welding.

Notwithstanding the limitations which have been pointed out, oxy-acetylene welding has a number of advantages which make desirable its use in the repairs of aircraft structures.

When a neutral flame is used, the deposited metal is free of slag inclusions and oxides, and the burning-out of additions is but inconsiderable. The weld thus produced is ductile and strong.

In gas welding, the flame power and the moment of filler rod introduction into the puddle are easier to control, which facilitates the obtaining of a good penetration and makes easier the welding of thin-sheet and non-ferrous metal parts (aluminum, magnesium and their alloys).

§ 28. Welding of Steel sheet and tubular elements

Long sheets are welded by the reverse-stepped method. For this purpose, the entire joint length is divided into sectors 150 to 200 mm long, these sectors being welded by turn, in the direction opposite to the direction of the numbering (Fig.76). Sometimes long joints are welded from the middle to both ends, by sectors (Fig.77). Do not weld long joints from the ends towards the middle (Fig.78), this will result in intensive warping and crack-formation.

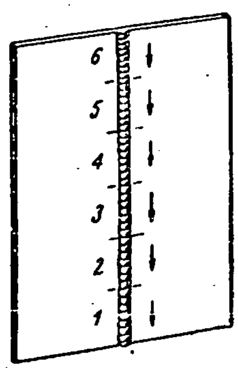


Fig.76. - Reverse-stepped method of welding long sheets.

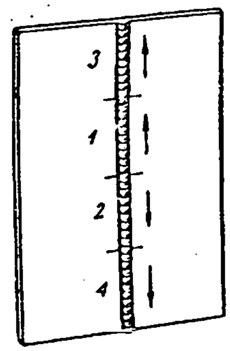


Fig.77. - Welding of long sheets from the middle towards the ends

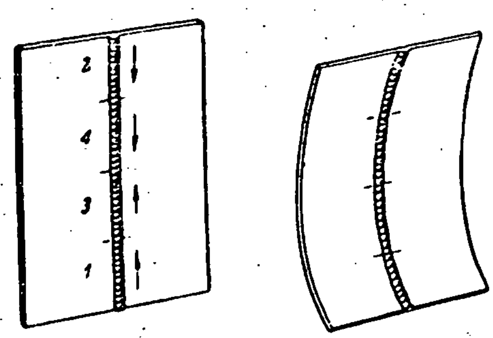


Fig.78. - Wrong sequence in sheet welding

1) wrong

I N welding washers and cover plates, select the direction of welding so that the weld, at a hole or bridging sector, is started at a more wide section of the workpiece and terminates at a more narrow part, (Fig.79). Non-observance of this rule results in crack-formation.

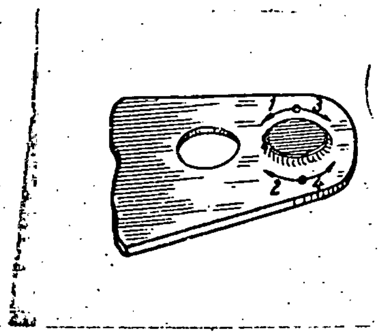


Fig.79. - Working order in welding a washer to a workpiece having a hole.

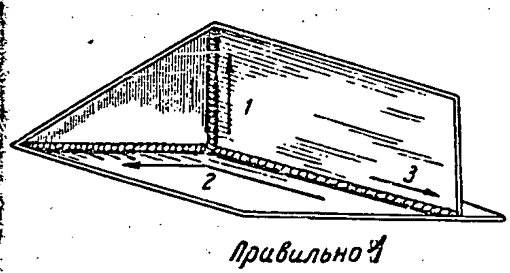


Fig.80 - Correct working order of welding a corner plate and rib.
a) correct

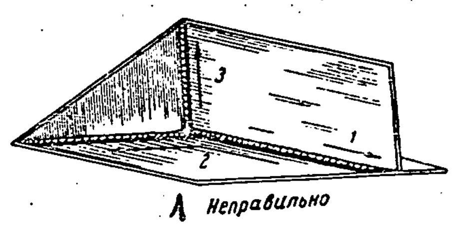


Fig.81. - Wrong working order of welding a corner plate and rib
a) wrong

W h e n w e l d i n g c o r n e r p l a t e s a n d r i b s, take into consideration not only the conditions involving warping of parts, but also the difficultly of ensuring penetration at the corners. For this reason, start the first weld (Fig.80) from the corner and direct it towards the nearest edge; the second weld should be started 10 or 15 mm from the edge and led through the corner, without a break, up to the opposite end of the corner plate; then the third length of weld is deposited in a direction towards the edge. If, on the contrary, the order of welding shown in Fig.81 be adopted, no penetration can be obtained at the copper of the corner plate.

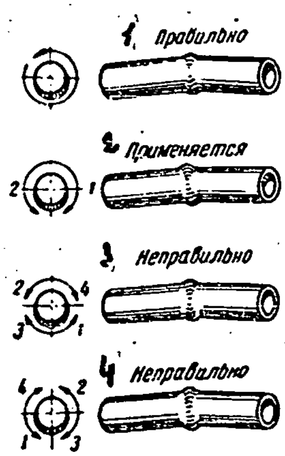


Fig.82 - Correct and wrong working order of tube butt-welding

1) correct, 2) may be used, 3) wrong, 4) wrong.

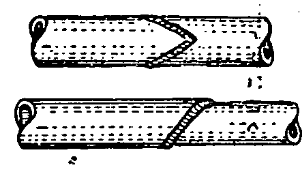


Fig.83. - Fish-mouth welding of tubes.

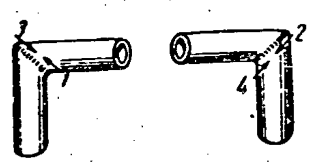


Fig.84 - Tube corner joints.

T h e b u t t - w e l d i n g o f t u b e s (Fig.82) should be performed without interruption; however, there is an alternative method consisting in the welding-up of half of the circumference and then returning to the starting point and depositing the weld along the second semi-circle. The result obtained in this case is somewhat lower. No other welding sequence should be adopted since this would only increase the degree of tube distortion. More often the tubes are not butt-welded, the fish-mouth joint being used, in which one of the tubes is inserted into a larger-bore second pipe (Fig.83).

T u b e c o r n e r j o i n t s (Fig.84) are welded in four stages. Welding is begun from the inner corner; the second weld is deposited in the same direction but is started from the outside corner. The third weld is welded also from the outside corner but in a reverse direction. The fourth weld is deposited beginning from the inner corner and in the same direction.

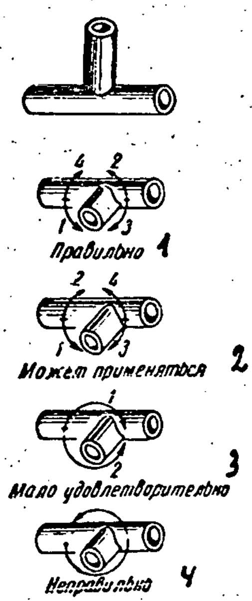


Fig.85. - Working order in welding a connection tube to a main tube

1) correct; 2) may be used; 3) hardly satisfactory; 4) wrong

T h e T e e - w e l d i n g o f t u b e s (Fig.85) is performed in four stages, in the following order. The first weld is deposited from the corner on the tube side; the second weld is started from the opposite corner and is deposited in the same direction on the other tube side; the third weld is started from the beginning of the second weld and ends at the first weld, while the fourth weld is started from the beginning of the first weld and is continued until it reaches the second weld.

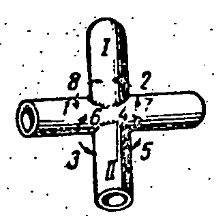


Fig.86. - Welding a cross-piece

Fig.87. - Welding of an inclined strut

1) wrong 2) may be used 3) correct

The welding of a cross-piece (Fig.86) is subdivided into eight stages. To begin with, connection pipe I is welded with two seams (1) and (2), then connection pipe II is welded with four seams (3), (4), (5) and (6), after which the welding of connection pipe I is completed by seams (7) and (8).

The welding of an inclined strut (Fig.87) is performed in an order similar to tee-welding, but here the first weld is started from the obtuse angle

The welding of an upright with a strut (Fig.88) should be started by welding the strut to the upright, from the corner between them. Firt the strut is welded to the tube, the welds being started from the corner between the strut and the tube; then the upright is welded to the tube, the welds again being started from the corner between the tube and the upright until they meet the welds by which the strut has been welded to the tube. The same working order remains true fot the case when both the upright and the strut are arranged at an angle other than 90° to the tube.

T h e t u b e c o r n e r j o n i t w i t h t w o r u t s is welded in the order illustrated in Fig.89, the first welds being used to join the tubes forming the right angle.

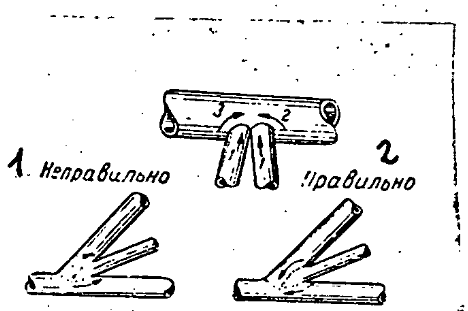


Fig. 88. - Welding an upright and a strut
1) wrong 2) right

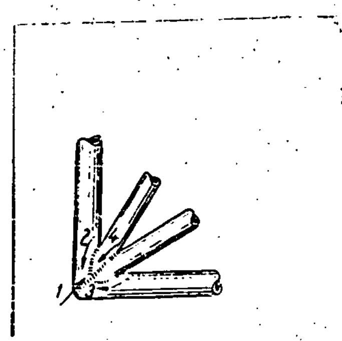


Fig.89 - welding a tube corner joint with two struts

T h e w e l d i n g o f a t u b e a n d a v e r - t i c a l u p r i g h t w i t h t w o s t r u t s i s shoun in Fig.90. Welded first is the vertical strut to the longitudinal tube. The welds, as in the case of tee-welding, are started from the corners and are directed to the sides, but are asually not joined, so that they will not be overlapped by the welds to be made for securing the side struts to the tube. The struts are first welded to the upright, and

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then to the tube. Like in all other similar cases, the welds are started from the corners. The last welds are connected somewhat to one side from the middle, so that their points of meeting do not coincide with the point of joining of the previously deposited welds required for securing the struts to the upright.

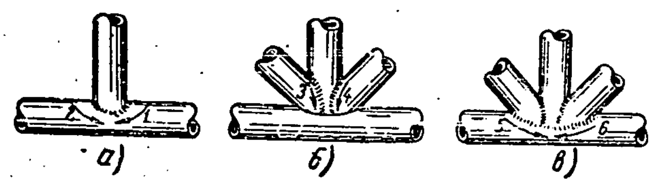

Fig.90. - Working order in welding a tube with an upright and two struts.

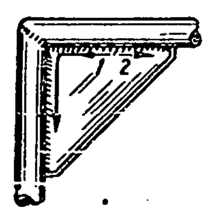

Fig.91. - Welding a corner plate.

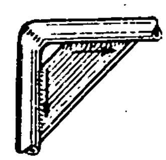

Fig.92. - Welding a corner plate with a trimmed corner.

The welding of corner plates in a tubular corner joint can be seen in Fig.91. The first weld should be started 10 or 15 mm from the edge and should be deposited along the entire joint; then, beginning from the same point, weld the unwelded length of the joint, bringing the weld up to the very edge. When the corner plate has a trimmed corner (see Fig.92), welding is started from the cut towards the edges, in to seams.

The welding of cut-in corner plates is performed at the two sides (Fig.93), the working order on the opposite side being similar to that on the face side. Prior to welding, remove the scale, using a metal brush.

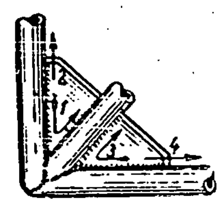

Fig.93. - Welding a cut-in corner plate.

The above examples of typical working techniques and procedures used in the welding of various structural elements, naturally, do not cover all the possible cases encountered by a welder in his practical work in connection with aircraft repairs. However, a thorough study of the described techniques will also enable the welder to select a correct welding procedure in all other cases, and thus avoid the warping of elements and the appearance of cracks during the welding.

§ 29. Welding of cracks

Welding of cracks is one of the most frequently encountered tasks in the repair of aircraft. Cracks (Fig.94) appear in the course of aircraft operation, normally, in those welded parts which are subjected to more severe stresses; such cracks either are a result of poor manufacturing quality or, which is more often, the case of fatique or dynamic stresses.

Welding of cracks requires a careful approach. The vital aircraft parts may be welded only on permission being given by engineering personnel, with the welding to be performed by highly skilled operators.

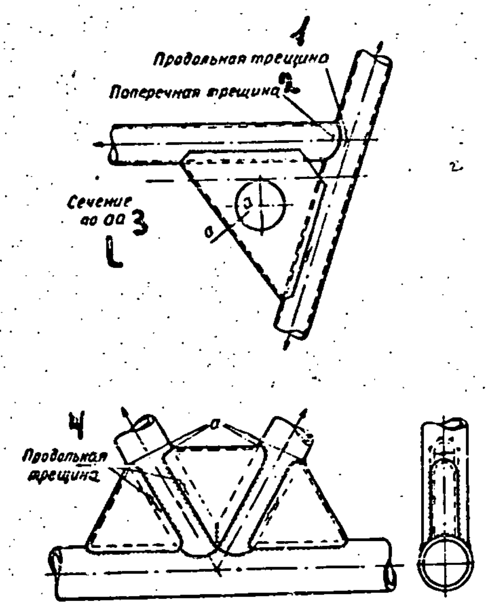

Fig.94. – Location of cracks in welded sub-assemblies

1) Longitudinal crack; 2) Transverse crack;
3) Section through a–a; 4) Longitudinal crack

The places to be welded should first be thoroughly cleaned of paint and other coatings. This is done by means of scrapers, solvents, emery cloth, etc.

