Gas Metal−Arc CO_2 Welding

Table of Contents

Gas Metal−Arc CO2 Welding

PROFacto

Authors:

Dipl.−Ing. Herbert Einicke,
Ing. Felix Timmermann,
Central Welding Institute at Halle (Saale), G.D.R.

Designed by

Günter Brabant

Prepared for publication by

Dipl.−Ing. paed. Günter Zweynert

Published by

Zentralstelle für Bildungswesen des Schwermaschinen − und Anlagenbaus
−7010 Leipzig, Barfussgäasschen 12

on behalf of

Institut für berufliche Entwicklung
−1080 Berlin, Französische Strasse 47

III−6−15 881−81 Ag 689−35−81

1. General

The outstanding development of welding over the past decades has led to a close study of its possibilities in almost all countries. No technology, perhaps, is advancing as fast as that of welding. Therefore, it is essential that particular attention should be given to education and training in welding.

By using our series of slides on arc, gas, and CO_2 welding, it is possible for courses in welding to be streamlined.

The series of slides on gas metal−arc CO_2 welding is designed for use in basic courses in CO_2 welding, but can also be used for the further education and training of CO_2 weldors.

Fundamentals of electrical engineering (basic electric quantities, voltage generation, types of voltage, effects produced by electric current) are discussed with particular reference to CO_2 gas−shielded arc welding equipment, with the various weld power sources and their volt−ampere characteristics as well as the acting together of arc characteristics and volt−amp characteristics being described in detail. Completing the series of slides is a number of pictures showing equipment for CO_2−shielded welding and illustrating CO_2 welding techniques. All of the slides have been designed on purely didactic principles, and this enables them to be used for different purposes in operator training and will cause the student's attention to be invariably called to essentials. This series of slides cannot be used for slide illustrated lectures.

Belonging to this series of slides on gas metal−arc CO_2 welding is a text containing explanations of slides, providing valuable information on important points, and helping interpret slides correctly.

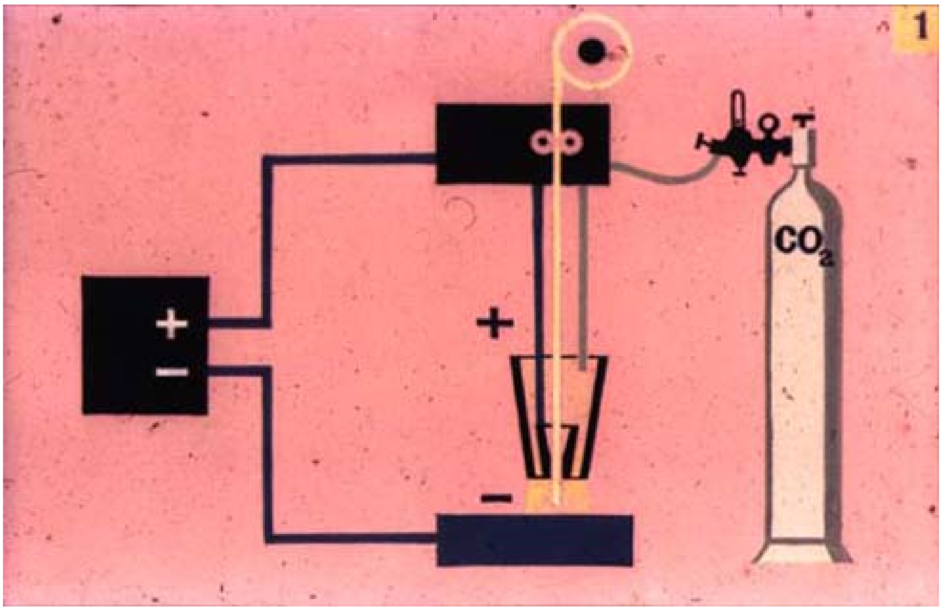
2. List of slides on gas metal−arc CO welding

Slide no.	Slide title
1	Principle of gas metal−arc CO_2 welding
2	Comparison of basic and welding power circuits
3	Magnetic voltage generation
4	A−C voltage generator
5	D−C voltage generator
6	A−C voltages
7	D−C voltages
8	Arc initiation
9	Ionization
10	Initiation of the CO_2−shielded arc
11	Magnetic effect
12	Arc blow
13	Corrective measures
14	Welding generator, principle of construction
15	Welding converter KW 400 VC, general view
16	Welding converter KW 400 VC, slope control
17	Welding transformer, principle of construction
18	Welding transformer “Junior”, interior view
19	Welding rectifier, principle of construction
20	Welding rectifier RGS 315, interior view
21	Welding rectifier RGS 315, interior view, with fan
22	Welding rectifier RGS 315, general view
23	Welding rectifier RGS 315, operational controls
24	Welding rectifier KGS 160
25	Open−circuit voltages
26	Open−circuit voltages in special spaces
27	Volt−ampere characteristics

28	Volt–ampere characteristics of a variable–characteristic power supply
29	Welding rectifier KG 400 VC, general view
30	Welding rectifier KG 400 VC, front view
31	Welding rectifier KG 400 VC, slope control
32	CO_2 arc welding unit ZIS 707, side view
33	CO_2 arc welding unit ZIS 707, front view
34	CO_2–shielded arc–welding torch
35	CO_2–shielded arc–welding torch RU 300
36	CO_2–shielded arc–welding torch PU 600 F
37	Supply of gas
38	Arc characteristic curves
39	Current density
40	Operating points in CO_2 gas–shielded arc welding
41	Splitting–up of CO_2 shielding gas
42	Transfer of metal in CO_2 gas–shielded welding
43	Spray–transfer–type arc
44	Weld preparation
45	Selection of parameters
46	Extremely high weld voltage
47	Extremely low weld voltage
48	Contact tips
49	Effect of gas nozzle
50	Effect of welding power lead
51	Gaging the throat of a fillet weld
52	Gaging the reinforcement of a V groove weld
53 and 54	Application examples

3. Explanations of slides

Slide no. 1 Principle of gas metal–arc 002 welding

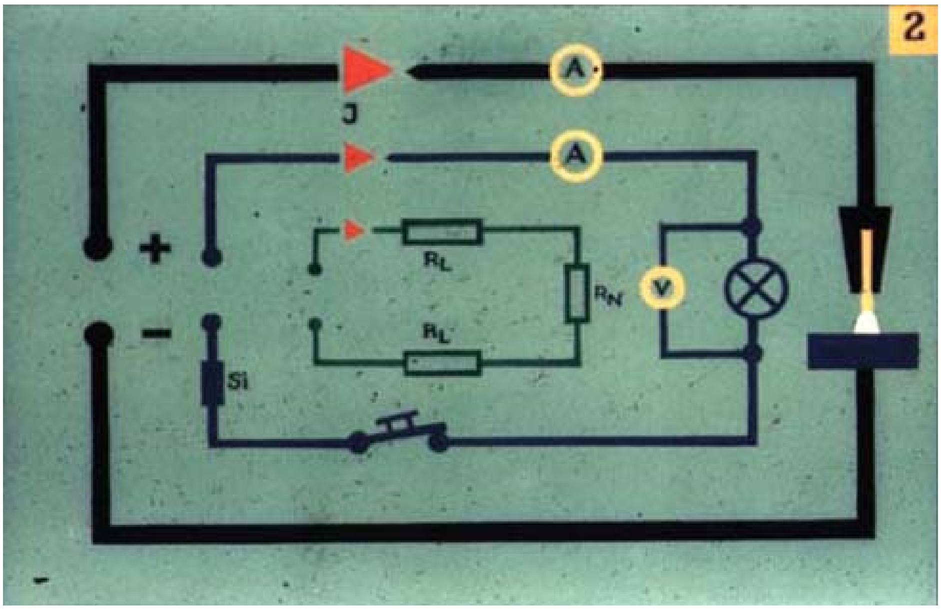


This slide shows the most essential components of a CO_2 gas–shielded arc welding unit and how they cooperate to enable operations of welding to be performed successfully. Metal–arc gas shielded welding with carbon dioxide shielding requires special weld power sources of which the operating principles will not be discussed until the fundamentals of electrical engineering have been described in detail.

The wire feeder of the weld setup provides for continuous filler metal feed. Filler metal is deposited in an atmosphere of shielding gas. Welding current is transmitted to the filler metal through the torch contact tip. CO_2 gas–shielded arc welding uses, as the name implies, carbon dioxide as the shielding gas. This is an active gas that is split up in the arc.

$$CO_2 \rightleftarrows CO + 1/2\ O_2$$

Slide no. 2 Comparison of basic and welding power circuits



The fundamental electric circuit can be assumed to be known to trainee weldors. Fundamental electric quantities (U, I, R) can be easily explained by using a fundamental circuit as an example.

A comparison of fundamental and welding power circuits shows these to differ in the following respects:

(1) There are no fuses and switches in the electric welding circuit.
(2) The lamp in the fundamental circuit is replaced by the weld arc as a useful resistance.

Fuses, which in fundamental electric circuits serve as short−circuit and overload protective devices, are not required in weld circuits.

NOTE: Short−circuits are required for arc initiation and welding.

Welding is started by striking the arc by touching down with the electrode, a process that involves short−circuiting.

NOTE: The electrode and work are elements of the switch.

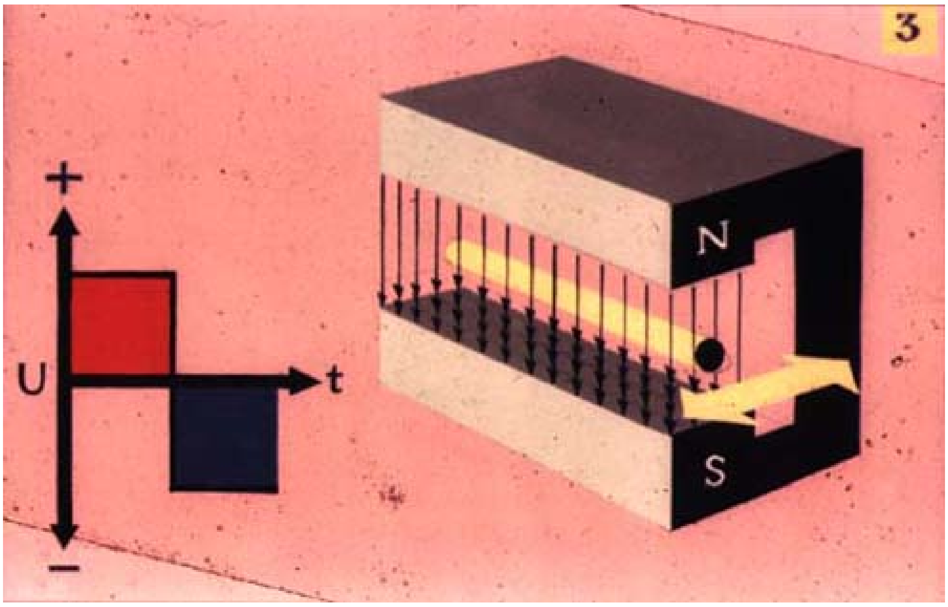
The equivalent circuit diagram (green) shows the resistances in the circuit, namely:

Line resistance, R_L – Welding power lead

Useful resistance, R_N – Electric arc.

In this connection, mention should also be made of Ohm's law.

Slide no. 3 Magnetic voltage generation

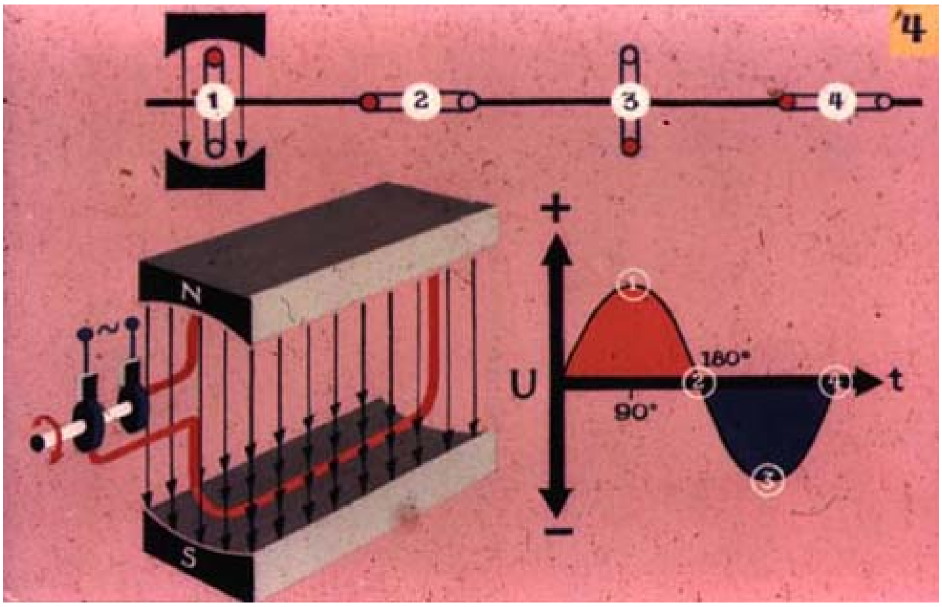


Voltage is the cause of current flow in the electric circuit. Therefore, it is not usually justifiable to use such terms as source of current or current supply source. This holds true especially for welding. There will be no flow of current until voltage is applied to an electric circuit. Well−known methods of voltage generation include

triboelectricity (electrostatic generator),
piezoelectricity (quartz oscillator),
photoelectricity (exposure meter),
thermoelectricity (thermocouple),
chemical voltage generation (battery), and
magnetic voltage generation (generator).

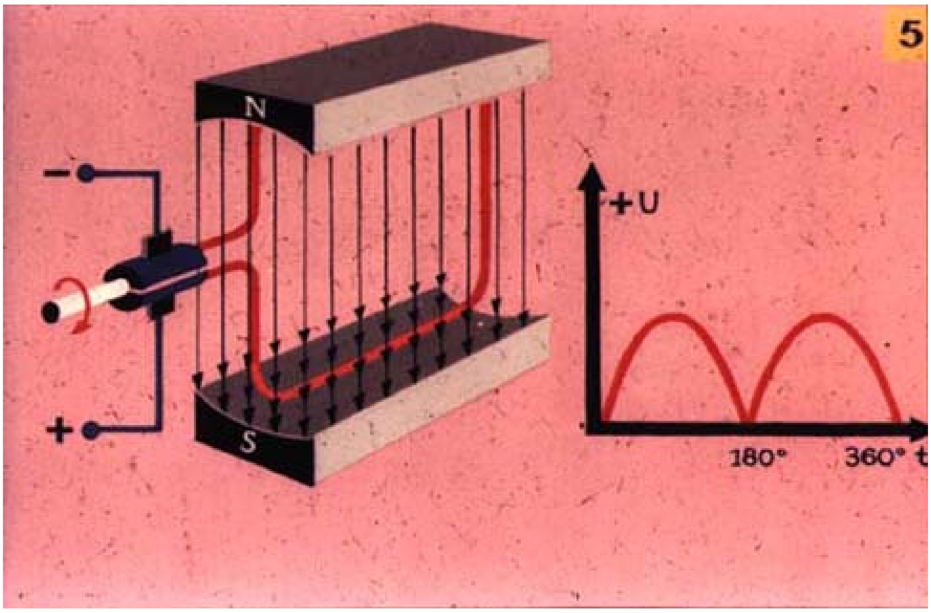
Magnetic voltage generation, of which the basic principle is shown in this slide, is of extreme importance to industrial power supply systems. Movement of the electric conductor in a magnetic field results in voltage being induced therein. A possible explanation of this process is that free electrons in the conductor will be pushed toward one side when intersecting the magnetic lines of force. The electrons will be pushed toward the other side when the direction of motion is reversed. A negative charge will be produced at that point which is characterized by an excess of electrons, whereas a positive charge will be produced at the opposite point. Voltage will be generated for as long as the conductor is kept moving. The relationship between voltage generation and direction of motion is shown in the accompanying diagram.

Slide no. 4 A–C voltage generator



If a conductor loop is substituted for the conductor shown in slide no. 3 and moved in a magnetic field, then rotation of this conductor loop will result in the generation of an a–c voltage that can be picked up off the generator slip rings. The magnitude and direction of the voltage thus generated depend on the location of the uniformly moved conductor loop. One full rotation results in the sinusoidal a–c voltage curve shown in the diagram. The magnetic field between the poles (N, S) is, in general, generated electrically.

Slide no. 5 D–C voltage generator

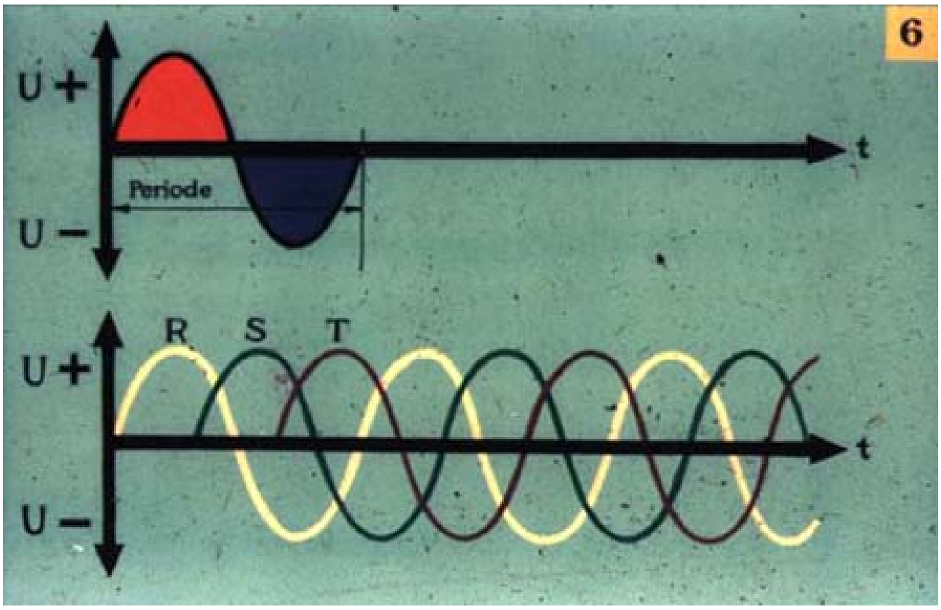


Substitution of a collector for the slip rings will give the wavy d–c voltage shown in this slide, provided of course a conductor loop is used.

Waviness or ripple decreases as the number of conductor loops and collector segments increases. Loop generators will supply a smooth d−c voltage.

NOTE: The collector invariably applies the positive side of the conductor loop to the positive carbon brush.

Slide no. 6 A−C voltages



This slide shows a comparison of single−phase and three−phase a−c voltages.

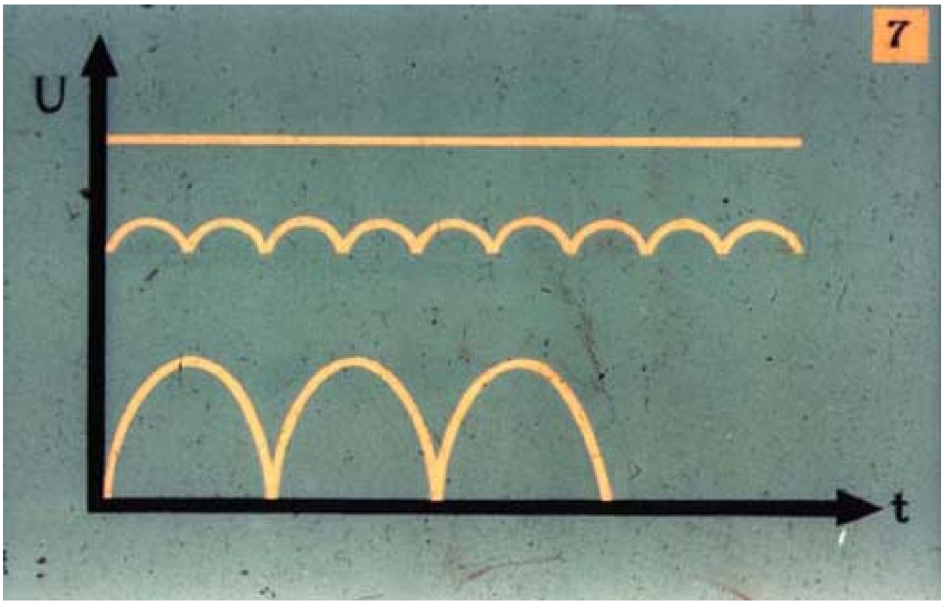
Representation in color allows to distinguish between positive and negative half−waves.

The major focus of instruction should be on the following points:

- Change of polarity in zero passage
- Period as sum of both half−waves
- Frequency, number of cycles per second
- Three−phase a−c voltage as a combination of three single−phase a−c voltages into a three−phase system (RST).

Be sure to point out the technical importance of a−c voltages.