The steel sub-assemblies contacting parts made of light alloys are welded after dismantling. In special cases the cracks detected in these sub-assemblies may be welded up by the electric-arc process, with accompanying intensive cooling of the place of welding by means of wet asbestos or by some other method.

As a rule, the cracks detected in the base metal at the seams and at a distance from the seams, in all the aircraft sub-assemblies may be welded up, barring the motor frames of piston engines and other aircraft parts normally operated under intensive vibrational stresses.

Generally speaking, no cracks should be left unwelded. In certain cases cracks of 5-mm maximum length located in the welded seam zone and occupying a position parallel to the direction of the main stress may be left unwelded.

Prior to repairing an aircraft part, detect the location of the crack by pickling the steel parts in a 10-per cent solution of nitric acid, by magnetic and luminiscent control, by a kerosene test or some other method.

On parts over 2 mm thick the ends of a cruck prior to welding should be bored by a 2.0 to 2.5-mm diameter drill and filed or milled until a V-shaped groove is obtained.

When welding up the cracks, see that complete penetration to the full depth of the crack is attained.

Repeated welding of a crack over one and the same length is normally performed once or twice only, since, as a rule, this brings no positive results. Should a crack reappear where it has already been welded up, this part is to be repaired by fully cutting out the defective weld.

In cases when cracks have a considerable length, the repaired places should be reinforced by the employment of straps, boxes, split inside and outside sleeves, etc.

§ 30. Repairs of tubular structures

The majority of the weldod assemblies of an aircraft are those of welded tubing. In many aircraft the fuselage frames, undercarriage frames, etc., are manufactured in the shape of spatial trusses consisting of tubular elements connected by welding. The tubes are manufactured of chromansil, grades 25ХГСА, 30ХГСА, 30ХГСНА, and are heat-treated, to obtain an ultimate tensile strength of σ_b=70 to 90 kg/mm^2, and, sometimes, as high as 110 to 130 kg/mm^2. x)

The majority of tubular assemblies are reinforced by corner plates, which greatly contribute to the strength of the structure but at the same time make repairs by welding a more complicated job. In the repair of tubular frameworks it is often required that defects be eliminated in framework elements, and, in some cases, that these elements are replace

Prior to repairing a tubular framework, it should be subjected to a thorough inspection, with the aim of detecting the defects. For this purpose, the complete assembly should be "levelled", that is, its dimensions should be checked, and then the individual tubes should be inspected for possible buckling-up, dents or bends of a size above tolerable. The defective places are repaired by welding. The welding specifications and the method of welding should be specially selected in each individual case, depending upon the thickness, grade and ultimate tensile strength of the metal.

R e p a i r s o f d e n t s a n d b u c k l e d t u b e s u r f a c e s. Dents the size of which remains within the tolerated limits shown in Table 25 may be left unrepaired, provided there is but one such dent per 300-mm of the tube length

Table 25

Allowable Dent Sizes on Tubes

Tube diameter (mm)	16	20	22	25	32	35	40	45
Depth of dent (mm)	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.0
Length of dent (mm)	9	10	11	12	16	17	20	22

If a dent exceeds the above dimensions but has smooth

x) For details on ultimate tensile strength see Chapter XII.

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slopes at its boundaries and a depth of not over 10 per cent of tube diameter., it is repaired by depositing weld metal which is finished down with a file(Fig.95).

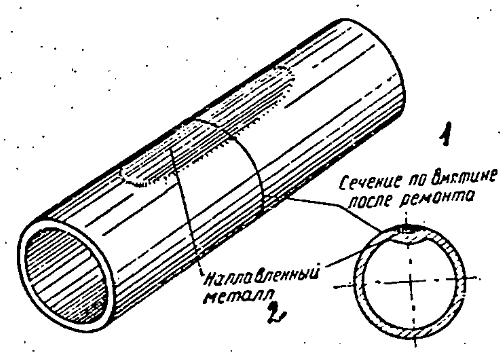


Fig.95. - Repairing a dent by depositing of weld metal

1) cross section through dent after welding
2) deposited metal

Tubes buckled to a degree above the limits shown in Table 26, should be replaced, When the size of a corrugation is below critical, it can be straightened or welded up, with subsequent filing.

Table 26

Allowable Limits of Buckling for Tubes

Tube diameter (mm)	16	20	22	25	32	35	40	45
Corrugation height (mm)	0.3	0.4	0.5	0.5	0.7	0.7	0.8	0.9
Length along circumference (mm)	16	21	23	26	33	36	42	47

The maximum allowable bending of a tube is 2 mm per metre of tube length. Tubes having a greater bend should be straightened.

In selecting or replacing tubes as well as during the detection of defects, check the tubes for ellipticity or out-of-roundness (that is deviation from their nominal diameter) which should not exceed the values contained in Table 27.

Table 27

Allowable Tube Ellipticity

Tube diameter (mm)	16	20	22	25	32	35	40	45
Ellipticity (mm)	0.6	0.8	0.8	1.0	1.85	1.5	1.6	1.8

If the ellipticity is above allowable value, the tubes should be straightened or replaced.

As a result of the repair of a fuselage frame or some other complicated assembly by welding, considerable warping is possible; therefore prior to removing defective rods, and especially during the welding of new rods, the distances between individual elements should be fixed by means of some clamping appliance, and all the dimensions should be checked by levelling.

A dent with a metal fracture located close to the juncture point of several elements is repaired by the use of a reinforcing strap. In doing so, the edges of the fracture should be thoroughly filed to prevent crack spreading. A strap made of Grade 30XГСА sheet steel or of a length of pipe of the same Grade is fitted over the damaged place. The strap thickness should be equal to that of the tube. The strap chosen should be from 60 to 80 mm longer than the dent (Fig.96). The strap should closely fit along its entire length to the damaged part of the tube. Prior to welding, the strap should be held on the tube by means of a clamp and then tacked in place by electric-arc or gas welding.

When a dent or hole has a considerable length, and is located at a distance over four tube diameters from an element of juncture, and when its size is so large that over 25 per cent of the circular form of the tube is distorted, a double-size strap is used (Fig.97).

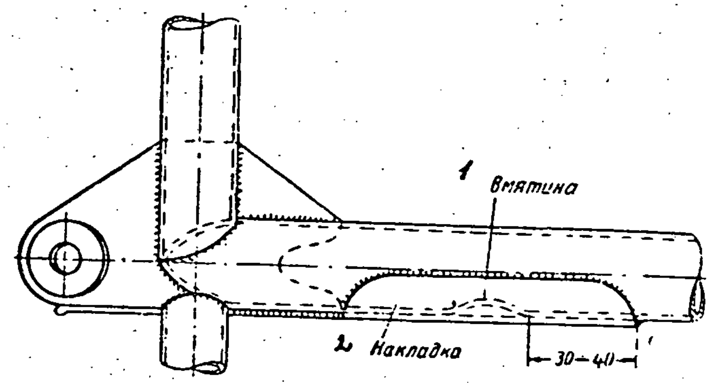


Fig.96. - Repairing a tube with a single-side strap
1) dent 2) strap

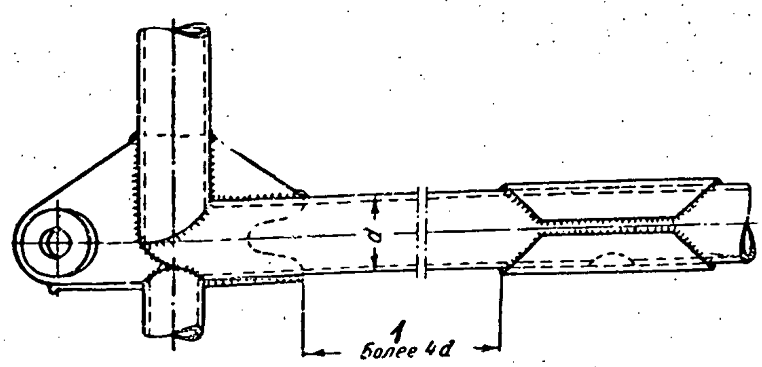


Fig.97.- Repairing a tube with a double-side strap
1) ever four diameters

Like in the previous case, the Grade of metal and the thickness of the strap should be identical to those of the tube being repaired.

When a tube has a deep dent and has a crack on the opposite side, it is repaired by cutting out the defective length and inserting a new pipe which is reinforced on the outside by straps (Fig.98.). The defective part is cut out at an angle of 45°. The new tube length is accurately fitted up with the aid of a clamping device, and then tacked by oxy-acetylene or electric-arc process. Only after this is it welded in place. After the weld has cooled, it is filed down flush with the tube surface, and the straps are made to fit up against the tube surfaces. The Grade and metal thickness of the straps should be similar to those of the tube.

Dents on the tubes, not accompanied by cracks, are welded and filed off flush with the pipe circumference, or are repaired by drawing. In the latter case, a 2 to 3-mm diameter rod is welded at its bottom end to the dent centre. The top end

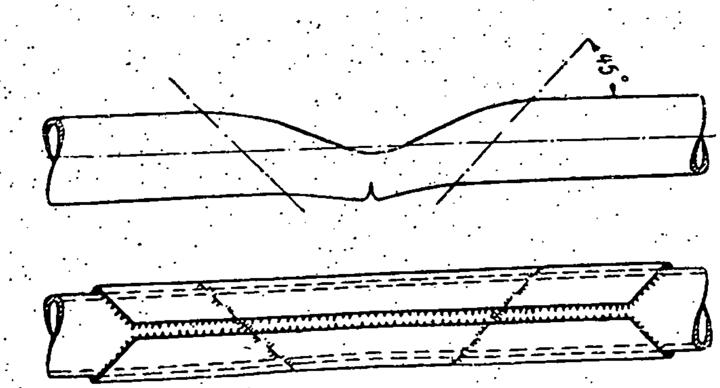


Fig.98. - Repairing a tube with a dent on one side and a crack on the opposite side

of the rod is then bent to form a loop into which a lever is inserted. The pipe is now heated and the dent straightened by actuating the lever (Fig.99). After the dent is straightened, the rod is cut off flush with the pipe surface. In places subjected to intensive stresses, a strap is normally welded over the place which has been thus repaired (Fig. 100).

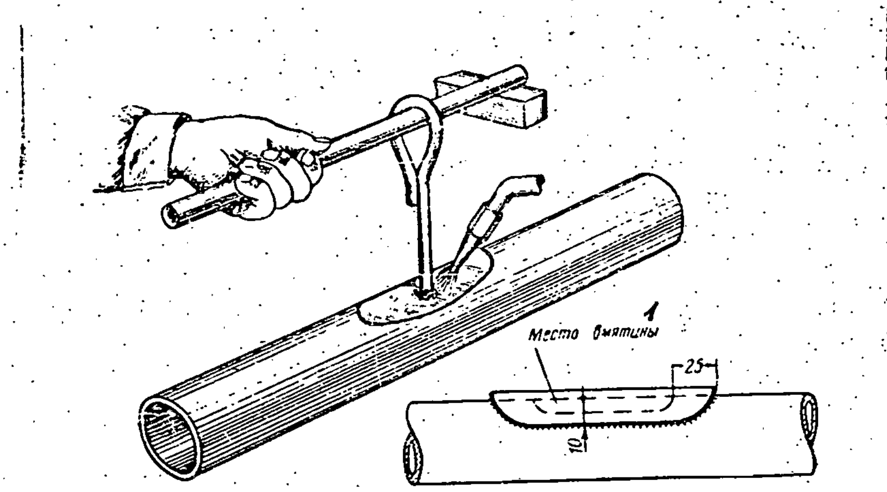


Fig.99. - Repairing a dent tube by drawing

1) place of dent

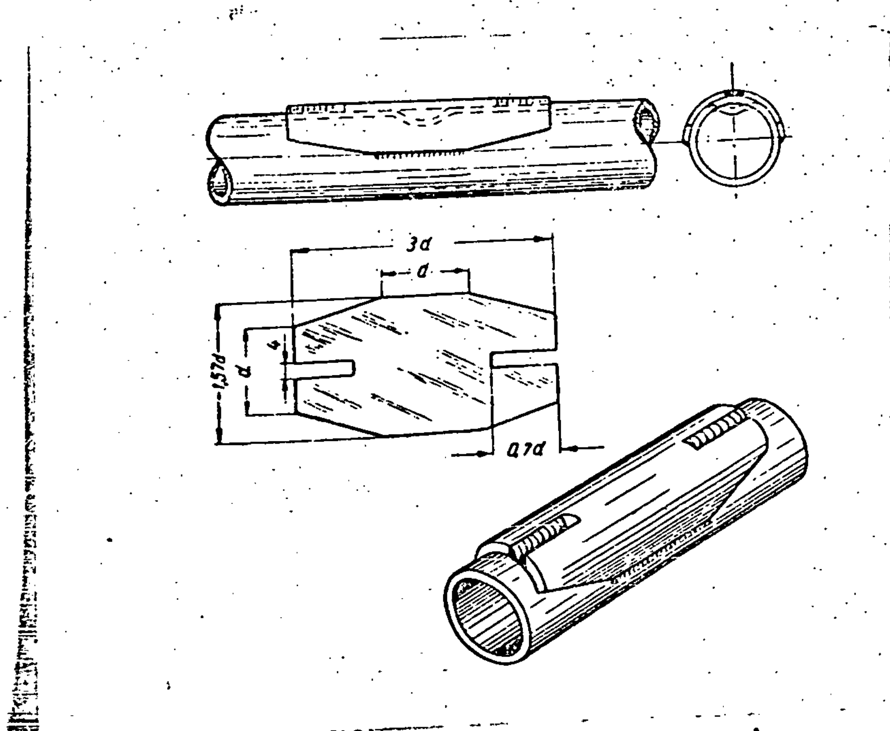


Fig. 100. - Repairing a dent tube by application of a strap.