Slide no. 7 D−C voltages

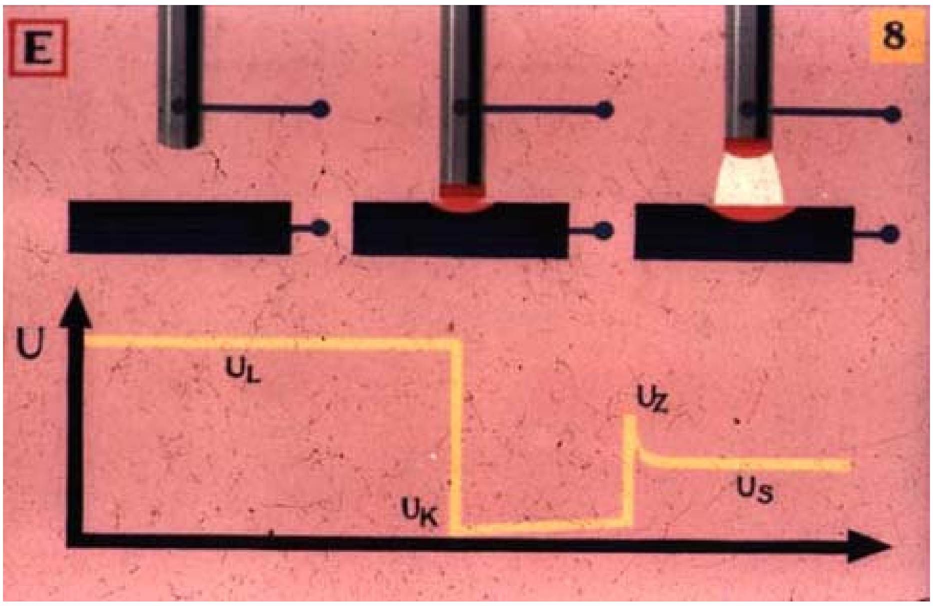


This slide shows different d−c voltage waveforms. D−C voltages of different waviness or ripple can be obtained depending on how voltage is generated.

Generator: No or negligible waviness.
Rectification of a three−phase a−c voltage: Large waviness.
Single−phase a−c voltage: Very large waviness.

The presentation in this slide relates to different phenomenal forms rather than to the magnitude of d−c voltages. The different voltage levels were chosen deliberately. The term waviness should be used in its general sense only. It need not be defined precisely.

Slide no. 8 Arc initiation



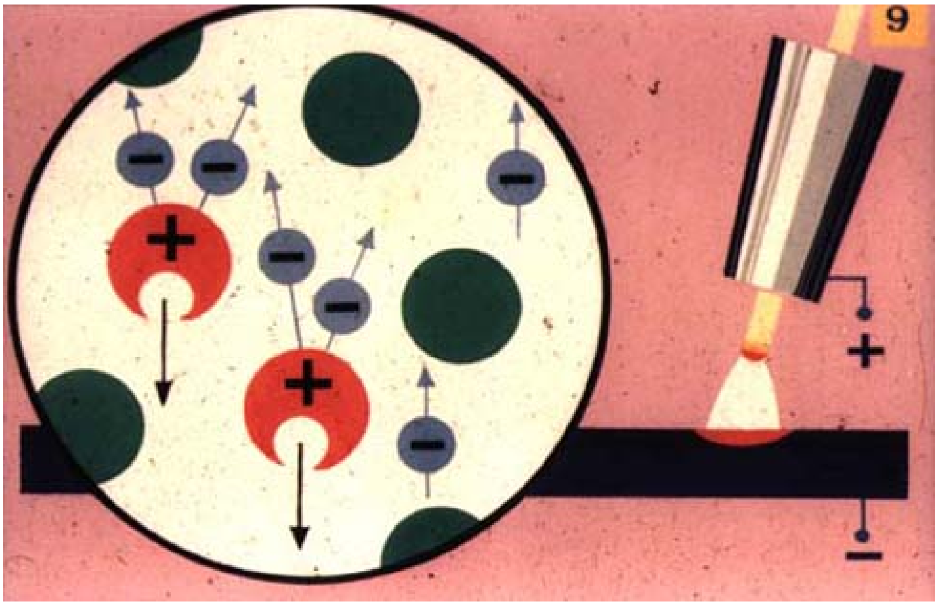
This slide shows the phases of starting the arc in electric arc welding. A distinction is generally made between no−load condition, ignition short−circuit, and arc.

No−load condition:	An arc is not established despite the presence of a high open−circuit voltage. Air acting as an insulator provides against any flow of current between the electrode and work.

Ignition short–circuit:	Touching down with the electrode results in the weld circuit being shorted (low voltage). High current density at the contact point causes the cathode (negatively connected electrode) to be heated, this being accompanied by electron emission. The ambient air is ionized, thus becoming conductive.
Electric arc:	When the electrode is lifted off the work, the arc will be initiated by the striking voltage. The arc will then operate at the necessary weld voltage which, in turn, is determined by the arc length.

Here, the letter symbols U_L, U_K, U_z, and U_s stand for open–circuit voltage, voltage, striking voltage, and weld voltage respectively.

Slide no. 9 Ionization



This slide shows processes proceeding in the plasma of the arc.

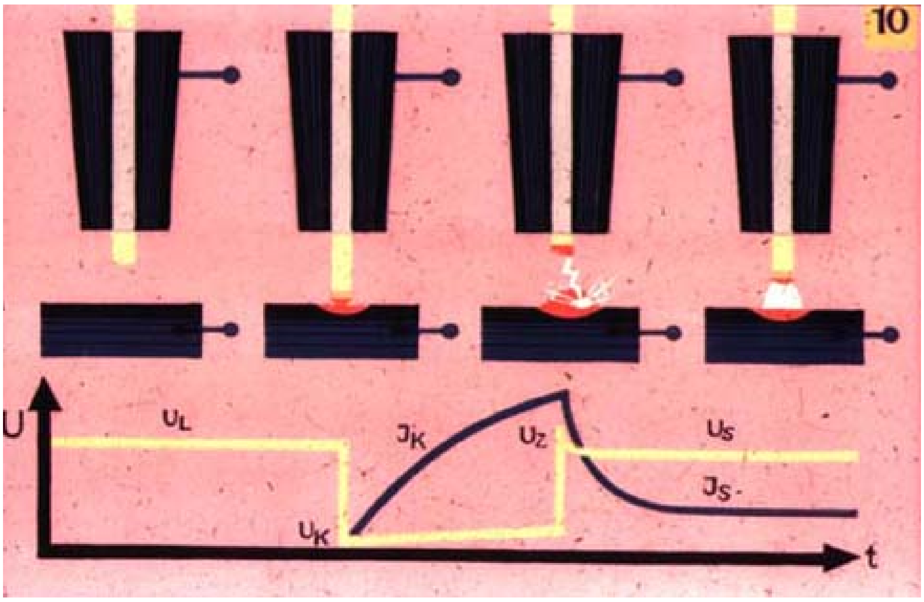
Presentation by a still of highly dynamic processes of motion proceeding within the arc plasma requires that a number of compromises be made. For example, it was necessary to use arrows to indicate the direction of motion of particles. The colors used for gas atoms, positive ions, and electrons are green, red, and blue respectively. Ionization by collision in the arc plasma is dealt with here only. Impact ionization is generally believed to be due to collision of electrons with gas atoms. However, instructors should point out that not all of the gas atoms which are present in the plasma of the arc are ionized, but only a certain part of them.

Simultaneous with the formation of positive ions, there proceeds an opposite process which involves the return of electrons to the circle of ions. This process, which is known as recombination, must be considered in connection with ionization.

A discussion of recombination has been dispensed with here so as not to detract from the comprehensibility of this text.

A temperature–dependent state of equilibrium will be established between charged and uncharged particles. The proportion of charged particles as compared with uncharged particles increases as the temperature rises. In the case of welding with the electric arc, plasma temperatures are between 5,400 and 6,000 K.

Slide no. 10 Initiation of the CO–shielded arc

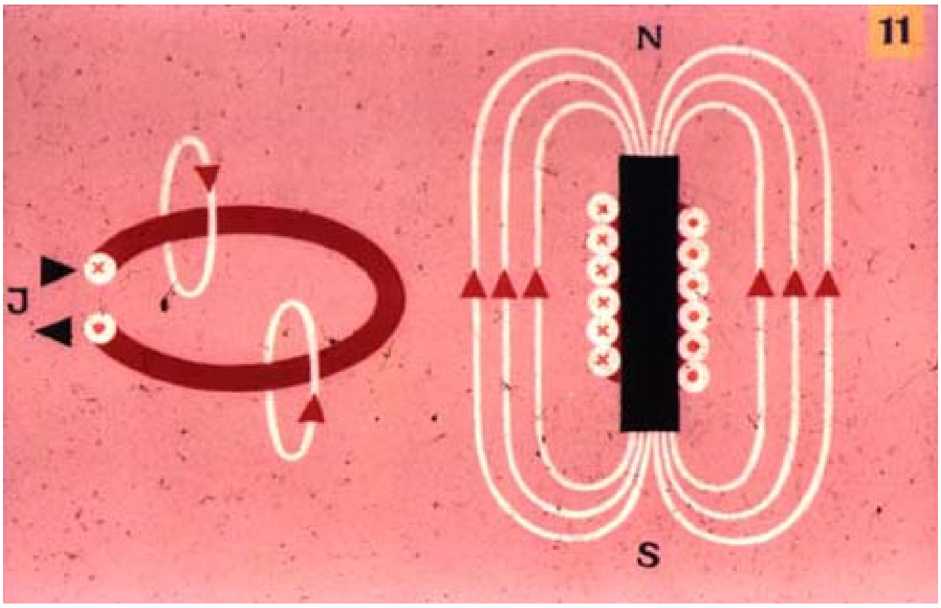


Starting of the CO_2 welding arc differs from arc initiation as shown in slide no. 8 in that the open−circuit voltage is lower (with UL being roughly equal to U_s) and the electrode need not be lifted off the work after ignition short−circuit.

The filler metal electrode is fed to the work at a constant speed. As with electric arc welding, an ignition short−circuit will occur when the electrode comes in contact with the work. The voltage curve is similar to that observed in electric arc welding. A rapid rise of current provides for high filler metal current density, and the wire bridge between the nozzle and work is melted. It is during filler metal melting that vaporization of metal and electron motion cause the arc gap to be ionized, with the arc being established.

The diagram shows the voltage and current curves during the process of starting the arc. It is important to note here that the shorting and arcing processes are repeated frequently.

Slide no. 11 Magnetic effect



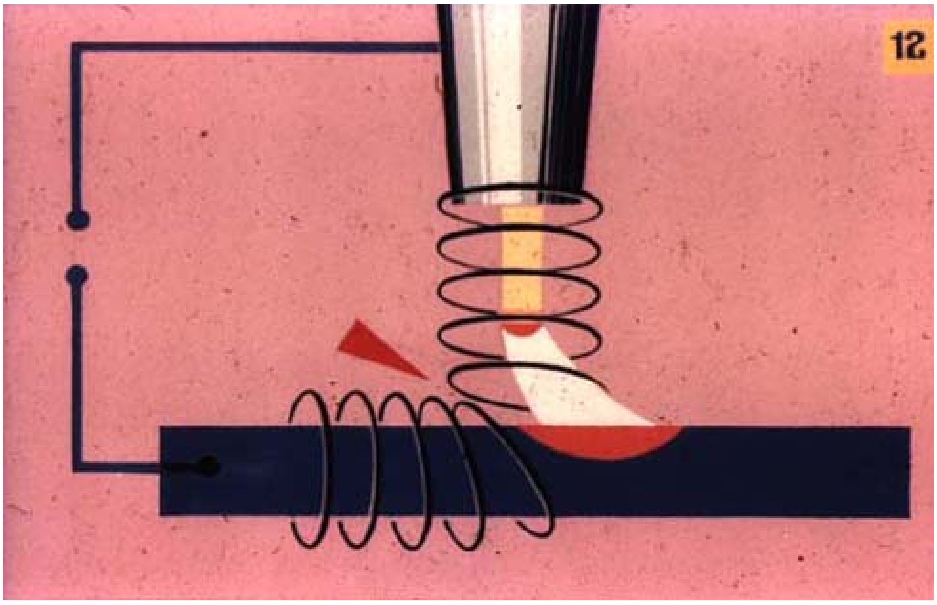
As is well known, current flow can be recognized only by its effects, and these include thermal, luminous, magnetic, chemical, and physiological effects.

This slide explains the magnetic effect. In welding, this effect may cause major trouble. The arc blow effect observed in welding operations is discussed in slide no. 12.

Shown on the left side of this slide is a current-carrying conductor. Forming around this conductor is a magnetic field which is indicated by the rings around the conductor.

In the case of a coil wound around an iron core, the magnetic field is formed around the entire coil. Within the iron core, the magnetic field will become denser and denser, with definite poles (N, S) being formed at the ends of the iron core. The principle of an electromagnet is shown on the right side of this slide.

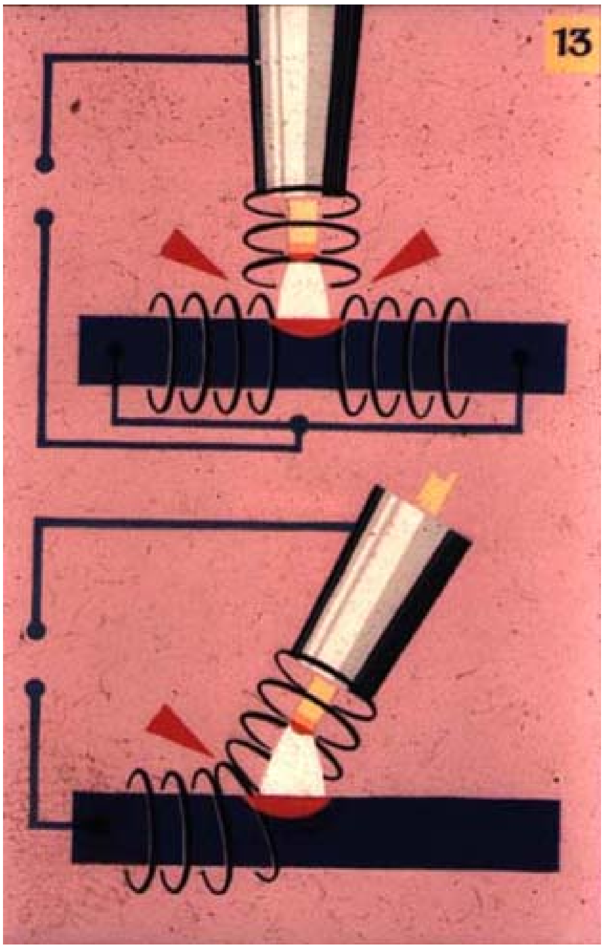
Slide no. 12 Arc blow



The formation of a magnetic field around a current-carrying conductor is known to have an adverse effect upon welding. This slide shows arc-blow-producing magnetic fields formed around the arc and work. The magnetic fields which are in a vertical relationship to each other cause the arc to be deflected in the direction of the arrow.

It is essential that the instructor should also point out that there are still other arc-blow-producing forces such as external fields, edge effects, and mass of steel.

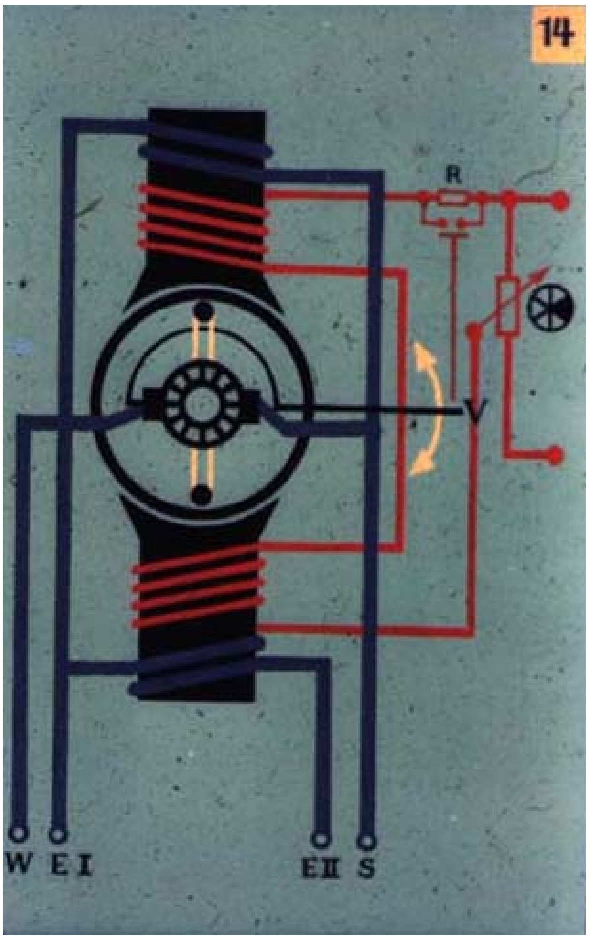
Slide no. 13 Corrective measures to counteract arc blow



Connection of two parallel welding cables in opposite places is shown in the upper part of this slide, whereas the lower half of the slide illustrates the inclining of the weld torch as a possible way of combating arc blow.

It should be pointed out that gas metal−arc CO_2 welding does not allow a−c current to be used as a means of avoiding arc blow. CO_2 gas−shielded welding is invariably done with the use of d−c current.

Slide no. 14 Welding generator, principle of construction



This slide shows the principle of construction of drooping and flat characteristic welding generators.

The windings provided on the pole shoes are required for the production of a magnetic field in which the conductor loops of the armature are moved.

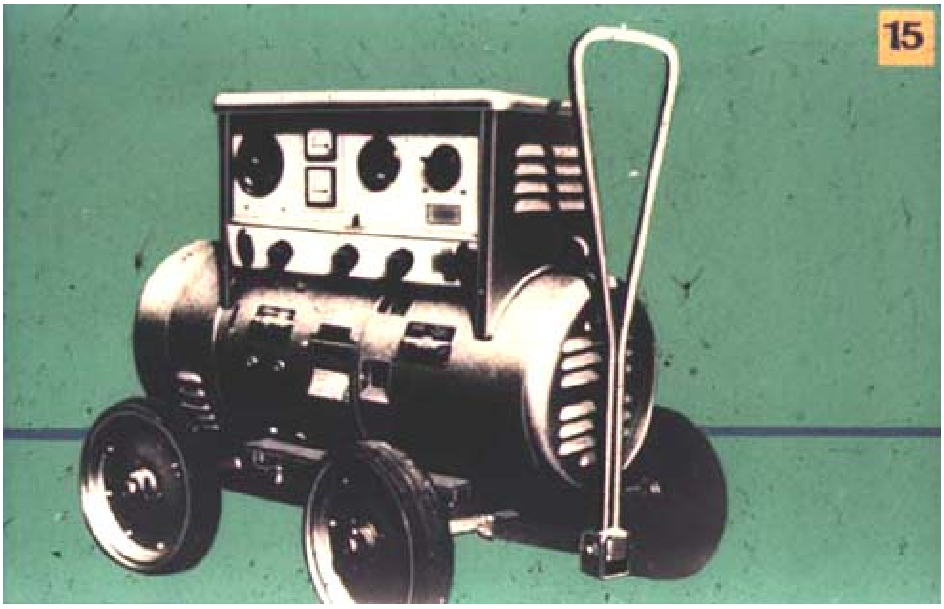
The principal field is produced by the red windings (exciting circuit), whereas the blue windings through which weld current flows tend to weaken the principal field.

Depending on terminal connections, the welder−generator will have an almost flat characteristic (low open−circuit voltage) for W−S, a drooping characteristic (high open−circuit voltage) for W−EI, and a steeply drooping characteristic (high open−circuit voltage) for W−EII.

Adjustment of the required open−circuit voltage is by switching resistor R on and off, respectively. It is important to note here that the carbon brushes should be correspondingly adjusted when choosing a different volt−ampere output characteristic. The possibility of making such an adjustment is indicated by the yellow arrow on lever V.

NOTE: To explain the principle of construction of a welding generator in as simple terms as possible, reference to other windings such as commutating poles or field−intensifying windings has been deliberately dispensed with here.

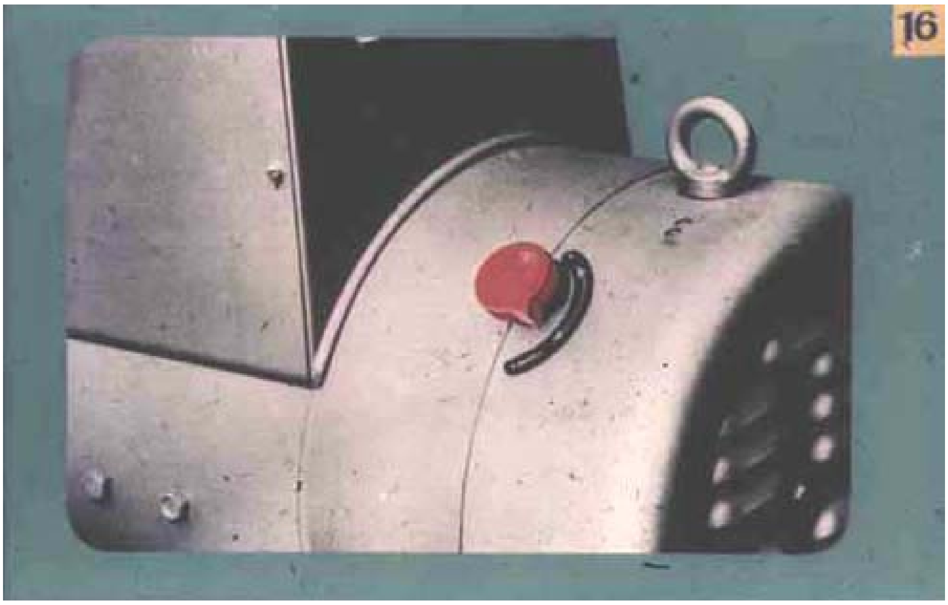
Slide no. 15 Welding converter KW 400 VC, general view



The following means are provided on the control panel of this motor–generator welding power source:

Upper row from left to right:	Slope control (CO_2 welding voltage) Weld current and voltage meters Star–delta switch Polarity reversing switch
Lower row:	Remote control socket Welding power lead sockets Auto/manual changeover switch Remote operation socket (for switching the weld unit on and off).