Cracks in a weld or in the tube base metal near the juncture point of several tubes are repaired by the use of boxes or straps made of the same metal as the tubes themselves. The boxes and straps are welded to the pipes mainly by longitudinal welds (Fig. 101).

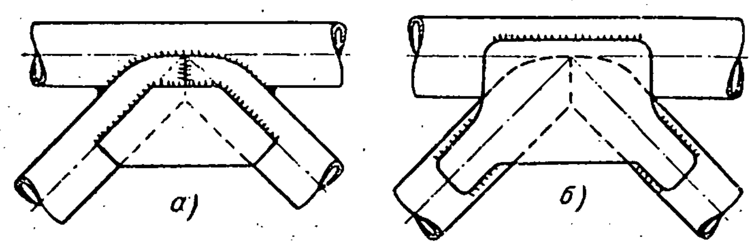


Fig. 101. - Reinforcing places of juncture by welding of boxes (a) and straps (b)

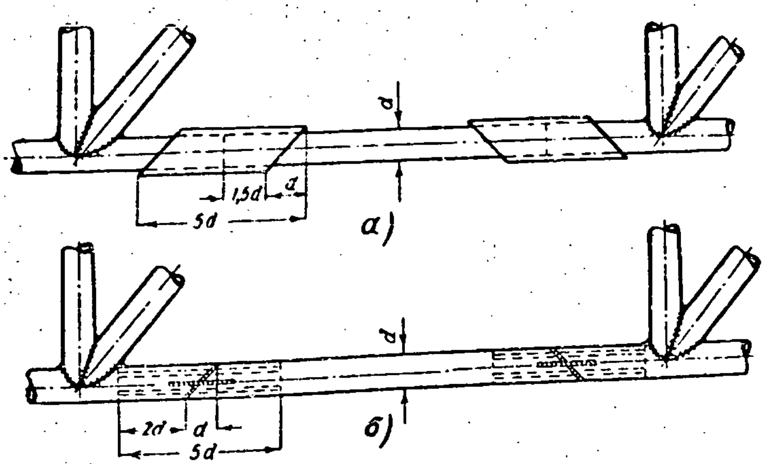


Fig. 102. - Replacing a pipe length by means of outside (a) and inside (b) sleeves

Separate tube lengths which are beyond repair should be replaced. The tubes are connected by means of outside sleeves, or by means of inside sleeves, when, for some reason, increase of tube outside diameter is not desirable (Fig. 102). When separate sub-assemblies cannot be repaired, they are replaced, their connections with the tubes being also made with sleeves.

In all the above-described instances of repairing aircraft steel parts by welding, time and labour consumption for actual welding is but inconsiderable. The main time-consuming factor is the preparation of the parts for repair and the preparation of the reinforcing elements. However, welding as a final operation is of a great importance. In all the cases when welding application is planned, prior to starting actual welding of the part being repaired, perform a short welding test on samples, and select the necessary conditions of welding, filler metal, coatings, etc., and only then proceed with the actual welding.

§ 31. Elimination of stress concentration during repairs by welding

In the repair of aircraft parts by welding, and especially in the manufacture of new structural elements, special attention should be paid to the reduction of stress concentration and to the improvement of the vibration strength of the parts being repaired.

Numerous studies confirmed by experience have proved that the so called stress concentration takes place in the corners of tubular structures, at the ends of cut-in and tee-joined elements of welded parts, at the ends of welds, in straps and in other places with abrupt changes in section.

This means that a part having a certain value of mean stress will be in places of abrupt change in section, at holes, recesses, bores and in other points indicated above subjected to a stress three times the mean value, or to even a higher value (see also Chapter XIII).

At static, i.e. constant loads, stress concentration plays no vital role in the process of destruction of parts made of ductile metals; this is due to the fact that the stresses having reached the yield point become equalized over the entire part section owing to their re-distribution in the process of metal flow. However, When the stresses are variable, stress concentration has a negative influence upon part strength.

In brittle heat-treated parts stress concentration produces a negative effect since it considerably reduces the strength of the part. For this reason, all possible measures should be taken, to prevent stress concentration.

It should also be borne in mind that the non-uniform structure of the weld and the presence in the weld metal of both coarse and fine grains also serve as a source of stress concentration, and to even a greater degree than abrupt changes in section of the part or assembly.

In repairing aircraft parts by welding, measures should be taken to eliminate, if possible, stress concentration, or to reduce it. Passage between a weld and the base metal should be smooth, especially in the places of stress concentration.

The following techniques are used to achieve this aim:

a) combined welding;

b) welding up of a tongue;

c) electric-arc welding with thickly coated electrodes;

d) mechanical filing of welds.

C o m b i n e d w e l d i n g i s used for metals of 130 kg/mm^2 maximum ultimate strength, employed in the manufacture and repairs of parts (or assemblies) operated at dynamic loads, as well as in all cases of welding of cut-in corner plates and knees. All the welds except those located in places of stress concentration are first welded by the electric-arc process, after which the ends of the welds and cut-in elements are welded by the oxy-acetylene process, in order to obtain smooth passages (Fig. 103). A part of the joint, from 10 to 15 mm long, is normally left to be welded up by the oxy-acetylene flame. The seam welded by the electric-arc process is overlapped by a 4 to 6-mm weld length of metal deposited by the gas process.

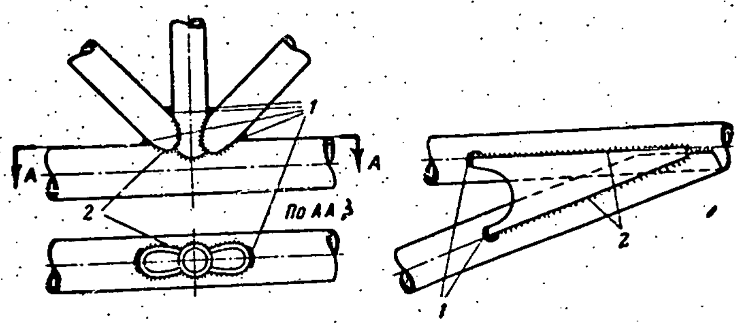


Fig. 103. - Combined welding of tubular structures

1 - gas welding; 2 - electric-arc welding; 3 - section AA

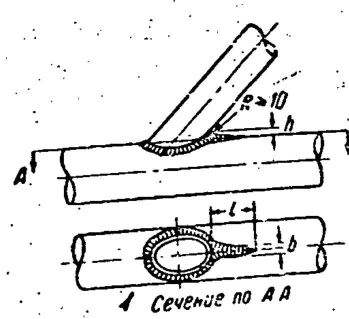


Fig. 104- Welding up a tongue

1) Section through AA

As a rule, angles below 45° in tubular joints, the ends of tee-joined corner plates and straps, and the ends of welds in cut-in eyes and corner plates should be subjected to oxy-acetylene finish welding, after they have been welded by the electric-arc process.

T h e w e l d i n g u p of a t o n g u e (Fig. 104) serves to increase the radius of rounding in places of passage between the weld and the base metal, and to thus reduce stress concentration. Tongues of the sizes shown in Table 28 are deposited by gas welding on parts of ultimate strength below 110 kg/mm^2, and by electric-arc welding on parts of ultimate strength over 110 kg/mm^2. Welding is started from the new weld, with a gradual reduction of the arc length in the process of travel towards base metal.

Table 28

Dimensions of Tongue Welded Up by Gas and Electric-Arc Welding

Welded Metal Thickness (mm)	Tongue Dimensions (mm)					
	Gas welding			Electric-arc welding		
	l	b	h	l	b	h
1.5 - 2.0	25	8-9	3	20	6-7	3
2.0 - 3.0	30	9-10	4	25	7-8	4

When welding up a tongue or finishing welding a seam, make sure to see that no burns-through, meltings-through or cracks are made.

M e c h a n i c a l f i l i n g is intended for use instead of combined welding. It is not used for finishing welds in cut-in joints. Filing should be performed so that the base metal is not damaged, and no deep scratches are left; and that a minimum 10-mm radius rounding is observed.

§ 32. Straightening of steel parts

Irrespective of the precautions taken during assembly and tacking prior to welding, and despite the special working order adopted in weld depositing the warping of workpieces still takes place in many cases during welding. The required part dimensions thus cease to be true and the parts can no longer be interchanged, or a part that has been repaired cannot even be fitted into position. At present, several methods have been worked out for straightening such destorted parts. They consist mainly in straightening parts after local preheating, by means of a reverse static deformation of the warped structural elements.

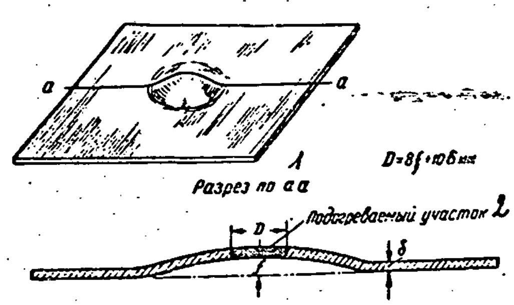


Fig. 105. - Straightening of a distorted sheet by heating
1) Section through a-a 2) Sector subjected to heating

For instance, if a 1-mm sheet made of Grade 30XГCA steel has a bulge 3 mm high, a round area of 30 to 35-mm diameter should be heated to 750 or 800°C by the oxy-acetylene flame in the centre of the bulge, and the sheet will thus be straightened (Fig. 105).

A welded truss element heated to a temperature of 750 to 800°C in the places marked by hachures in Fig. 106 can be straightened. If after a first heating cycle this element is not completely straightened, a repeated heating should be applied to some other place.

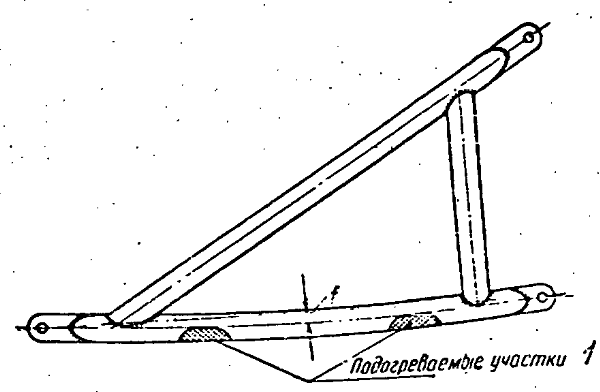


Fig. 106. - Straightening a distorted tubular element by heating
1) heated sectors

During the straightening of steel structures the temperature of heating is checked by the temper colour. A dark cherry-colour corresponds to a temperature rande of 600 to 650° C, a dark-red colour to from 750 to 800° C.

The parts having ultimate strength of up to 90 kg/mm² are normally subjected to cold straightening. In cold straightening, the stress is applied gradually and evenly, through the tube-shaped pads. The straightening of welded elements by hammering is not allowable.

In all cases after straightening, the workpiece should be thoroughly checked for cracks. The cracks are detected by visual inspection (through a magnifying glass), as well as by magnetic control and by pickling with a 10-per cent solution of nitric acid.

Good results are obtained if the place being checked is coated with kerosene which is then completely removed, this place then being marked over with chalk; should there be a crack, the chalk absorbs kerosene out of the crack, and its contour becomes vividly seen on the white chalk surface. This method is known as a kerosene check.

CHAPTER XI

REPAIRS OF AIRCRAFT PETROL TANKS BY WELDING

§ 33. Preparing the tanks for repair

Inthe repair of aircraft petrol tanks the scope of welding is rather considerable. This is explained by the fact that the tanks are of welded design and, therefore, in repairing them, the application of welding proves to be most practicable. Various mechanical methods of tank repairs, irrespective of their original nature, have found no practical application because welding remains the simplest, cheapest and quickest means of tank repairs; only soldering which is being introduced into this field commences to supplant welding in certain cases because it requires lower temperatures of heating. The discovery by Soviet engineers of new fluxes and solderes possessing high mechanical and corrosion-resistant properties contributed to the successful development of soldering aluminium.

The task of repairing petrol tanks is to be entrusted to the most highly skilled welders possessing sufficiently wide experience in the welding of aluminium.

A petrol tank handed over for repairs is subjected to a thorough inspection. All the plugs are removed, and the tank interior, its partitions and fittings are thoroughly examined.

In order to detect possible pin holes, cracks or leaky fitting joints, the tank is submerged in water and is filled with air to a pressure of 0.2 to 0.3 kg/cm^2 (If a water bath is not available, the tank can be covered on the outside with soap foam). The leaks can be easily detected by the soap bubbles, due to escaping of the air. The leaks are to be marked with a pencil and in due turn repaired.

Special attention should be paid to the places where the protector has lost bonding with the tank and has swollen; leaks are usually found in such places.

Prior to repairing, the tanks should be thoroughly prepared, to eliminate the danger of explosion. Experience teaches that non-observance of the approved rules for preparing tanks for repairs may lead to an explosion, with dangerous consequences. For this reason, prior to welding, the tanks should so be prepared that not only the remainder of the petrol, but its vapours as well are thoroughly removed.

The oil and kerosene tanks are first washed with gasoline, after which they should be treated like gasoline tanks.

Three methods of treating gasoline tanks are recommended here.

M e t h o d I. 1) Rinse the tank three or four times with water heated to 70 or 90°C.

2) Fill the tank with hot water having a temperature of 70 to 90°C, leave it filled for a period of 8 hours, and then rinse again at least three times.