Slide no. 16 Welding converter KW 400 VC, slope control



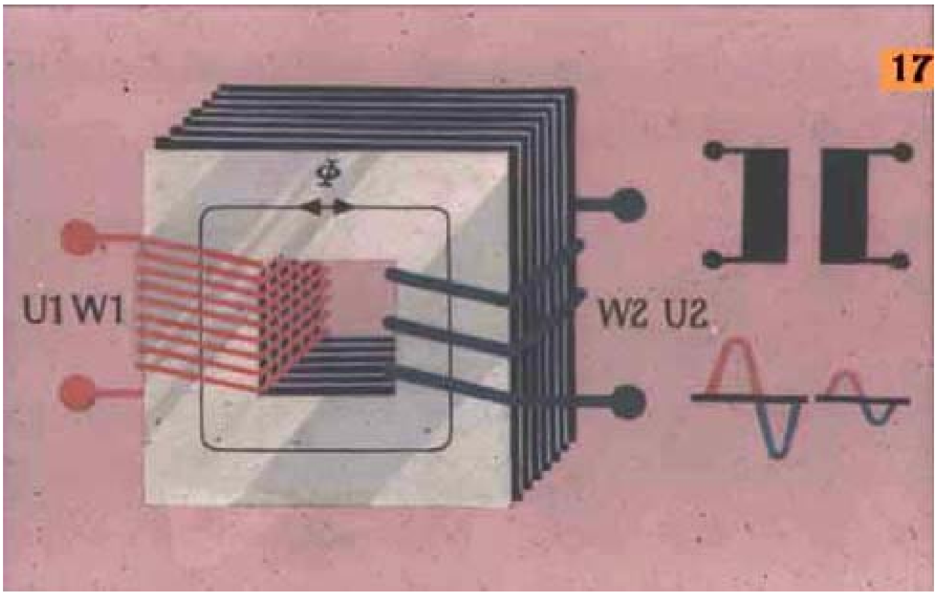
This motor–generator type welder, which has different volt–ampere output characteristics, can be used for open–arc, CO_2–shielded, and other welding processes.

This slide shows the slope control knob, it being possible to choose between drooping and flat characteristics.

Use a flat characteristic for welding in CO_2 shielding gas.

Power source characteristics will be dealt with in detail later.

Slide no. 17 Welding transformer, principle of construction



Welding type transformers are, in principle, comprised of a laminated iron core with separate primary and secondary windings.

W_1 – Primary winding with primary voltage U_1
W_2 – Secondary winding with secondary voltage U_2

In a transformer welding power source, the applied line voltage, U_1, is transformed to the secondary voltage, U_2, at the particular transformer ratio.

$$\frac{W_1}{W_2} = \frac{U_1}{U_2} = \frac{I_2}{I_1}$$

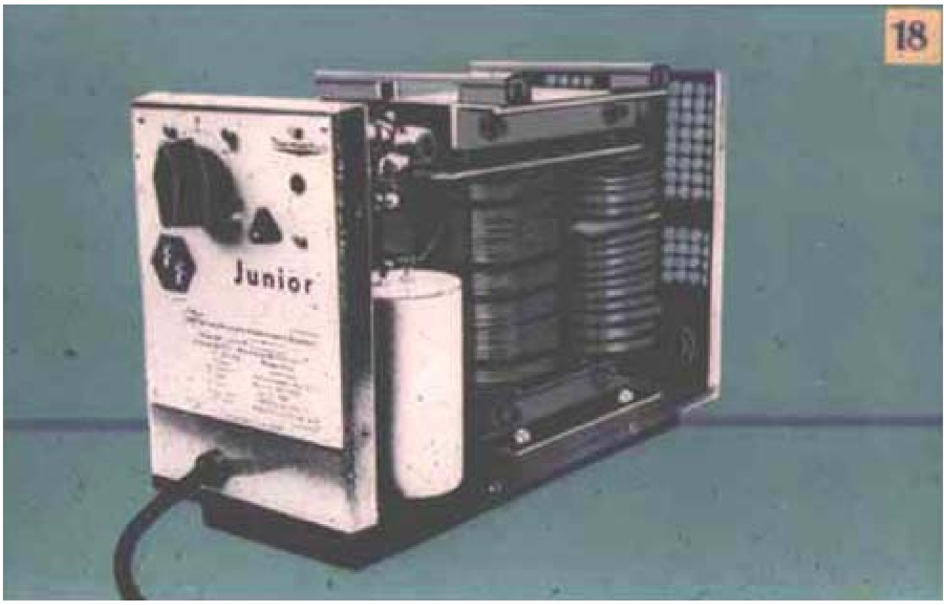
Perspective and engineering drawings are shown.

Voltage levels on the transformer primaries and secondaries are obtained from the transformer ratio.

A representation of individual principles has been deliberately dispensed with here.

Important principles of adjustment can be described, namely, step control, movable core, and preliminary magnetization.

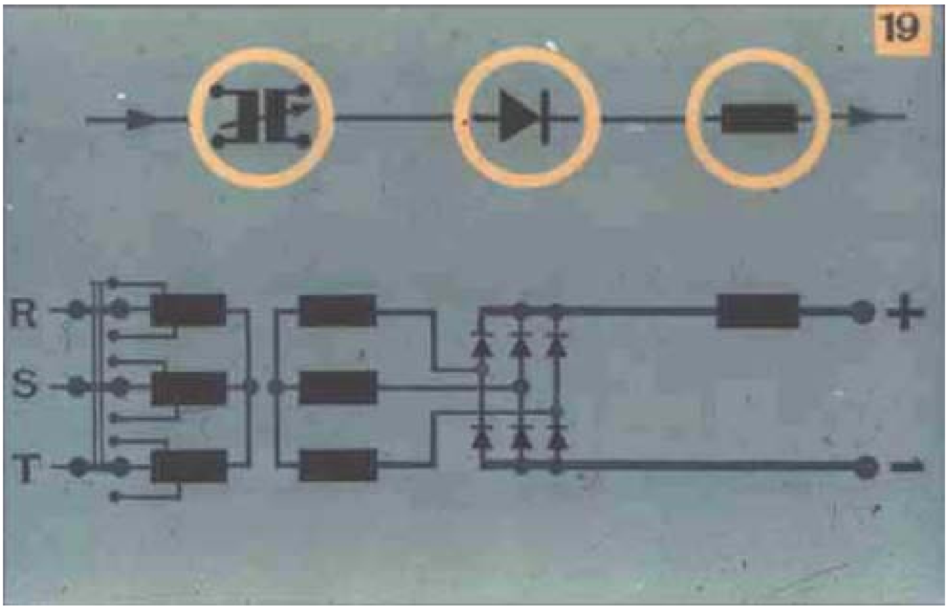
Slide no. 18 Welding transformer “Junior”, interior view



This slide is an interior view of the “Junior” welding type transformer, showing the primary and secondary windings of the transformer welding power source and the simplicity of mechanical construction thereof.

Located in the front part is a capacitor (phase shifter) of which the purpose is to improve the power factor. There is provided a panel step switch for weld current setting.

Slide no. 19 Welding rectifier, principle of construction

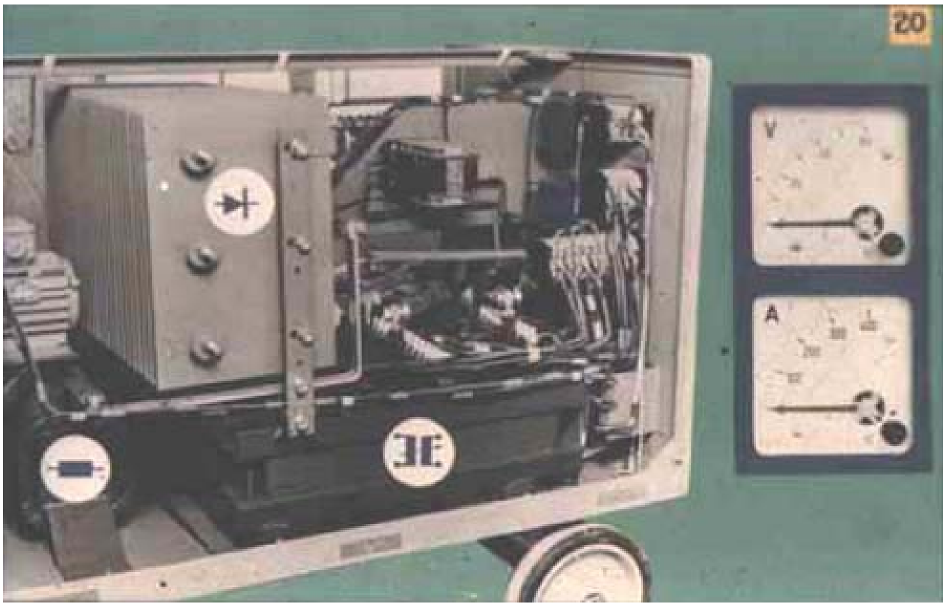


The most important components of a rectifier–type welding power supply are the transformer, the rectifying element, and the reactor. These can be seen in the upper part of the slide.

The transformer, which is usually of the three–phase type, is coupled with suitable control means. Preferably, selenium rectifiers or silicon diodes are used as rectifying elements.

The reactor is used to adjust the welder power unit to the particular conditions for gas metal–arc CO_2 welding. The widely used principle of stepped control of rectifier units for CO_2–shielded arc welding is shown in the lower part of the slide.

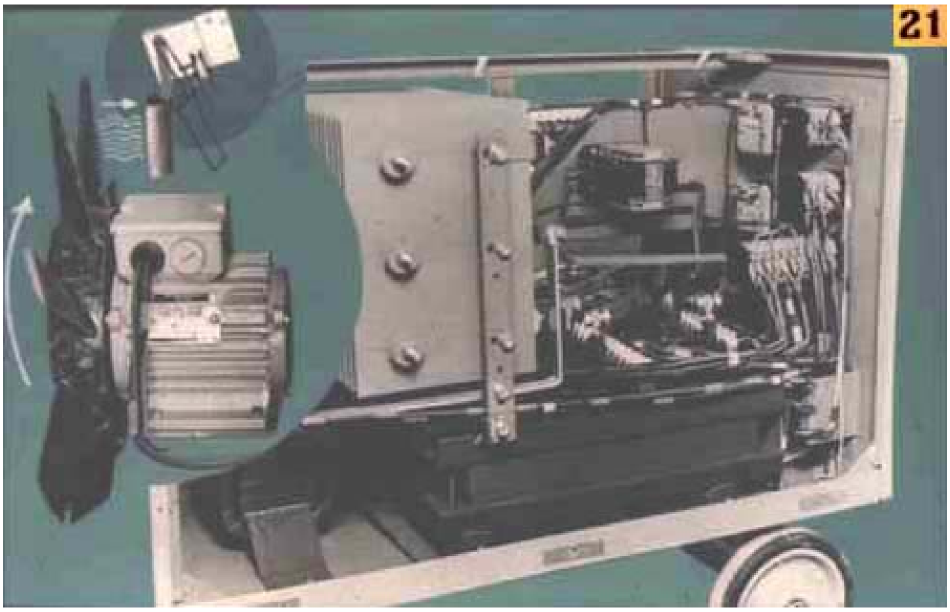
Slide no. 20 Welding rectifier RGS 315, interior view



The principal components of this welding rectifier power source (namely, the transformer, rectifier, and reactor) are marked by symbols.