3) After each hot water washing, dry the tank for 10 to 15 minutes with compressed air having a maximum pressure of 0.2 to 0.3 kg/cm^2.

M e t h o d II. 1) Blow off the tank with hot steam for 15 or 20 minutes, so that the tank walls are well heated and have a temperature of 80 to 100°C. This is the quickest method which, however, requires a source of hot steam supply.

M e t h o d III. Blow off the tank with internal combustion engine exhaust gases for 15 to 20 minutes. As seen in Fig. 107, motor-truck engine exhaust gases are used.

From the motor-truck exhaust pipe the gases are fed through the aircraft neutral-gas filter into the tank. The inlet temperature of the gases should not exceed 250° C, this temperature being controlled by altering the length of the feed pipe. As a result of blowing off, the tank walls should also be heated to a temperature of 90 to 100° C.

A greater degree of reliability is achieved when two preparation methods are used: Nos. I and II Nos. I and III.

In all cases of tank preparation for welding, all openings should be fully open. The places to be repaired should be thoroughly cleaned of grease, dirt, paint and rubber glue. Contamination during welding results in weld porosity and considerably hampers the process of welding.

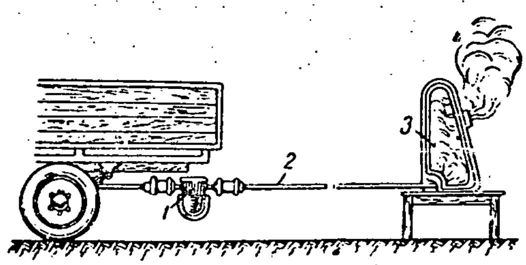


Fig. 107. - Tank blowing off with motor-truck exhaust gases 1-aircraft inert-gas filter; 2-piping; 3-petrol tank.

Normally petrol tanks are manufactured of an aluminium-magnesium alloy which can be readily welded by the oxy-acetylene process. When repairing a rubber-protected tank, cut a slit in the protector, bend back the edges and cover them with wet asbestos.

Welding should be performed with care, in order to avoid burn-through, taking into consideration the great difference between the flame temperature and the melting point of aluminium on the one hand, and the difference between the melting point of the aluminium oxide film and that of the aluminium itself, the former being three times higher than the latter.

Welding is performed by a neutral flame of the gas torch, with obligatory use of a flux.

For filler metal, Grade Ak pickled wire or aluminium-magnesium alloy strips are used. To pickle the filler wire, proceed as follows:

a) wash it with hot water at 60 to 80°C;

b) pickle it in a 10-per cent solution of sodium hydroxide at 60 to 70°C;

c) wash the wire in hot water at 60 to 80°C;

d) brighten the wire in a 30-per cent solution of nitric acid at room temperature;

e) wash it in hot water at 60 to 80°C;

f) dry it in a drying cabinet at 110° to 120°C.

Grade AФ-4A flux for welding aluminium is normally furnished factory-made and packed in air-tight sealed cans. The quantity of flux required for the job is diluted with water. The diluted flux should have the consistency of thick cream. The flux is applied to the filler rod by dipping and to the joint edge, if required, with a brush.

In repairing petrol tanks by welding, it is essential to correctly select the torch number, filler wire diameter and oxygen pressure. Welding conditions depend mainly upon the thickness of the workpiece and should be selected from Table 7.

§ 34. Welding of pin holes and cracks

When a leak in a petrol tank occurs due to the porosity of a welded seam, or the tank shell rim or the welded-round throat, all these places may be welded up after they are adequately cleaned. This work is normally performed with a No. 1 torch. Prior to welding, heat the tank surface evenly up to 80° or 100°C around the place to the repaired and expecially the closely located welded-around throats and the tank shell rim, and then proceed with the welding of the defective place. The maximum allowable increase of the welded-round throat is 18 mm. Filler rods of 2 or 3-mm diameter should be used. On completion of welding the flame should be moved gradually away to avoid crack-formation.

One and the same rivet or a same place on the welded seam should be repaired by welding but once. If after the welding the old defect still remains, the new measures of repair should include the cutting out of the damaged section of metal.

Cracks on petrol tanks prior to welding should be examined, cleaned and bored at the ends by a 2 or 3-mm drill. Cracks may be repaired by welding only when the cracks have a maximum length of not over 25 mm, and the cracks which run over into the base metal have a maximum length of 15 mm, previded their total number per a tank does not exceed five.

§ 35. Repairs of tank bottom plates and elimination of leaks on welded-round rivets

A tank bottom plate having holes or cracks of over 25 mm in length is not repaired by welding up the defective places; the repairs are made by cutting out the damaged sector and welding in a patch made of material of similar thickness and Grade. In this case proceed as follows. Around the damaged place plot auxiliary holes along a circle on a smooth curve and, using a pair of snips, cut out a hole. Then using a hammer and dolly, flange out the hole edges to a height of 2 to 5 mm (Fig. 108), after having first bent the edges up by aid of the narrow end of the hammer.

The patch should be cut with a necessary allowance for flanging and is then fitted to the hole so that the maximum clearance between the flanged hole edges and the patch edges is 1 mm. Since

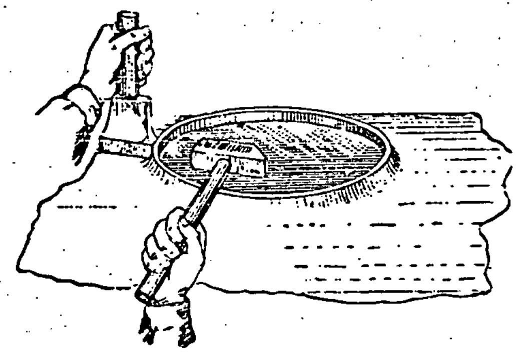


Fig. 108. - Flanging tank hole edges.

the hole and the patch, the flanging should be performed by light hammering. After patch shaping and fitting have been finally completed, the tank interior should be cleaned of shavings and filings and thoroughly washed. See that no shvings, filings or dirt remain inside the tank since their removal after the patch is welded into position is very complicated.

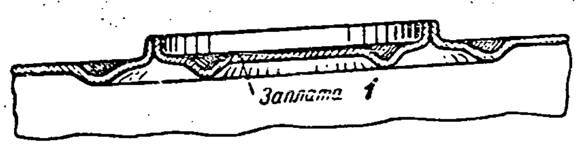


Fig. 109. - Patch and corrugated shell surface

1) patch

The patch is then tacked in place and welded along its entire periphery. The weld should have dood penetration, free of considerable meltings-through. See that no molten metal drops fall into the tank.

In cases when the patch diameter is over 100 mm, the hole and patch edges are corrugated, to reduce internal stresses (Fig. 109). Besides this, corrugation contributes to tank wall strength.

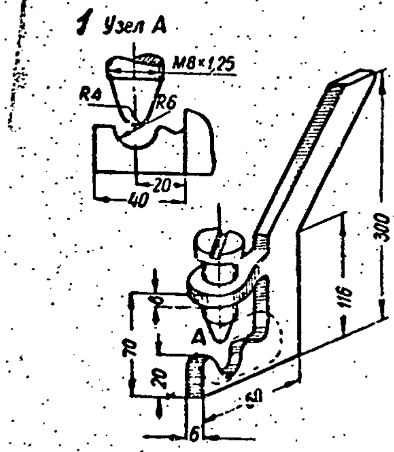


Fig. 10. - Metal-corrugating device

1) Detail A

Corrugation can be performed with the help of a simple device (Fig. 110), prior to edge flanging. To do so, slip the jaw of the device over the tank shell edge or the patch edge and turn the screw down; then, by striking with a hammer at the base of the device, drive it along the edge until its entire periphery is corrugated; to facilitate this work, the patch should be clamped in a vice having soft metal jaws.

The tanks welded of an aluminium-magnesium alloy normally have partitions which increase tank rigidity and sometimes accommodate valves, etc. These partitions are secured to the tank bottom by means of round-head rivets made of the same alloy. The riveted down heads, after the rivets are fixed in position, are additienally welded. These rivets are made in accordance with No.853A Specifications; the figures indicating rivet diameter and shank length are added to the number of the Specifications. Thus, if a drawing contains instructions that a 853A3X8 rivet should be fitted, it means that an aluminium-magnesium alloy round heat rivet, 3 mm in diameter and 8 mm long should be used.

Should a rivet break occur, to repair it proceed as follows:

a) Cut the tank protector (if present) by slanting cuts so that a tank wall area of 200 mm around the rivet is exposed. To facilitate release of the protector from the tank wall, the glued joint is moistened with gasoline.

b) Plot and cut out an access port of 100-mm diameter adjacent to the broken rivet, to provide access to the rivet for the operator's hand holding a dolly.

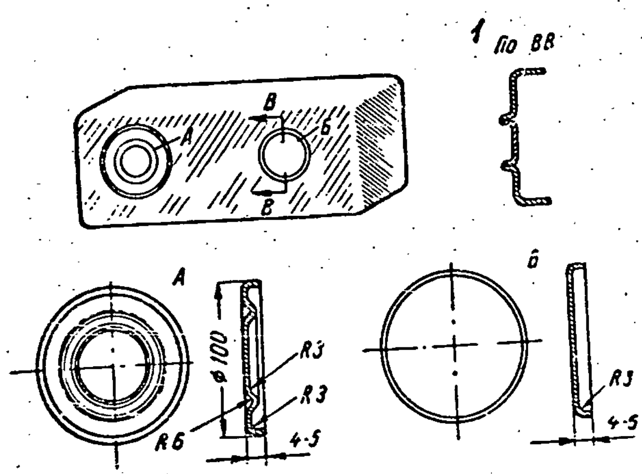


Fig. 111. - Access ports for tank repairs

1) Section BB

c) At a distance of 15 to 20 mm to both sides of the broken rivet drill two holes, insert new rivets made of the aluminium-magnesium alloy, having first placed 1-mm thick washers (type 223A) made of Grade Д17 alloy under the rivet heads; then set up the rivet to form the closing heat which should project above the tank wall by 3 or 4 mm.

d) Using a No.0 torch, melt the projecting rivet heads, having first preheated the metal around the damaged rivet. The torch flame should be directed at the rivet head, parallel to its axis, and should not be removed until the set up rivet is completely molten; only then proceed with the melting of the shell surface around the rivet, and with the introduction of the filler wire. When welding is completed, the torch flame should be gradually moved away. Flux should be used during the welding.

All the three rivet heads should be welded at the same time. The rivet head with the welded-up metal should be symmetrical relative to the rivet shank.

After welding-up, the height of the rivet heads should be within a range of 2.5 to 4 mm, their new diameter being 12 to 16 mm. It is recommended that the minimum values of the above limits be observed.

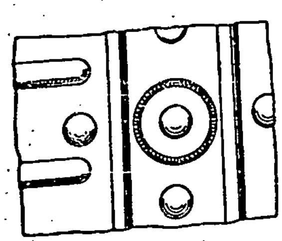


Fig. 112. - Plug with welded-round rivet.

e) After the rivets are welded up, remove all foreign objects from the tank interior, wash the tank and then fit in position and weld the access port cover.

Should cracks appear besides the welded-up rivet head on the tank shell, bore out the rivet head and cut a 40 to 45-mm diameter hole in this place. Then flange the edges of this hole, prepare, fit in position and secure by welding a patch, then fit a new rivet and weld in the closing heat of the rivet (Fig. 112).

§ 36. Repairs of tank fittings

Should fittings require repairs, such as a damaged inlet connection, a broken thread, etc., they may be repaired by welding. For instance, cracks on a pipe-union may be welded up or repaired by the use of a strap.

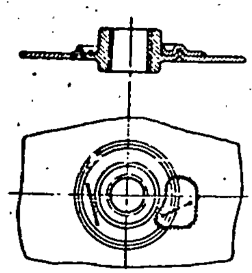


Fig. 113. - Cracks on a tank outlet or inlet

If the crack on an inlet connection (Fig. 113) does not reach out to the shell proper, make a bore using a 2-mm drill, then cut the crack edges by a chisel or file so that a V-shaped groove is formed, after which weld up the crack without the use of straps. The surplus of deposited metal should be removed by scraping or filing.

When the crack on the inlet connection reaches out to the tank shell, it is repaired with the used of a shaped strap or patch which is accurately fitted over the place being repaired and is than lap-welded.

§ 37. Repairs of tank shell

When an aircraft is in long service, corrosion may appear on separate sections of the tank shell. In this case large sections of the tank shell are to be replaced. Proceed as follows:

a) Using a spherical milling tool fitted to a pneumatic drill remove the welded rivet heads, then bore out the rivets proper on the shell section to be removed.

b) Plot and cut out the damaged section of the shell, then corrugate and flange the edges as described above; the height of the flanged edges depend upon tank wall thickness but should not be below 2.5 to 3 mm. The edge of this hole should be located at a minimum distance of 30 to 35 mm from the nearest row of rivets or from partitions.

c) Cut a patch from a sheet of rolled aluminium-magnesium alloy, to fit the seize and shape of the hole, with allowances for flanging. Corrugate the patch edges and the metal along the future rivet rows. It is desirable to use a sheet bending machine to perform this work. See that a 0.5-mm gap is left between the flanged patch edges and those of the hole.

Using a corner drill inserted into the tank through the access ports, bore the required number of rivet holes in the tank walls, to correspond to the holes in the tank partitions and the patch. Simultaneously prepare the covers for the access ports.

d) After the patch is prepared, secure it by aluminium-magnesium alloy rivets to the partitions, then tack it to the shell edge, weld up the closing heads of the rivets and finally weld the patch to the tank shell over the entire contour.

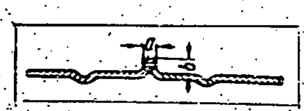
e) When the welding is completed, thoroughly clean the tank of all foreign objects, wash it and weld the covers to the access ports.