All of the meters provided in the rectifier welder are marked with different colors. In addition, they are separately shown in the right part of the slide. Located on the right of the meters are switches that can be used to control the welder rectifier. Provided on the left of the meters is a contactor which can be used to cut the weld power supply in and out.

Slide no. 21 Welding rectifier RGS 315, interior view, with fan



This d−c rectifier welding power source is provided with a fan of which the purpose is to cool the various component parts, and more particularly the rectifier unit.

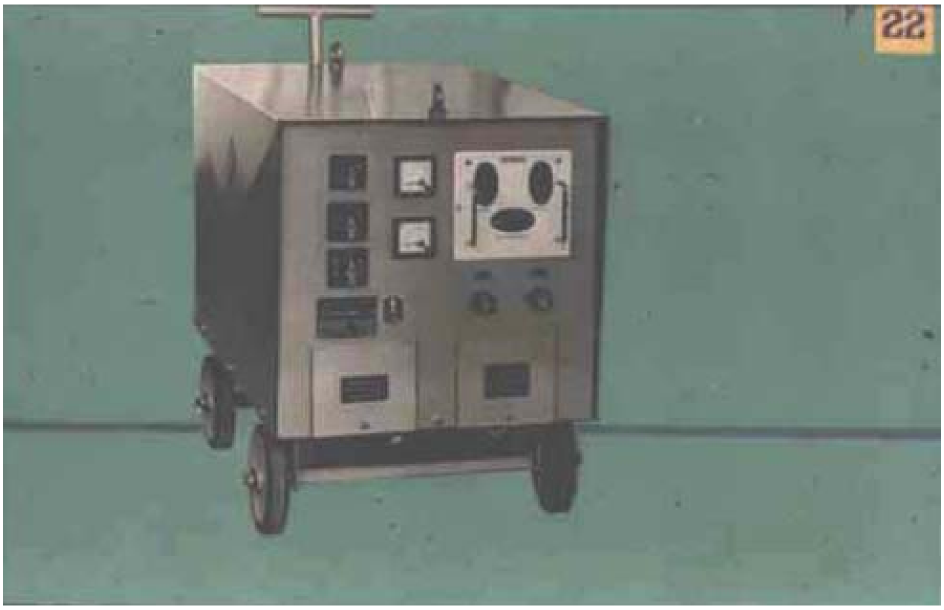
The rectifier−type welder will be ready for operation only when an adequate amount of cooling air is provided. An air 'flap' (which is shown in the upper left part of the slide) causes the welder rectifier to be cut in and out through a relay.

NOTES: 1. Cooling air must flow to the rectifier unit.

2. Cooling air must be allowed to freely enter the rectifier−type welding machine.

3. In the case of an improper sense of rotation of the cooling fan, it is necessary that the power supply be changed by an expert serviceman.

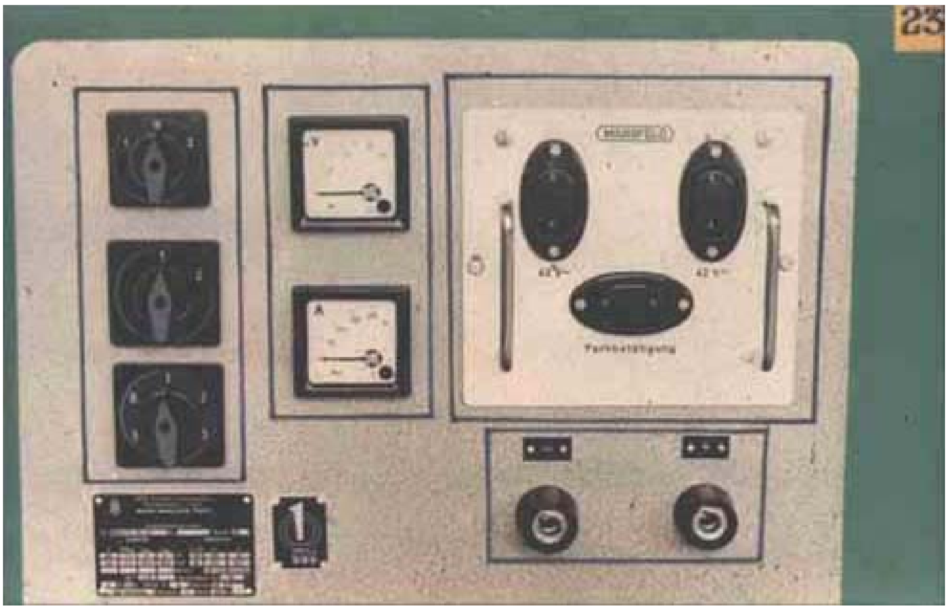
Slide no. 22 Welding rectifier RGS 315, general view



All of the operational controls of the rectifier welding machine are of the panel−mounted type, and these include a terminal board for the supply of power and a terminal board for switching from one welding range to another.

For further details see slide no. 23.

Slide no. 23 Welding rectifier RGS 315, operational controls



In the left part of this slide you can see the switches with which this rectifier welding power supply is provided.

Top switch:

This is used to cut the welder power source in and out and switch from manual to automatic operation, the switch positions being as follows:
0 – OFF
1 – ON (manual operation)
2 – Power source is operated by the welder (automatic operation)

Center switch: Coarse weld voltage setting

Bottom switch: Fine weld voltage setting

In the right part of this slide you can see a power pack with connector receptacles, namely, 42 V — for a weld unit and 42 V ~ for a heat cartridge. Use switch position 2 for remote cut–in and cut–out of the weld power source.

Located underneath the power pack are receptacle outlets for the welding power leads.

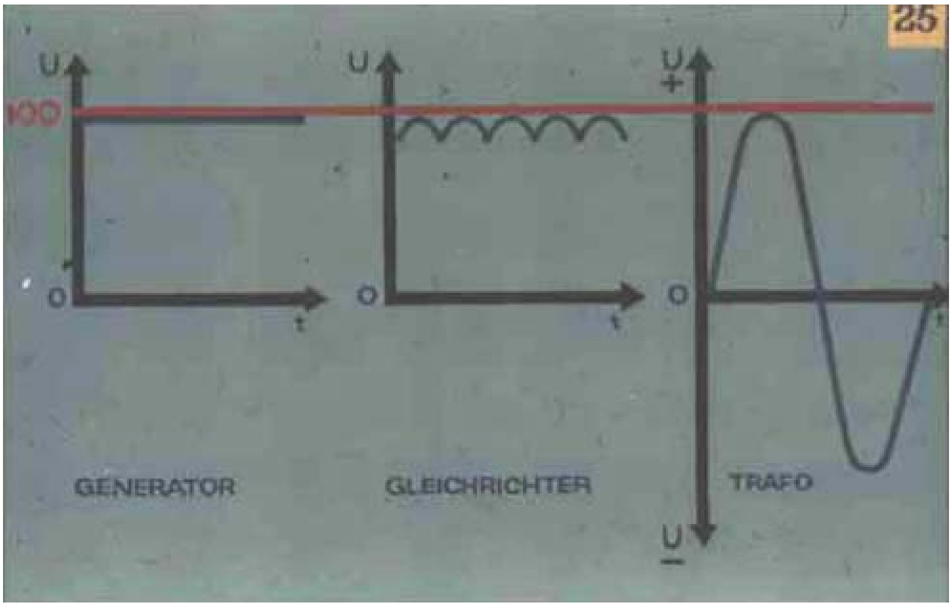
Slide no. 24 Welding rectifier KGS 160

This rectifier–type d–c welding power supply is designed for weld amperages up to 160 A and allows wire diameters ranging from 0,6 mm to 1.0 mm to be used. Weld voltage setting is in two coarse–adjustment steps and six fine–adjustment steps, the latter being selected using the switch provided on the upper right side.

Also provided are the following operational controls:

On–off switch for switching the power supply on and off, switch “1, 2” for switching from one range to another, remote–control receptacle outlet, and outlets for the connection of welding power leads.

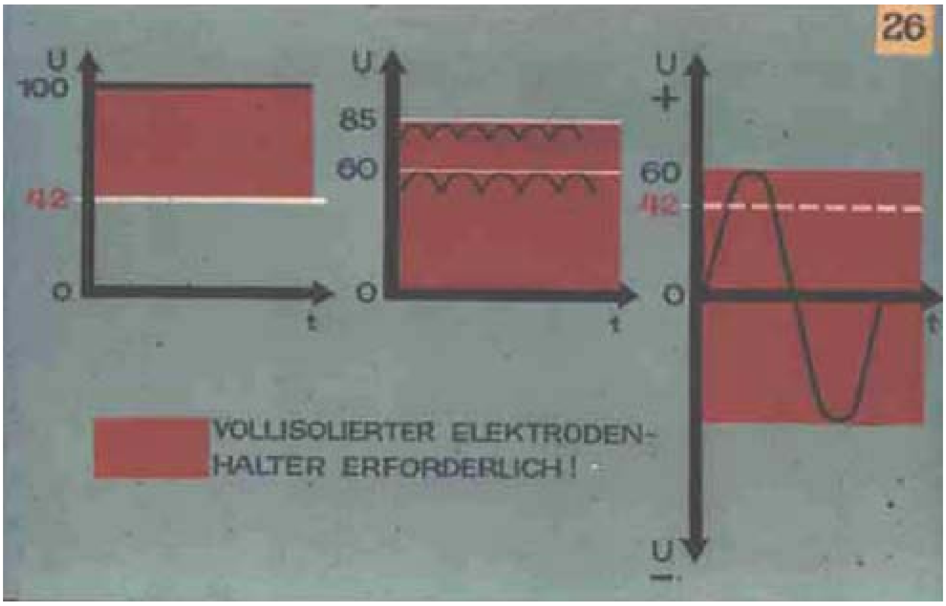
Slide no. 25 Open–circuit voltages



No−load voltages are limited to a maximum of 100 V for power sources for welding operations. It can be seen from this slide that these maximum values relate to the peak voltage. Be sure to point out that the voltmeters provided in welding power sources indicate r.m.s. (root mea square) values rather than peak voltages.

In the case of d−c ripple voltages, the r.m.s. value is smaller than the peak value.

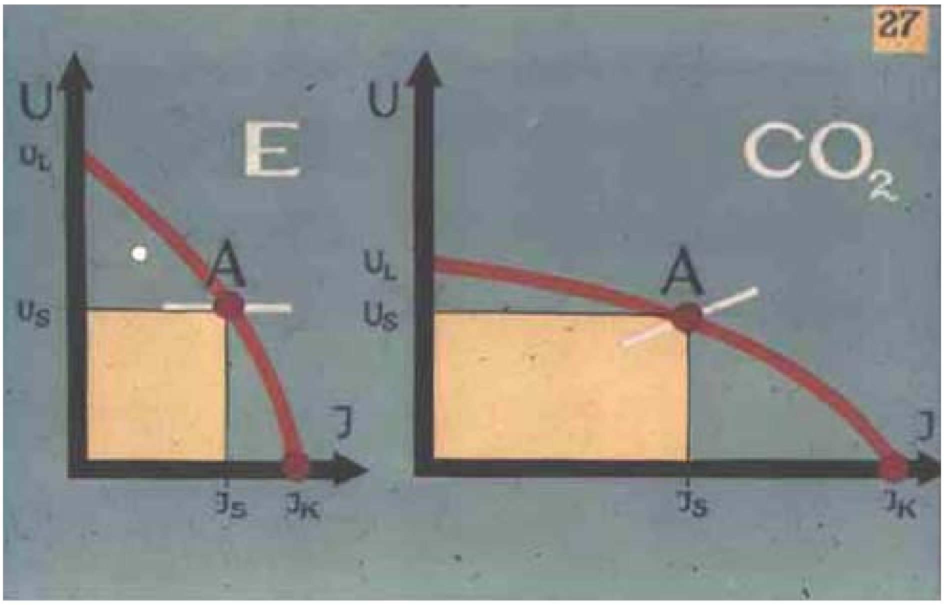
Slide no. 26 Open−circuit voltages in special spaces



For welding in confined and moist spaces, it is necessary to set limits on the weld power source peak voltages.

General arc welding requirements apply equally well to CO_2−shielded welding. Be sure to call the students' attention to the importance of low voltages up to 42 V (applicable without any qualification to motor−generator welding power sources only) and to the hazards of welding in confined and moist spaces.

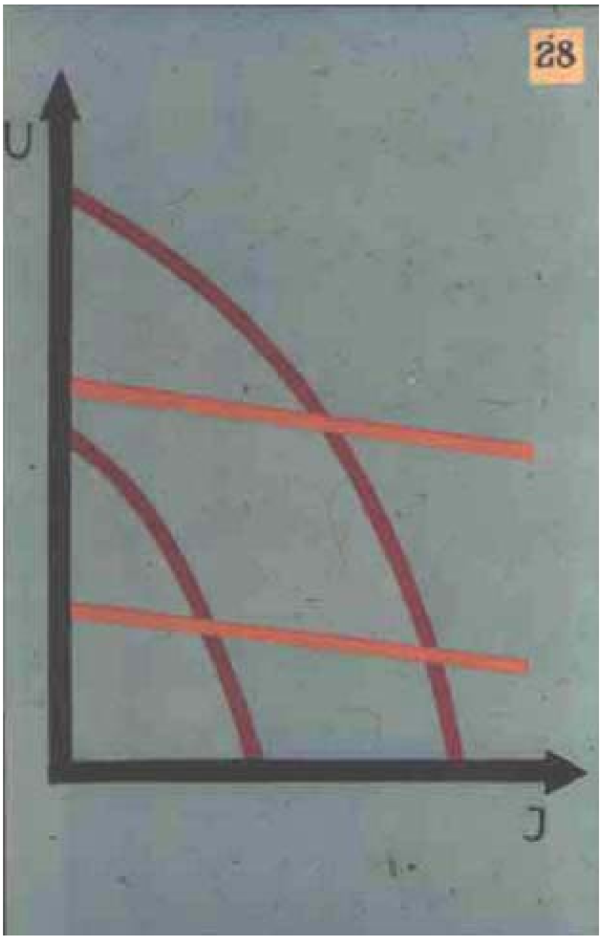
Slide no. 27 Volt−ampere characteristics



This slide shows the two basic forms of volt−amp output characteristic required for welding. Shown in the left and right parts of the slide, are respectively the drooping volt−ampere characteristic required for electric arc welding and the nearly flat characteristic used for gas metal−arc CO_2 welding. Volt−ampere characteristics usually run from point U_L (open−circuit voltage) to point I_K (short−circuit current).

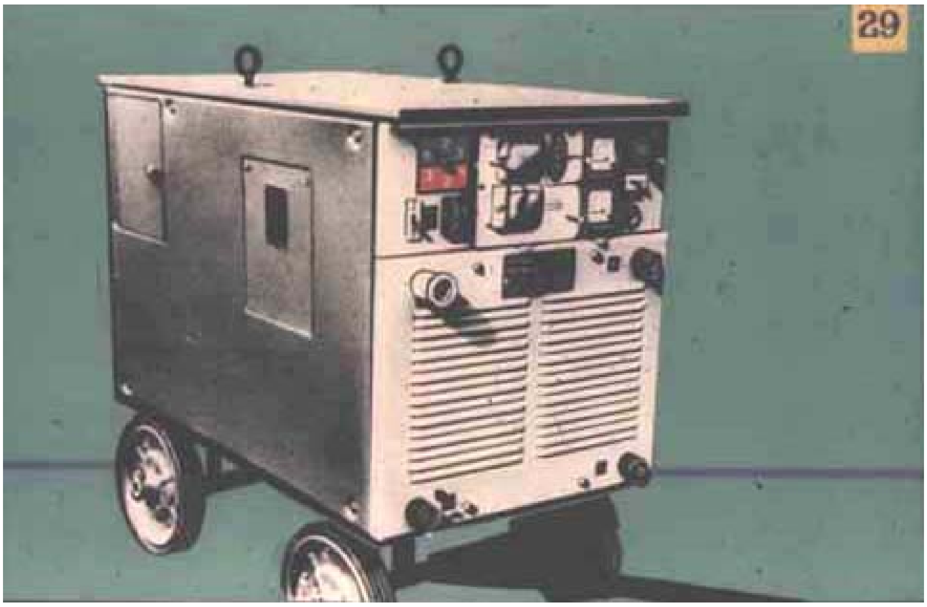
During welding operations, there appears a mean operating point with parameters U_s (welding voltage) and I_S (welding current).

Slide no. 28 Volt−ampere characteristics of a variable−characteristic power supply



Variable−characteristic power sources allow different volt−amp curves to be set. Shown in this slide are the volt−ampere curve ranges of a variable−characteristic type of welding power source.

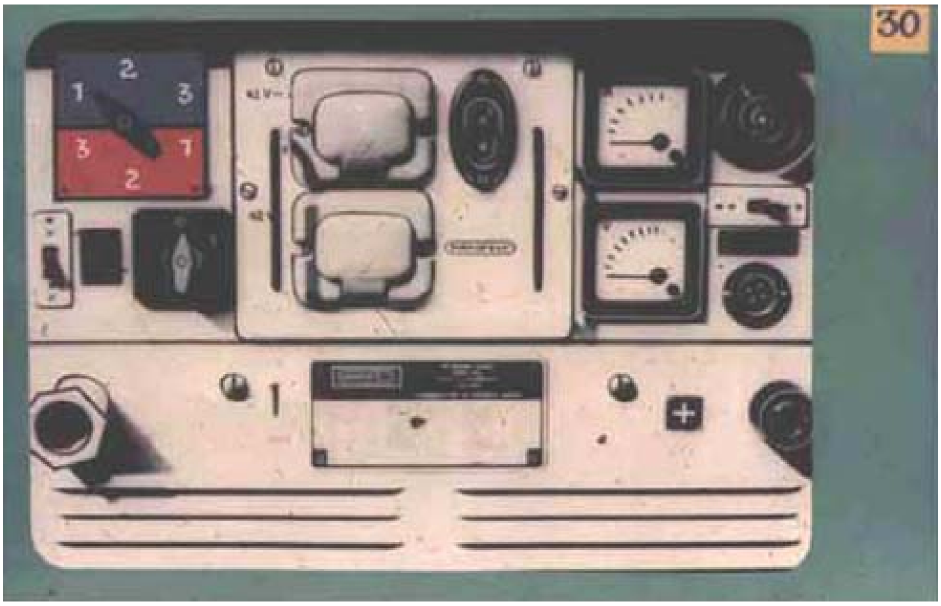
Slide no. 29 Welding rectifier KG 400 VC, general view



This slide shows the welder rectifier KG 400 VC and its control panel. Means provided at the upper left corner of the side panel is used to set power source characteristics, thus enabling this rectifier−type welding power supply to be employed for different welding processes (see also slide no. 31).

For details of operational controls see slide no. 30.

Slide no. 30 Welding rectifier KG 400 VC, front view



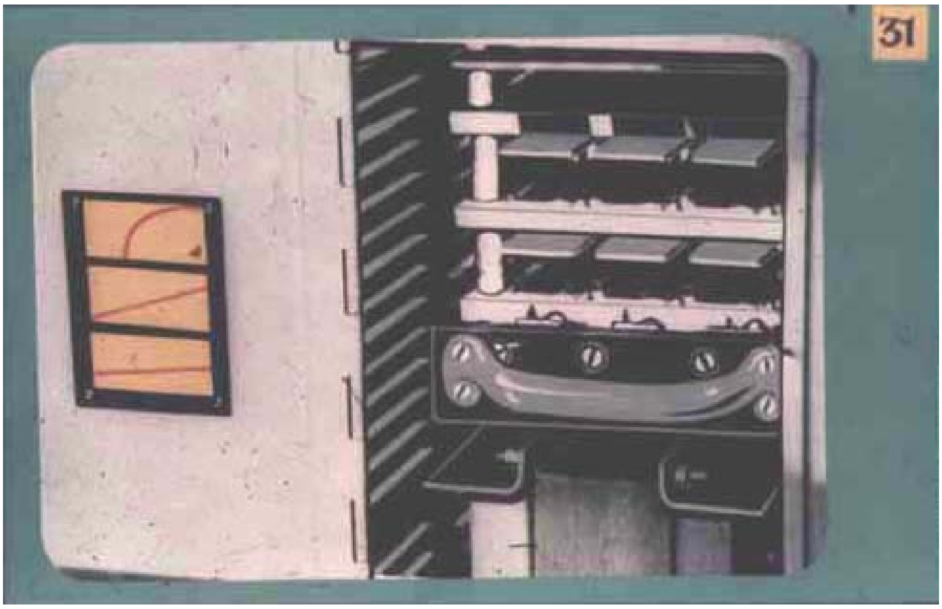
This close−up presents an overview of the most essential operational controls.

Located on the upper left side are the step switch for coarse volt−amp characteristic slope control, the auto/ manual changeover switch, and the mains on−off switch.

Provided in the middle is a power plug−in unit for connection of a gas metal−arc CO_2 welding setup.

Located on the right of the welding current and voltage meters are a potentiometer for fine volt–amp characteristic slope control and an outlet for the connection of remote control means.