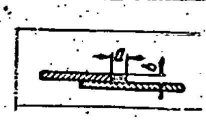
The descriptions of aircraft tank repairs by welding which have been given above naturally do not cover all the possible cases. These are but the basic techniques and methods of repairs.

A welder repairing aircraft tanks of welded design should endevour to deposit a weld, uniform as to height, width and smoothness. For recommended weld dimensions which should be selected for the welding see Table 29.

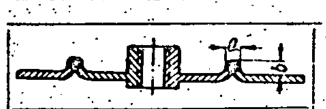
Table 29

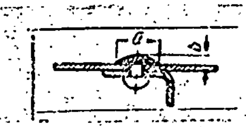
Dimensions of Welds for Repairing Tanks by Welding





Sheet thickness (mm)	Grade AM1 filler wire		Grade AK filler wire	
	a	b	a	b
0.8	4-5	1-1.2	-	-
1.2	5-5.5	1.5-2.0	7-10	2-2.5
1.5	6-6	2.5-3.0	8-12	2.5-3.0
2.0	8-10	3.0-3.5	9-13	3.0-3.5





Sheet thickness (mm)	Grade AK filler wire		Grade AK filler wire	
	a	b	a	b
1.2	5.5-8.5	3-4	12-16	2.5-3.0
1.5	5.5-8.5	3-4	14-18	2.5-3.5
2.0	8.5-10.0	4-5	14-19	3.0-4.0

Washing flux off the welded seams

On completion of welding, the welds are to be cleaned of flux by washing.

The washing of welds is a very important operation which should be performed with a high degree of thoroughfulness, since the flux, if left inside the tank, causes intensive corrosion which, in turn, may become a cause for an aircraft crash. For this reason, immediately after the welding of tanks or other elements made of aluminium alloys is completed, proceed as follows.

1) thoroughly wash the weld workpieces with hot water (60 to 80°C) on both sides, using hair brushes;

2) wash the workpieces with a water solution of chromium trioxide or, in a final case, with potassium bichromate solution (20 gm per litre of water);

3) wash the workpiece with hot water of the same temperature for the second time.

After washing, the welds should have a clean bright surface. To check the quality of weld washing, proceed as follows. Spill a drop of 2-per cent silver nitrate on the weld and wait for a white sediment to be produced as a result of the reaction; should such sediment appear, it means that the weld is not yet properly cleaned and the washing of the tank should be continued until positive results are obtained.

CAUTION. The petrol tanks which have been repaired by welding, prior to being installed in position in the aircraft should be thoroughly inspected by technical personnel, with the aim of ensuring that there are no shavings, molten metal flows and solidified drops inside the tanks. A tank should on no account be mounted in position until all foreign matter are completely removed and the tank is thoroughly checked.

If a tank is equipped with steel fittings, for the post-welding washing use only a potassium bichromate solution , since chromium trioxide may cause intensive corrosion of steel parts.

CHAPTER XII

DEFECTS OF WELDS AND THEIR ELIMINATION

§ 38. Weld external defects

As a result of deviating from recommended techniques in the course of welding of metals, certain defects which reduce the strength and reliability of welded joints originate in the welds.

The most common causes of defects are:

a) Poor quality of preparing the workpieces for welding;

b) Improperly selected welding conditions;

c) Deviations from welding techniques.

The external defects of welds and the causes of their origination are described below.

1) W e l d o f w r o n g s h a p e a n d g e o m e t r i c a l d i m e n s i o n s. The defects of this group are normally caused by faulty and careless edge preparation, uneven movement of the electrode or torch and that of the filler wire. These defects worsen weld general appearance and cause weld weakening due to the difference in dimensions which should be similar. Besides, uneven destribution of the deposited metal along the weld and the difference in deposited metal shrinkage may also cause crack formation, both in the deposited metal of the weld and in the base metal of the adjoining zone. For this reason, thoroughly check such welds for cracks, weld them up, if any, and deposit reinforcing welds in the places which have been weakened.

2) E x t e r n a l c r a c k s may be encountered both longitudinally and transversally relative to weld direction, and may be found both in the weld proper and in the weld zone. These cracks are a result of internal stress caused by

uneven metal heating and cooling during welding, as well as by weld shrinkage. Cracks are more often formed in metals characterized by poor weldability, and also as a result of a wrong working order in weld depositing. Cracks are a dangerous defect. Sections of weld with cracks should be cut out and rewelded.

3) U n d e r c u t s. The undercut is the thinning of metal at the point of juncture between the base metal and the weld metal. This defect results from using excessive currents or a torch of excessive power. In both cases too much heat is produced at the weld edge, resulting in the over-melting of the base metal. To eliminate this defect, clean the undercut and deposit a reinforcing bead here.

4) L a c k o f p e n e t r a t i o n. The lack of penetration means that the base metal has not merged with the deposited metal. Due to the lack of penetration the cohesion of particles of metal is not strong enough and the weld at this point is weakened. Consentration of stresses in the places where there is a lack of penetration additionally weakens the weld and deprives it of any strength at all.

The lack of penetration results from welding with a low current or with an unsufficiently powerful torch, from an excessively high travel speed of the electrode or torch tip, from the angle between the bevelled edges being too small, from inadequate preparation of workpiece surfaces prior to welding, etc. To eliminate the lack of penetration, the deposited metal should be cut out and the defective place rewelded.

5) C o n v e x i t y. This defect results from the electrode or filler wire melting too rapidly while the base metal is not yet sufficiently heated. Thus an over-flow of liquid metal on to the workpiece surface at the joint takes place,

with simultaneous lack of penetration. These metal excrescences should be cut off, and the welds thoroughly checked for possible lack of penetration.

§ 39. Weld internal defects

1) Porosity of welds. Porosity may result because of the following reasons:

a) Absorption of gases by the molten metal, for instance absorption of hydrogen, oxides of carbon, etc., which fail to exude from the molten metal puddle due to quick metal solidification and which remain in the metal in the form of gas bubbles.

b) Poor quality of joint edge degreasing and inadequate cleaning of dirt, rust, etc.

c) Metal shrinkage during its crystallization. To detect the internal porosity of a weld, it is tested by kerosene.

In gas welding, the elimination of porosity is achieved by forging. Porous welds detected in vital aircraft parts should be cut out and rewelded.

2) Lack of penetration at the joint edges. At a point of weld fracture the lack of penetration can be seen in the shape of a dark line between the base and the deposited metal. The lack of penetration may result from using an unsufficiently powerful arc or torch, as well as from excessive travel speed of the electrode or torch along the joint being welded. The lack of penetration may be detected only by X-ray control. The defective places should be cut out and rewelded.

3) Internal cracks are due to the same reasons as external cracks. When cracks are detected, the defective place should be cut out and rewelded.

4) Overheating of metal consists in an excessively rapid growth of grain size . The larger the grain size, the higher is metal brittleness and the lower its impact strength. Overheating of deposited metal occurs after the weld is heated above a certain temperature. This phenomenon is more often encountered in gas welding, when the metal is subjected to high and prolonged heating.

Weld overheating can be remedied by heat-treatment.

5) Burning of metal is accompanied by the burning out of carbon and the appearance of metal oxides at the grain boundaries of the metal.

Burning is caused by using an oxidizing flame or an excessively long arc during welding. The burnt metal is characterized by high brittleness; therefore the defective places should be cut out and rewelded.

For the classification of defects originating in welds in oxy-acetylene and electric-arc welding, see Tables 30 and 31, respectively.

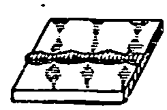
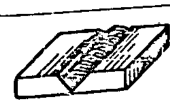
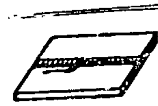
Table 30

Defects of welds in Oxy-Acetylene Welding

Type of Defect	Characteristics of defect	Probable Cause	Remedy
1. Weld of irregular shape	Convexity, weakened portions of weld, unwelded length, unwelded bead ends	Faulty welding technique	Welding up and removal of flows
2. Oxidation of deposited metal (metal burning).	Oxide and slag inclusions inside weld. Uneven weld surface, with fine pin holes and pores.	Welding by oxidizing flame.	Beyond remedy. Should be cut out and rewelded.
3. Carbonization of deposited weld metal.	Smooth, compact and wide weld. Large pin holes on weld surface.	Welding by carbonizing flame.	Beyond remedy
4. Lack of penetration.	Lack of molten metal mixing in bottom part of joint.	Torch tip size (number) is too small; excessive speed of welding small angle of edge bevelling.	Bevelling of edges and welding on work-piece opposite side.
5. Undercutting	Base metal molten adjacent to weld.	Wrong angle of torch, or excessive flame power.	Depositing of supplementary bead.
6. Overheating	Intensive grain growth in weld metal or in heat-affected zone.	Heating of molten metal or weld zone during excessively long period or by excessively high temperature.	Heat-treatment.
7. Burn-through	Burning-through of a hole when welding thin metal.	Low welding speed, or excessively large torch tip, or excessive angle of torch incline.	Edge preparation and repair by welding
8. Crack	Destruction of metal at the grains or at their boundaries.	Faulty welding technique, over heating of metal.	Beyond remedy. Should be cut out and rewelded.

Table 31

Defects of Welds in Electric-Arc Welding

Defect	Characteristics of defect	Schematic view of defect	Probable Cause	Remedy
1. Uneven weld surface	Partial lack of proper penetration.		Excessive arc length or low current	To be cut out and rewelded
2. Intensive spatter, large crater	Non-uniform weld shape. Solidified drops of spattered metal in weld zone		Welding current too high	Defective portion to be cut out and rewelded
3. Narrow weld	Weld is narrower than normal. Weld surface uneven. Poor penetration		Excessive welding speed	Entire weld length to be cut out and rewelded
4. Convexity, over high bead	Excessive bead height. Metal overflow at sides of weld. Uneven weld surface		Low welding speed excessively long arc, small electrode diameter	Same
5. Lack of penetration	Lack of merging between deposited and base metal or insufficient depth of penetration of deposited metal into base metal		Low welding current; high welding speed; large electrode diameter; wrong edge bevelling	Defective portion to be cut out and rewelded
6. Burns	Presence of oxide films at grain boundaries and appearance of foreign particles in deposited weld metal		Excessively long arc; high current	Defective portion to be cut out and rewelded
7. Burn-through	Hole molten through in base metal		High current; excessively low arc	Edges to be bevelled again and rewelded

8. Under-cuting	Melting of base metal at weld sides	Improper movement and incline of electrode; high current	Undercuts to be welded up
9. Cracks	Metal broken in the seam or close to seam	Wrong welding order	Bevelling of edges and re-welding

§ 40. Methods of weld control

Weld control by external inspection. To ensure the required degree of welded joint reliability, the quality of welding should be thoroughly controlled. Depending upon the purpose and importance of a welded joint, various methods of weld control, differing in complicacy and accuracy, may be used. The simplest method of weld control is checking by external examination and with the help of a magnifying glass. This method allows surface defects to be detected, and for the checking of weld shape and dimensions.

Such defects as roughness, undercutting, slag inclusions, surface porosity and surface cracks are detected by external inspection. A sound weld has a uniform appearance, a clean smooth surface, even edges, gradual change in section from deposited to base metal, and is free from shallow portions, bulges and undercuttings.

Before inspection, a weld should be thoroughly cleaned with a steel brush. The weld should be preferable inspected through a magnifying glass, since the unaided eye may fail to detect fine cracks. To check weld dimensions and shape, use a set of templates (Fig. 58).

For the same weld size the template has two contours, one of them indicating the allowable minimum size, the second ... size. When the weld cross section is smaller than rated, the strength of the welded structure is also reduced. An excessive increase in cross section of a weld may cause warping of the workpiece during welding and its faulty performance after repairs.

W e l d c o n t r o l b y p r o c e s s t e s t s. No special equipment is required to perform process or technological tests which allow for the practical evaluation of weld quality directly under field conditions. These tests are especially desirable when training welders, since they clearly demonstrate the influence of weld quality upon weld strength. The methods of weld control by the process tests described below can be used in practically any aircraft-repair shop.

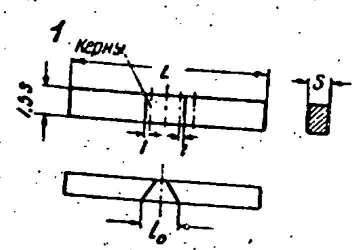


Fig. 114. - Sample for bend test

1) bead core

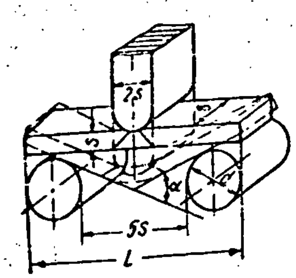


Fig. 115. - Schematic view of bend test

W e l d m e t a l d u c t i l i t y t e s t. To check weld metal for ductility, bend tests are performed. For this purpose, a sample of a definite size is cut from a welded plate (Fig. 114). The sample is placed on cylindrical supports spaced at a distance equal to the fivefold thickness of the sample. The bending is performed by means of a punch located in the middle of the sample and midway between supports (Fig. 115). The load applied to the punsh should be removed after the first crack appears in the sample. The greater the angle α of the bend, the greater the ductility of the metal. For instance, the angle of bending for welds in low-carbon steel may be as large as 80 to 100° if these welds possess high ductility. For the same welds, when they are poorly welded or when bare electrodes are used, the angle of bending may be reduced to from 5 to 10°.

Checking the depth of penetration. Th check the depth of penetration, the tearing-off test and the method of weld boring are used. To perform a tearing-off test, two plates of 100X1.50-mm size are made of the same metal of which the welded workpiece has been manufactured. The plates are then lap-welded (Fig. 116). After the weld has cooled off, a wedge is driven between the two plates from the side opposite the weld until the weld is broken.

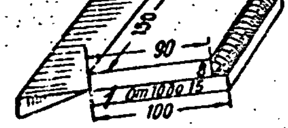


Fig. 116. - Tearing-off test
1) 10 to 15 mm

Should the joint fail along the deposited metal and a great depth of penetration be revealed, the quality of welding is considered satisfactory. However, if the destruction of the joint occurs on the boundary between the base and deposited metal and a distinct lack of penetration is revealed, the quality of welding is considered unsatisfactory. The examination of the fracture also permits checking for weld porosity, the presence of slag inclusions and cavities.

The method of checking penetration depth by boring consists in cutting a bore in the weld with a drill of 2 or 3-mm larger diameter than the weld width. The weld should so be bored that the boundaries of the deposited metal are seen. Then the walls of the bore are ground with emery paper and pickled with a 10 or 12-per cent water solution of double cuprous and ammonium chloride salt. The thin coating of copper which is left after pickling should be removed by a soft napkin. The contours of the base metal, deposited weld metal and zone of penetration may then be distinctly seen on the pickled surface.

L u m i n e s c e n c e   m e t h o d   o f   w e l d   c o n t r o l. Prior to commencing the check, the weld to be checked and the adjoining zone of the workpiece surface should be cleaned and thoroughly wiped with waste soaked in gasoline. Then the cleaned surface, with a brush, is coated with a film of fluorescent liquid consisting of a mixture of aircraft engine oil (15 per cent of total volume) and kerosene (85 per cent). Ten or fifteen minutes later the remaining liquid is removed from the metal surface with the help of a hair brush and a developer is applied to the surface being checked. For the developer, burnt magnesia or reactive magnesium oxide in the form of dry and clean powder may be used. The powder is then removed by shaking the workpiece and by blowing it off with dry air (the maximum air pressure being 0.05 kg/cm^2 g.p.).

The surface thus prepared is then irradiated by a violet ray lamp in a dark chamber or under a cover protecting the workpiece against the surrounding light. Under the ultravio- let light of the lamp the cracks will appear as bright luminous lines. After the check is completed, the workpiece is rinsed with gasoline and wiped off with dry waste.

C h e c k i n g w e l d t i g h t n e s s i n t a n k s a n d p i p e s. To check weld tightness in tanks and pipes, hydraulic or pneumatic tests are performed. In a hydraulic test, the tank is filled with water and, by using a pump, is subjected to a pressure which is one and a half times higher than the tank working pressure. Leaks or sweating of the seam discovered in places which are not adequately tight will reveal the defective portions of the weld.

In a pneumatic test, an air pressure amounting to 0.75 per cent of the working pressure is set up inside the tank which is either submerged in water or has its welded joints coated with soap water. The leaky places in the seam will be detected by the appearance of soap bubbles.

If the air pressure in the tank being checked is raised above 1 kg/cm^{2}g.p., safety precautions should be taken, to prevent accidents in case of tank destruction. To perform pneumatic checks of welded tanks, use a pump equipped with a reservoir, and check the pressure by pressure gauge. On no account is compressed air from airfield cylinder to be used.

The most perfect method of weld quality control allow- ing for the detection of internal defects is radiography. In radiography, use is made of X-ray radiographs and radioactive salts. The results of radiographic control are recorded on a film and, provided the operator possesses the necessary degree of skill and experience, permit such inside defects as porosity, slag inclusions, cracks, etc., to be accurately detected. In all cases when vital aircraft parts are repaired by welding they should be preferably, if possible, radiographed. Radiograph or X-ray units are normally available in stationary repair bases, industrial works or scientific establishments.

CHAPTER XIII

FUNDAMENTALS OF CALCULATION OF WELDS

§ 41. General information on stresses in welds

Every operator performing practical welding should remember that a welded joint is designed to communicate stresses from one structural element to other elements. The quality of welding has a great influence upon the value of stress which can be safely communicated by a given weld without danger of its destruction.

The main principle which is usually employed as the basis for calculation and design of welded joints is that the weld strength should approach the strength of the workpiece proper. This principle is also accepted as a guide in selecting the methods of repairing a damaged part. The aim is that the strength of a part repaired by welding be equal to that of a newly manufactured part.

It is true, that this requirement can not always be satisfied, but calculations help to evaluate the degree of strength reduction and to take a correct decision as to the method of repair to be chosen.

A welder employed in an aircraft repair shop should be familiar with some of the elements of strength calculation in general, and with calculation of equal strength in welded joints in particular. To begin with, he should become acquainted with some of the general laws pertaining to stresses.

When a rod (Fig. 117) is stretched (subjected to tension) by two equal and oppositely directed forces P, certain stresses are set up inside the rod. The greater are the forces applied to the rod, the higher are the stresses.

A stress is the internal force applied to 1 sq.mm. of ... to the action of outside forces.

Stress is designated by Greek letter σ (sigma).

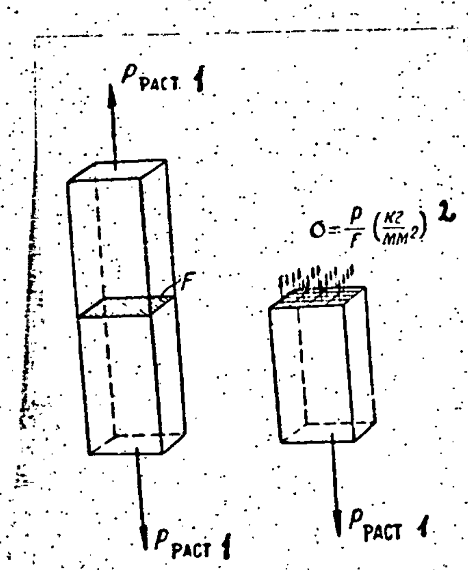


Fig. 117. - Strethcing a rod

1) Pten. 2) $\sigma = \frac{P}{F} \left(\frac{Kg}{mm^2}\right)$

If a rod having a sectional area of F = 100 mm^2 is stretched by a force P = 3,000 kg, the stress inside this rod will be:

$$\sigma = \frac{P}{F}, \qquad (1)$$

or

$$\sigma = \frac{3000}{100} = 30 \text{ kg/mm}^2$$

When outside forces reach a certain value, the rod may fail to withstand the stresses set up by these forced and will be ruptured. Therefore, by comparing the value of the acting stress with the value of the stress which will result in rupture of a given material, one may judge whether a given part is adequately strong. The value of the stress resulting in rupture of a given material as a result of tension and the value of the allowable stress are usually known for all the

If it is known that the material of which the rod has been is ruptured by a stress $\sigma_z = 90$ kg/mm^2 (this stress is termed ultimate tensile strength or simply tensile strength), the safety factor possessed by this rod can be easily calculated.

The safety fector n shows how many times the acting stress is lower than the ultimate stress.

In fact, in the example given above, the safety factor $n = \frac{\sigma_z}{\sigma} = \frac{90}{30} = 3$, which means that the value of the stress acting in the rod is three times less than the ultimate strength.

So far we have been discussing tensile stress only. Suppose now that the same rod is compressed by forces (Fig. 118). Here the nature of the stress is different. The rod is subjected to a compression stress. The value of the stress, if the forces are equal, is the same as in the case of tension:

$$\sigma_{compr.} = \frac{P_{compr.}}{F} \qquad (2)$$

Consider now a third case, that is when the rod cross section is subjected to the action of two forces directed so as if to cut the rod (Fig. 119). In this case, in the rod there originate shearing stresses, i.e. the internal forces which resist the shearing of the rod. These shearing forces, or shearing stress, applied to a unit of rod cross sectional area are designated by the Greek letter τ (tau) and are measured in kg. per sq.mm (kg/mm^2).

$$\tau = \frac{P_{sh.}}{F} \qquad (3)$$

In addition to the above cases of application of forces to a part, cases of rod bending, tension, and others may be met with. The methods of calculating these stresses will vary accordingly, but the nature of the stresses inside the part remains always the same, that is, either the normal stresses of tension or compression (σ), or the tangential stresses of shearing (τ), or, more often, combinations of these three stresses.

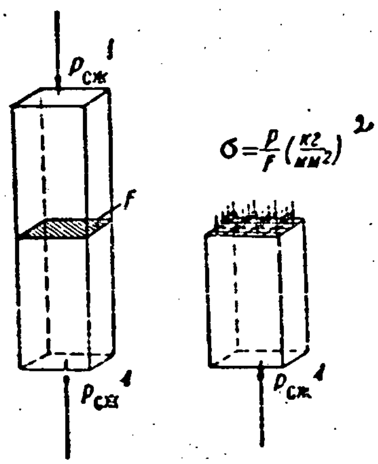


Fig. 118. -Compressing a rod 1)$P_{compr.}$ 2) $\sigma = \frac{P}{F}$ ($\frac{kg}{mm^2}$)

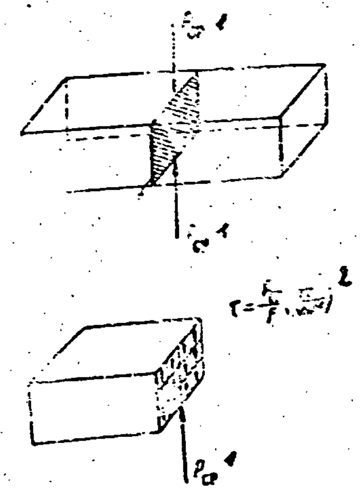


Fig. 119. - Shearing a rod 1)$P_{sh.}$ 2) $\tau = \frac{P_{sh.}}{F}$ ($\frac{kg}{mm^2}$)

§ 42. Calculation of welds

When calculating the strength of welded joints, it is considered that as a result of welding the base metal becomes weakened, irrespective of the fact whether the workpieces being welded are made of hardened or soft steel.

Specially performed tests as well as the study of welded pieces which have failed for some reason show that, when a weld has beenproperly deposited, the workpiece breaks not along the welded joint proper, but close to the weld, in the heat-affected zone. For this reason, the calculation of the strength of a workpiece is based not upon the strength of the weld itself though upon the strength of the weakened zone of metal near the weld.

The ratio of material weakening due to welding is not standard and is normally accepted in accordance with weld quality, the nature of the welding process being used and other factors. As a rule, this ratio is equal to from o.7 to 0.9.

The type of weld has a relatively small influence upon weld strength.

Some examples of calculating weld strength are given below.

1. It is required to find the value of tension force $\underline{P}$ which can be withstood by a steel strip welded of two pieces fig. 120); thikness of strip δ = 4 mm, width $\underline{b}$ = 50 mm, ultimate strength σ_b = 70 kg/mm^2, safety factor $\underline{n}$ = 2.5, ratio of weakening due to welding $\underline{k}$ = 0.75.

Strip sectional area is $F = b \cdot \delta$ and $F = 50 \cdot 4 = 200$ mm^2.

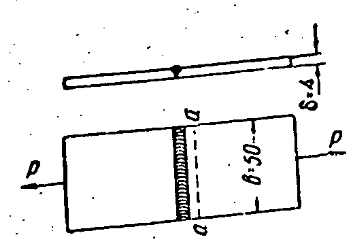


Fig. 120. - Example No. 1

The allowable stress for the portion of the strip weakened due to welding is $R = \frac{\sigma_b \, k}{n}$

and $R_z = \frac{70 \cdot 0.75}{2.5} = 21$ kg/mm^2; but $R_z = R_z \cdot F$; and $R_z = \frac{P}{F}$, whence the tension force is

$$P = 21 \cdot 200 = 4200 \text{ kg}$$

... value of length h_1 of

a weld used to connect two steel sheets (Fig. 121); thickness $\delta = 5$ mm, $\sigma_\text{б} = 60$ kg/mm^2, safety factor $n = 3$; ratio of weakening due to welding $k = 0.8$; and a tension force applied to the sheets $P = 8{,}000$ kg.

$$R_z = \frac{\sigma_\text{б}\, k}{n} = \frac{60 \cdot 0.8}{3} = 16 \text{ kg/mm}^2;$$

$$R_z = \frac{P}{F}\ ; \text{ whence } F = \frac{P}{R_z} = \frac{8000}{16} = 500 \text{ mm}^2, \text{ but}$$

$$F = b_1 \delta, \text{ whence } b_1 = \frac{F}{\delta} = \frac{500}{5} = 100 \text{ mm}$$

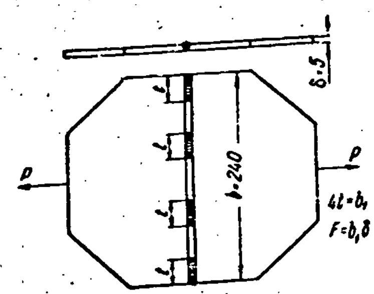


Fig. 121. - Example No. 2

Consequently, b_1 is the required weld length which is smaller than the sheet width $b = 240$ mm. This means that the two sheets may be welded by an interrupted weld having a total minimum length $b_1 = 100$ mm.

Welds subjected to compressing stresses are calculated in a similar way.

In the practice of welded-structure designing and repairing, if the workpieces are subjected to great stresses, joints in which the weld is subjected to tensile stresses should be avoided, because the weld, when under tension, does not yield with plastic flow and is ruptured almost instanteneously, as a brittle material.

... from welds subjected

shearing because here plastic flow takes place. For this reason in designing or repairing an aircraft part it is always endeavoured to communicate stresses through welds subjected to shearing stresses (that is flank welds), or through combined welds (that is tangential welds) subjected simultaneously to shearing and tensile stresses.

Like in the case of tensile stresses, the calculation of shearing stresses is made not for the weld proper but for the material weakened due to welding. The area of shearing is calculated by multiplying the weld length by the thikness of the thinner of the two pieces being welded. This can be seen from the example below.

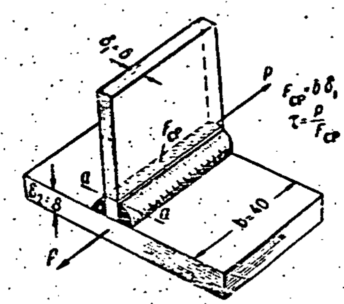


Fig. 122. - Example No. 3

3. It is required to calculate the allowable value of force P which can be withstood by the weldment shown in Fig 122, if $\sigma_b = 70$ kg/mm^2; safety factor $n = 2.5$; ratio of material weakening due to welding $k = 0.75$, and an allowable shearing stress $R_{sh} = 0.8\ R_{te}n$.

The area of shearing is $F = \delta_1 \cdot b$, but not $\delta_2 \cdot b$ and not the weld area.

$$R_{ten.} = \frac{\sigma_b k}{n} = \frac{70 \cdot 0.75}{2.5} = 21 \text{ kg/mm}^2$$

$$R_{sh} = 0.8 \cdot 21 = 16{,}8 \text{ kg/mm}^2;$$

$F = \delta \cdot b = 6.50 = 300\ mm^2$

$P = R_{sh.} \cdot F = 16.8 \cdot 300 = 5050\ kg$

Like in the previous examples, the weakest zone of the weldment is considered the zone of annealing caused by the welding heat. In Fig. 122 this is the zone of the thinner element (section a - a) where a rupture is more likely to occur.

Below is another example, in which the direction of force application does not coincide with the weld direction.

4. It is required to calculate the value of the force P which can be withstood by a strip of the size shown in Fig. 120 (Example No. 2) but welded with a diagonal seam as shown in Fig. 123(a).

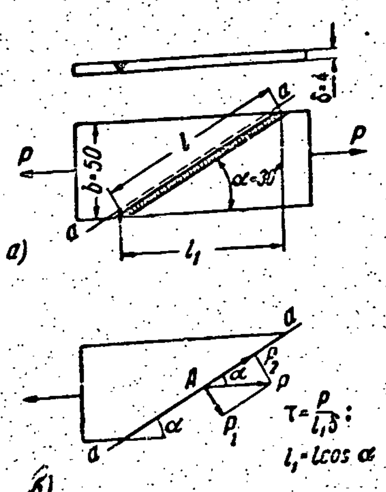


Fig. 123. - Example No. 4

In such cases it is the general rule to take the weld length as equal to the length of the projection of the weld on a line parallel to the direction of force application, that is in Fig. 123(a) the weld length is not l, but l_1. The actual value of l_1 can be found by plotting the welded parts on paper to their natural size, or by trigonometric calculations.

The weld total length $l = \frac{b}{\sin \alpha}$; $l = \frac{b}{\sin 30^\circ}$

$\sin 30^\circ = 0.5$; $l = \frac{50}{0.5} = 100$ mm

The projection of the weld length $l_1 = \frac{b}{tg\,\alpha}$;

$\alpha = 30^\circ$;

$tg\,30^\circ = 0.58$ (as found from a table);

$$l_1 = \frac{50}{0.58} = 86 \text{ mm}$$

The area of shearing $F_{sh.} = l_1 \cdot \delta$;

$F_{sh.} = 86 \cdot 4 = 344$ mm^2

Using the data accepted for the previous examples, and assuming that $\sigma_t = 70$ kg/mm^2, the stresses are:

$R_{ten.} = 21$ kg/mm^2 and $R_{sh.} = 16.8$ kg/mm^2

$P = F_{sh.} \cdot R_{sh.} = 344 \cdot 16.8 = 5450$ kg

Comparing this result with that obtained in example No. 1, it can be seen that the same strips when welded by a diagonal weld (Example No. 4, Fig. 123 (a)) can communicate a force of 5450 kg, instead of 4200 kg, that is, an increase of 30 per cent is obtained.

The closer the direction of the weld to the direction of the force applied, the greater the force which can be communicated by the weld, because in this case pure shearing stresses will be met with; in example No. 4, however, a tensile stress is also present, although it was neglected in the calculation.

Now, let us attempt to evaluate the error which has been made due to the accepted approximations and as a result of neglecting the tensile stress. To do so, first calculate the actual stresses which originate if the weldment is subjected ... $P = 5450$ kg (as found above).

Proceed in accordance with the general practice adopted in making calculations. After the sample is cut along the weld, let us take away its right-hand part and shift the force P along the direction of its application up to the joint itself (Fig. 123, b). In accordance with the laws of mechanics, force P can be resolved into two component forces: P_2 acting along the joint and P_1 acting across the joint. The first force develops shearing stresses and the second - tensile stresses.

The values of P_1 and P_2 can be found by plotting to a scale, or by trigonometric calculations.

$P_1 = P \sin\alpha$; $\alpha = 30°$; $\sin 30° = 0.5$;

$P_1 = 5450 \cdot 0.5 = 2725$ kg;

$P_2 = P\cos\alpha$; $\cos 30° = 0.85$;

$P_2 = 5450 \cdot 0.87 = 4720$ kg

$\sigma = \frac{P_1}{F}$; $F = 1\delta$; $F = 100 \cdot 4 = 400$ mm^2;

$\sigma = \frac{2725}{400} = 6.9$ kg/mm^2;

$\tau = \frac{P_2}{F}$; $\tau = \frac{4720}{400} = 11.8$ kg/mm^2

Thus, we find that in the same place, namely at the point A, two stresses act simultaneously, i.e. the tensile stress $\sigma = 6.9$ kg/mm^2 and the shearing stress $\tau = 11.8$ kg/mm^2.

The summing up of the stresses acting in the same place may be performed in accordance with various theories of the strength of materials.

In our case the total stress σ_0 may be found from the formula

$$\sigma_0 = \sqrt{\sigma^2 + 3\tau^2};$$

$$\sigma_0 = \sqrt{5.9^2 \div (3 \cdot 11.8^2)} = 21.6 \text{ kg/mm}^2$$

In the approximate calculation we accepted $R_{ten} = 21$ kg/mm^2, ... that is, it is great...

$$\frac{21.6 - 21}{100} = 3 \text{ per cent}$$

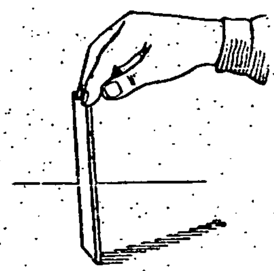
This error in calculation has no practical importance; consequently, the diagonal welds may be calculated in accordance with the simplified formula, that is, without taking into consideration the tensile stresses, and by assuming that the weld length is equal to its projection upon the line of direction of the action force.

§ 43. Calculation of equal strength and control calculations in repairs

In making calculations, especially when it is necessary to check whether a part has been properly repaired, and when the value of the force acting upon this part is not known, the accepted procedure is as follows. First, a control calculation of the welds made on the part in question is made, and the value of the forces which can be communicated by the undamaged part is found; then a control calculation is made or the dimensions of the welds for the part being repaired are calculated.

In making such calculations special attention should be paid to do nature of the loads acting upon the repaired part, especially if separate rod members are subjected to compression.

To illustrate this, let us take a wooden ruler 250 to 300 mm long and compress it with the fingers as shown in Fig. 124. Until a definite value of the acting force is exerted, the ruler will be compressd but will not be bent. Now let us try to compress, with the same force, a second ruler of an equal cross section but 600 to 800 mm long (Fig. 125). This ruler will fail to withstand the force, will be bent and may even be broken.



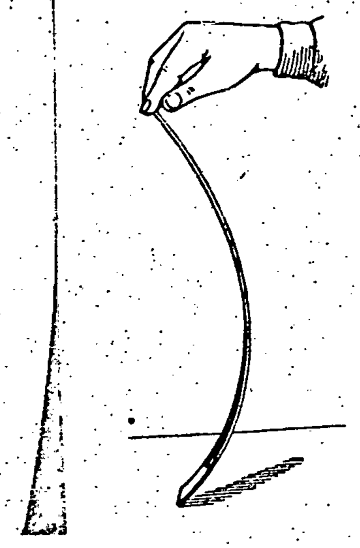


Fig. 124. - Example No. 5 Fig. 125.

The compression stress $\sigma_{ccmpr.}$ in both cases is equal because the cross-sectional areas and the acting forces are equal. Nevertheless, for long rods there is a danger of the so called longitudinal bending which occurs when the compressing force is increased to a certain critical value $P_{cr.}$. For this reason the calculation of long rods for column action (bending) is made according to special formulae.

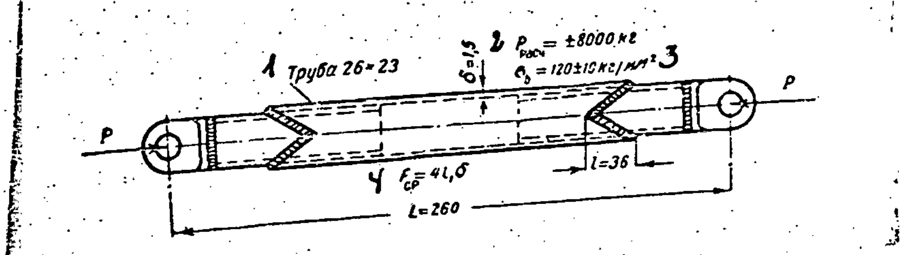


Fig. 126.

1) Pipe 26X23; 2) P_{rated} = ± 8000 kg
3) σ_b = 120 ± 10 kg/mm²; 4) F_{mean} = 41,6

5. It is required to find the value of the safety factor possessed by the repaired strut shown in Fig. 126, if R_{rated} =

= ≈ 8000 kg. The number of welds subjected to shearing m = 4. The thickness of the pipe wall is $\frac{26 - 23}{2} = 1.5$ mm. For weld length should be taken the projection of the weld full length <u>l</u> in the direction of the acting force, that is the value $l_1 = 36$ mm.

The total area of shearing $F = ml_1\delta = 4 \cdot 36 \cdot 1.5 = 216$ mm^2.

The shearing stress is $\tau = \frac{P_{rated}}{F_{sh.}} = \frac{8000}{216} = 37$ kg/mm^2

After heat-trearment the material of the pipe obtained an ultimate tensile strength of $\sigma_b = 120 \pm 10$ kg/mm^2

The ratio of weakening due to welding is taken as k = 0.7, with $R_{sh.} = 0.8\ R_{ten.}$

Consequently, $R_{sh.} = 0.8 \cdot k \cdot \sigma_b = 0.8 \cdot 0.7 \cdot 110 = 61.6$ kg/mm^2

The safety factor is then

$$n = \frac{R_{sh.}}{\tau} = \frac{61.6}{37} = 1.67, \text{ or 67 per cent.}$$

Since the strut being repaired has a considerable length, in addition to the compression check, it should also be checked for column action, and the value of the critical force $P_{cr.}$ should be found (i.e. the force under which the rod loses stability and begins to be bent when compressed). The calculation is made by the formula $P_{cr.} = F\sigma_{cr.}$, where F is the cross-section area of the tube;

$$\sigma_{cr.} = f\left(\frac{L}{i}\right), \text{ where}$$

f - is a factor depending upon the ration of $\frac{L}{i}$, upon the method of securing of the tube ends and other factors; this ratio may either be calculated or found from special diagrams given in designer's handbooks.

<u>i</u> is the radius of gyration which depends upon the dimensions of tube section; it can also be calculated or found from tables.

In our example $F = \pi d_{mean}\delta$; $\pi = 3.14$

$$d_{mean} = \frac{26 + 23}{2} = 24.5 \text{ mm}$$

$$\delta = \frac{26 - 23}{2} = 1.5 \text{ mm}$$

$$F = 3.14 \cdot 24.5 \cdot 1.5 = 115 \text{ mm}^2$$

For a 23 x 26 tube: $i = 8.6$ mm

For $\frac{L}{i} = \frac{260}{8.6} = 30.2$, the value of $\sigma_{cr.}$ is 79 kg/mm^2 as found on a diagram

Consequently, the critical stress for this tube, P_{cr}, is;

$P_{cr} = \sigma_{cr} F$, and $P_{cr} = 79 \cdot 115 = 9100$ kg;

the safety factor being: $n_1 = \frac{P_{cr}}{P_{rated}} = \frac{9100}{8000} = 1.14$, or 14 per cent.

Thus we have found that, after the repairs have been made, the safety factor for column action (or longitudinal bending) of this rod is considerably lower than the safety factor for compression.

The above examples and some of the fundamentals of weld strength calculation have been given here in a most elementary form; however, even such approximate calculations are of great assistance in evaluating the possibilities of the chosen method of repair of stressed structural elements. A qualified airforce welding foreman is expected to understand and use these fundamentals. Especially is this true in regard to the technicians who are directly in charge of aircraft repairs.

CHAPTER XIV

SAFETY MEASURES IN WELDING

All welding operations should be performed with strict observance of labour protection and safety regulation requirements. When these rules are adhered to, the electric-arc and oxy-acetylene processes are not dangerous or harmful to the welder's health. For this reason, only those who have thoroughly mastered welding equipment and safety first rules may be allowed to perform welding.

The drops and spattering of the molten metal may be the cause of a fire or of burns suffered by the welder. Scattered to a considerable range, drops of molten metal can set inflammable materials on fire, this danger being further aggravated by the fact that the fire may break out several hours after the completion of welding. This is the reason why the floors and partitions of welding shops should be made of non-combustible materials. Accumulation of inflammable materials in welding shops and in the vicinity of welding areas should not be tolerated.

When working close to wooden structures, protect the wooden elements and other parts made of inflammable materials by sheets of asbestos moistened with water, or by metal sheets.

To protect himself against burns, the welder should wear a jacket, trousers and gloves made of dense tarpaulin; a leather apron is also desirable. The trousers should be long enough to be worn over the boots and should cover the latter. The jacket should not be tucked into the trousers, and its pockets should be always closed with flaps. The foot-gear should closely fit the welder's feet and be laced up. The welder's head should be covered with a brimless cap.

During welding, the air becomes polluted with dust, gases and vapours which are a result of the burning of oil, paint, dirt, electrode metal, filler material, fluxes and the workpiece metal.

The quantity of noxious gases increase when dirty, painted or greased articles are being welded. The dust and gases originated during welding are harmful to the human organism. Especially harmful are the dust and gases produced in the process of welding alloys containing lead and copper.

To reduce the harmful influence of dust and gases upon the welder's organism, the welding shops should be provided with adequate ventilation facilities.

The accumulation of gases may also become a cause of explosions and fires.

In this connection, an especially high degree of care should be exercised in the repair of aircraft gasoline and kerosene tanks when welding is used. As a result of heating of the metal during welding, even the smallest quantities of gasoline or kerosene left produce vapours which may cause an explosion.

For this reason, prior to welding, the tanks should be thoroughly washed until all the remaining inflammable liquid is fully removed, as instructed above. It is also recommended to blow the tanks off with air during the welding.

To reduce fire hazards, electric-arc and oxy-acetylene welding equipment should not be accommodated in the same premises, and, more so, should they not be used simultaneously.

§ 44. Safety measures in electric-arc welding

50X1

The main factors producing harmful effect upon the human organism during electric-arc welding may be the arc radiation, electric current, and dust produced by the arc.

The welding arc eradiates visible light rays and invisible infrared and ultraviolet rays.

The visible light rays cause injury to the iris and retina of the human eye. These injuries occur due to the fact that the brightness of the welding arc is several thousand times greater than the brightness which can be endured by unprotected eyes.

The short time action of visible arc rays is to cause temporary blindness; their prolonged action upon unprotected eyes results in injuries to the retina and impair keenness of eyesight.

The prolonged action of infrared rays upon unprotected human eyes may result in dimming of the crystalline eye lens and in reduction of keenness of eyesight.

The ultraviolet rays cause reddening of the skin and its pigmentation (the so called electric-arc tanning). As a result of prolonged ultraviolet ray exposure, painful burns of the skin may be experienced.

To protect the welder's eyes against electric-arc rays, protective glasses of a dark colour should be used; these glasses are fitted in welder's helmets, masks or shields.

The shield, helmet or mask are designed to protect the welder's face against the harmful influence of electric-arc rays, as well as against spatter of metal.

The USSR industry manufactures TWO coloured glasses of three Grades.

No.1 - the darkest glass used for welding at currents o over 350 amperes;

No.2 - medium-dark glass used for currents of 100 to 350 amperes;

No.3 - for currents up to 100 amperes.

The ТИС glasses fully absorb invisible arc rays and reduce the brightness of visible rays.

To protect the ТИС glasses against spattered metal, they are covered, on the outside, by common white glasses. As the latter become dirty, they are wiped clean or replaced.

To protect other personnel working in the vicinity or passing through the welding area, portable screens made of ply-wood or thin boards should be used. The screens are to be painted black or gray, and are arranged around the area in which the electric-arc welding is performed.

It is advisable to place warning in the vicinity of welding area, where they can be well seen; these warnings are, "DO NOT LOOK AT THE ELECTRIC ARC", "GUARD YOUR EYES AGAINST THE ELECTRIC ARC", etc.

To reduce the harmful action of electric-arc rays, the walls of the welding shop should be painted in dark dull colours.

Electric current on passing through the human body may cause harmful consequences, and, in some instances, even death. For this reason the welder is required to closely watch the condition of the welding equipment and on no account to commence welding until he is absolutely sure that the work is safe.

Prior to commencing work, the welder should check the condition of the insulation on the cables. If cables with ... the welder should eliminate the defect himself, or should report it to his superiors. On no account should angle iron, pipes or other pieces of metal be used as current conductors.

Before starting work, the welder is required to reliably ground the welding apparatus housing. Special conductors should be used to ground the apparatus, and no machine or structural elements may be used for this purpose.

The electric cables connecting the welding apparatus to the control board and to the workpiece should be well insulated and protected against the action of hifh temperatures and against mechanical damage. The knife-switches, switches and fuses should be protected ty hoods or be in enclosures.

In the course of welding, regularly check the condition of the cable insulation. Do not touch the current-carrying parts with the bare hand when the supply switch is not yet switched off.

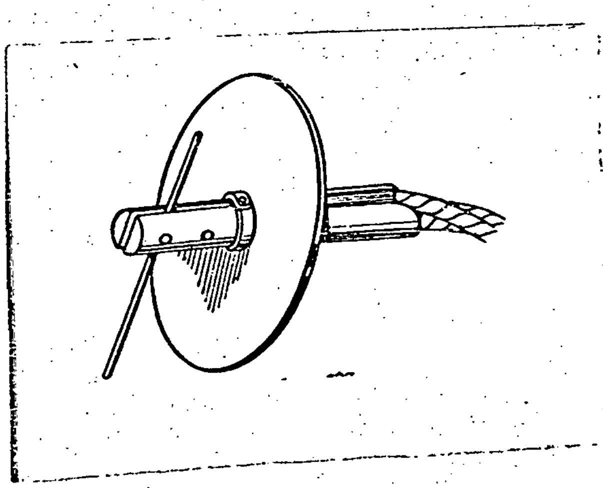


Fig. 127. -

The electrode-holder grip should be securely insulated. A circular shield (Fig. 127) protecting the welder's hand against metal spatter, slag and arc heat should be mounted on the electrode-holder grip. The electrode-holder grip may be made of fiber, pressboard, a moulded plastics or of hard wood.

§ 45. Safety measures in oxy-acetylene welding

The specific requirements of safety measures in oxy-acetylene welding are connected with the use of acetylene and oxygen, as well as with the design features of gas welding equipment.

It has already been pointed out that even a small content of acetylene in the air produces an explosive mixture. Therefore, if there is a strong smell of acetylene in the welding room, work should be discontinued at once, the premises thoroughly ventilated and the causes of gas leak eliminated.

When operating the ГВР-1.25 and Record generators, it should be borne in mind that this equipment is designed for use in the open. For temporary erection work, these generators may be temporarily installed in living-house premises or workshops, provided the premises are well ventilated and have a minimum volume of 300 cu. m.

Gas generators may on no account be operated in premises where substances producing explosive mixtures with acetylene are present (for instance, in boiler rooms and close to the air-intake ducts of air-compressors and ventilating fans).

Gas generators should be installed at least 10 meters from the place of welding or from any other source of open flame or intensively heated equipment, etc.

Prior to commencing generator operation, check the water level in the water seal. Such checks should be made at least three times per working shift, as well as after each backfire, adding water whenever required.

On no account should the safety diaphragms of the [illegible].25 generator water seal and housing be replaced by fibre, rubber, wooden or other gaskets, or by plugs.

Under-size granulations of carbide should not be used to charge the generator; the use of carbide dust is extremely dangerous since it inevitably distrubs normal generator operation and may cause an explosion resulting in accidents. For this reason, prior to being charged into the generator, carbide should be screened.

Do not overcharge the generator basket with carbide.

Carefully watch that there are no gas leaks from cracks, plugs and other joints. If a leaky plug or cock is detected, tighten it up. Should a more serious gas leak occur (for instance, through a weld or a threaded joint), first exhaust the remainder of the carbide charge, then wash and inspect the generator, and only after this proceed with elimination of leaks, using tools which produce no sparks (brass or aluminium tools).

Prior to igniting the torch (or cutter), blow off the water seal and hoses with acetylene, to remove the air in them.

Do not attempt to obtain a greater than rated capacity from a generator, because this may result in acetylene overheating.

Prior to charging the generator retort, make sure that the chamber is filler with water.

On no account open a retort which contains carbide that has not yet decomposed. Should there arise a need to take the basket out with live carbide in case of an insufficient supply of feed water), this may be done only after the generator retort has been allowed to cool off during a minimum period

[illegible] pressure has been brought

down.

To clean the generator chamber of slime, use brass scrapers. No steel tools should be used for this purpose.

When working in a cold room or in the open, in winter, see that water in the generator housing and in the water seal does not freeze; to prevent water from freezing, drain water in anticipation of a long-time idle period.

To prevent the water seal from freezing, it is recommended to fill it with a 15-per cent solution of common salt.

Should water freezing occur in the generator or water seal, warm them only by means of hot water or steam., without the use of an open flame (torches, heated metal, etc.).

Do not chip ice out of the generator. To remove ice, the generator should be brought into a warm room.

Oxygen on coming in contact with grease or oil sets them on fire. Metal in an atmosphere of oxygen begins to burn, which can immediately cause a cylinder explosion. For this reason, there should not be even the slightest signs of grease or oil on the cylinder valve, its thread, on the surface of the cylinder proper, on the oxygen pressure reducer or hoses.

Acetylene generators and gas-welding equipment should be kept clean and tidy. Accumulation of sediments containing carbide particles inside the generator may result in accumulation of acetylene. When air enters the generator, the acetalene thus accumulated may cause an explosion.

Water should not be used to extinguish a fire in a generator. The fire should be smothered with sand, or by means of a tarpaulin, or a fire-extinguisher should be used.

The handling of oxygen cylinders demands special care. Carelessness may result in a cylinder explosion, normally involving large-scale destruction and damage.

Explosions of oxygen cylinders may be caused by:

1. Falling, shaking and jolting of a cylinder. In such cases a sharp increase in the stresses on the cylinder body occurs, and the cylinder may be ruptured if the metal of the body possesses low impact ductility or is badly rusted.

2. Cylinder pollution by grease or oil. When grease or oil gets inside the cylinder, they are rapidly oxidized by compressed oxygen, this process being accompanied by heat discharge. As a result of temperature rise, the oil or grease are ignited, the oxygen facilitating and intensifying the burning. This causes a pressure rise inside the cylinder and may result in a cylinder explosion.

The following rules should be strictly adhered to when handling oxygen cylinders:

1. Do not subjected cylinders to shocks or jolting.

2. To transport cylinders over short distances, use barrows or carriages.

Inside working premises cylinders may be moved by carefully turning them on the shoe edge (Fig. 128). On no account should cylinders be carried in the hands.

3. If a cylinder is being used in a lying position, it should so be arranged that the valve at the top is somewhat higher than the shoe (Fig. 129).

4. If a cylinder is being used in a vertical position, it should be secured to the wall by means of a chain or clamp, to prevent it from falling.

5. One cylinder only should be stored at the welder's post.

6. Do not place cylinders close to a source of fire as

a heating system.

Fig. 128. - Moving a cylinder by turning

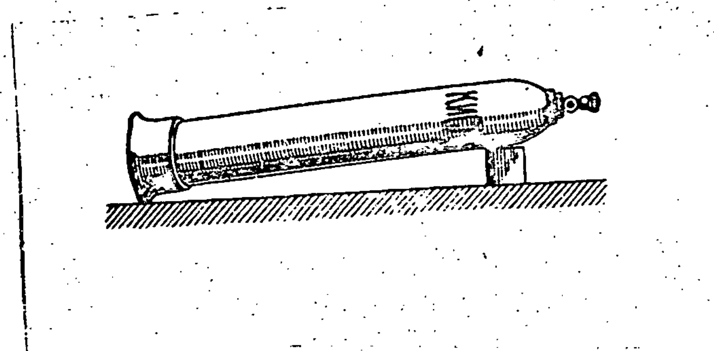


Fig. 129. - Arranging a cylinder in lying position

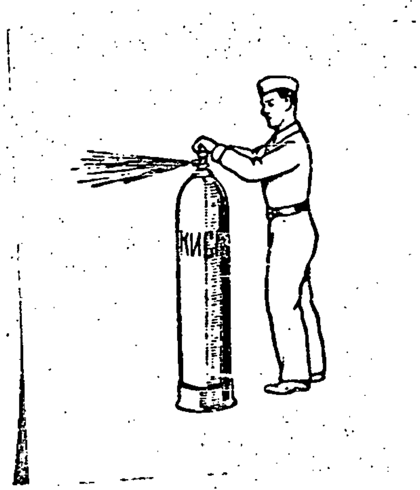


Fig. 130. -

7. See that oil and grease are not allowed to get on the cylinder and its valve.

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8. Do not stand opposite the discharge outlet when blowing off the cylinder valve (Fig. 130).

9. In cases of freezing, cylinders should be warmed by hot water only.

10. Do not use up all oxygen contained in the cylinder; discontinue work as soon as the oxygen pressure inside the cylinder drops to 5 kg/mm^2 g.p.

Carefully protect oxygen pressure reducers, hoses and torches against contact with oil.

Should the reducer become frozen during work at sub-zero temperatures in the open, it should not be warmed by torch flame or by open fire. Wrap the reducer in a clean rag and pour hot water over it.

When handling acetylene cylinders, observe the rules given above in connection with oxygen cylinders. In addition, the following rules should be adhered to:

1. Do not subject cylinders to violent jolts and shocks, to prevent the porous mass from being packed down and to avoid cavity formation.

2. Do not subject cylinders to considerable heating (over 30°C), since this results in decrease in acetylene solubility in acetone, with subsequent rise in acetylene pressure.

3. When working in the open, cover acetylene cylinders with a tarpaulin wetted with water, to protect them against heating by sun rays.

4. Contrary to oxygen calinders, acetylene cylinders during welding should be positioned only vertically; if a cylinder is laid down, loss of acetylene may occur.

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