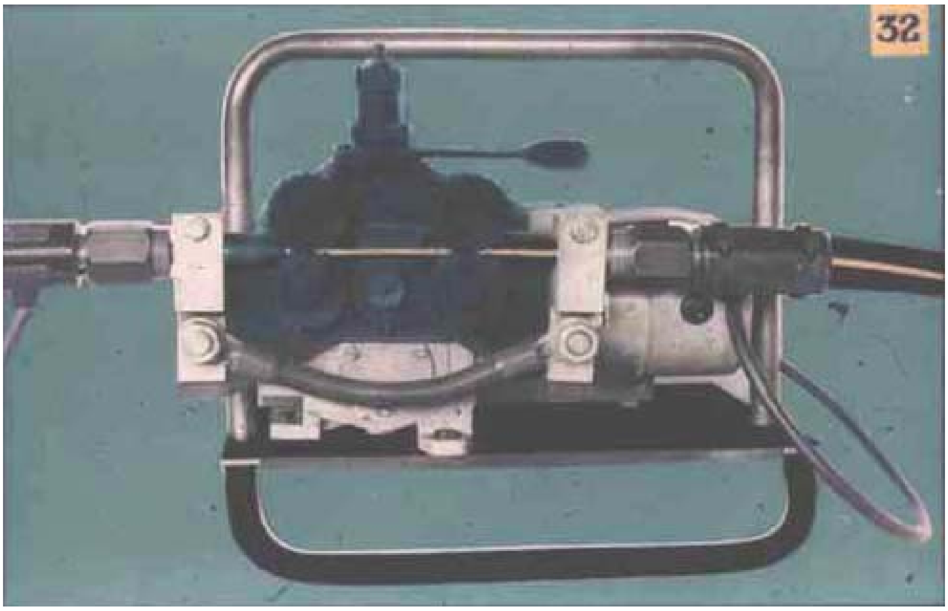
Slide no. 31 Welding rectifier KG 400 VC, slope control



This slide shows how to control the volt–ampere characteristic slope for different processes of welding. A knife blade is switchable in three planes lying upon each other.

Shown on the inside of the cover plate is the power source setting to be chosen. For gas metal–arc CO_2 welding, the knife blade is used in the central or lower plane respectively.

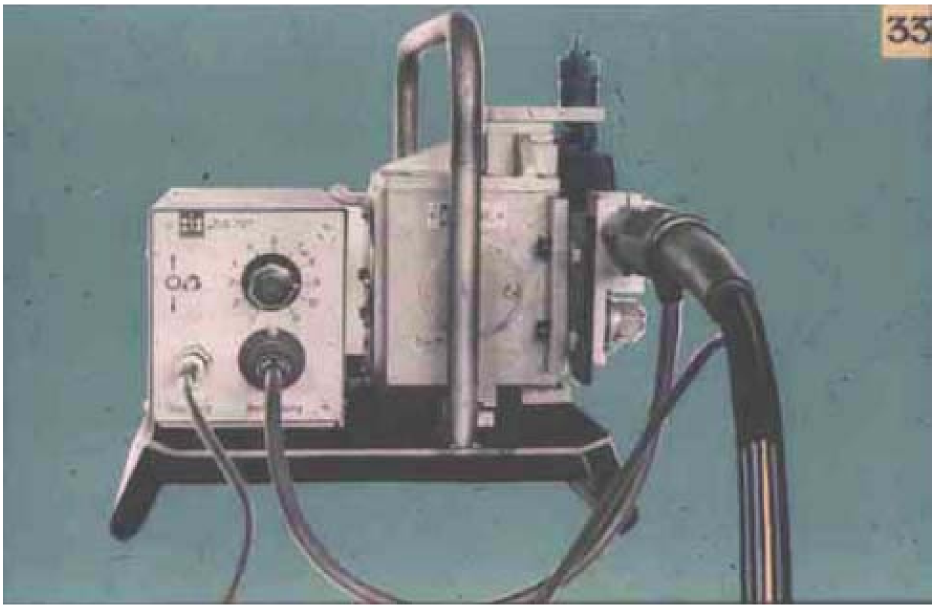
Slide no. 32 CO arc welding unit ZIS 707, side view



This slide shows the wire feed unit with filler metal drive rolls. Adjustment of the contact force of the wire feed drive rolls (which is necessary for constant–speed wire feed) is by means of an adjustable pin provided in the upper part. The wire, drive rolls can be set using the lever that can be seen in the upper part of the slide.

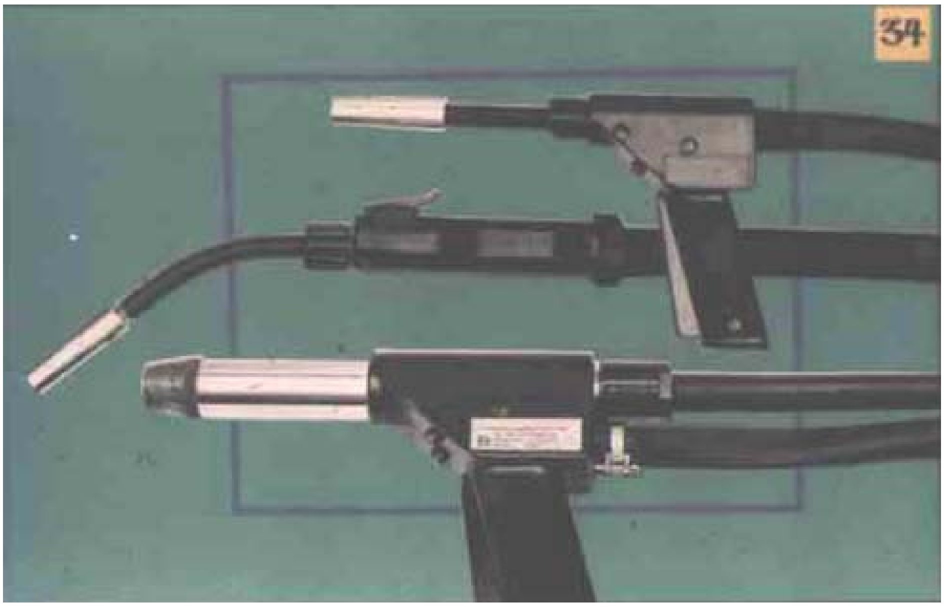
Wire is fed from the right, the welding torch connection being on the left. The weld wire is shown here marked in yellow.

Slide no. 33 CO arc welding unit ZIS 707, front view



Provided on the left side is the control unit including a potentiometer for wire feed speed control as well as connections for shield gas and for the weld torch control line. The sectional view of the welding torch hose assembly gives an idea of its various functions. A detailed description has been deliberately dispensed with here. Give brief information on weld wire, introduction of the weld current, supply of shield gas, and control line.

Slide no. 34 CO−shielded arc−welding torch



CO_2 welding torches are available for use with different wire sizes and welding amperages. There are supplied by welding products manufacturers not only uncooled or water−cooled but also pistol−like and gooseneck welding torches.

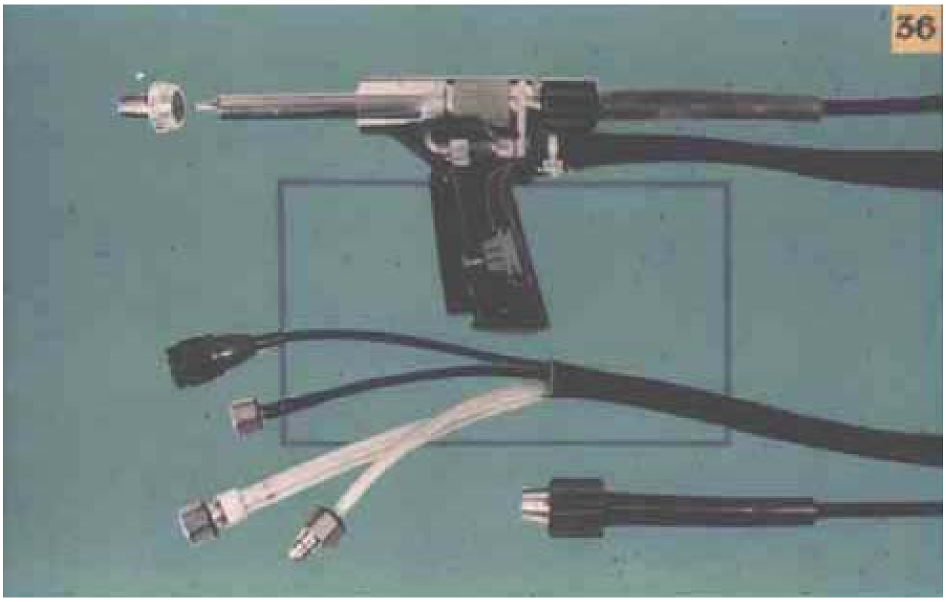
This slide shows the following makes of torch:

PU 300	(300−A uncooled pistol−type torch)
RU 400	(400−A uncooled goosenecked torch)
PU 600 F	(600−A water−cooled pistol grip torch)

Slide no. 35 CO−shielded arc−welding torch RU 300

This slide shows an uncooled type of welding torch and torch accessories.

Slide no. 36 CO−shielded arc−welding torch PU 600 F

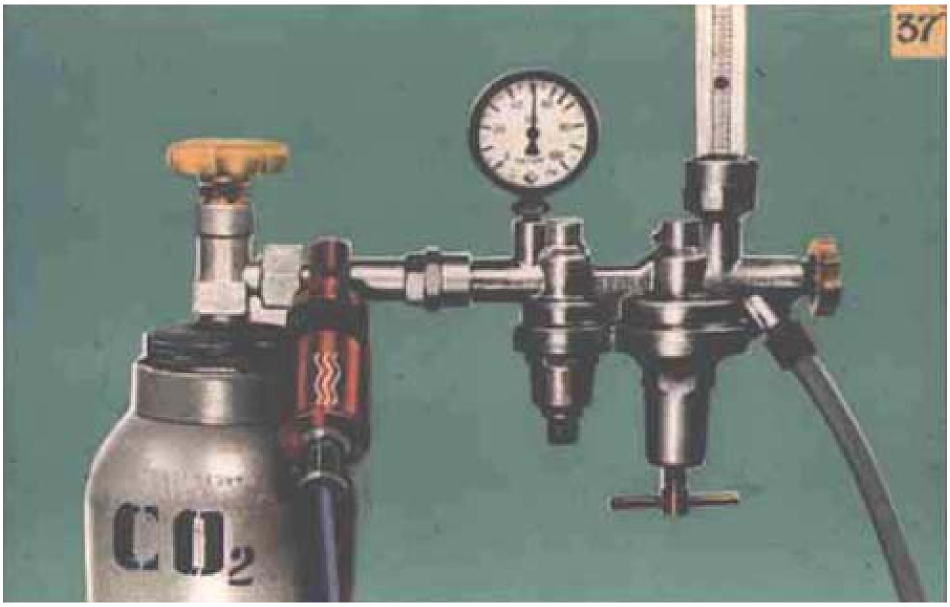


This slide shows the interior of a welding gun.

Housed in the handle of the torch is a switch for controlling the weld unit.

Torch connections can be seen in the lower part of the slide, and these include, in order, the control line, gas supply, water return means with welding power lead, water supply, and wire feed means.

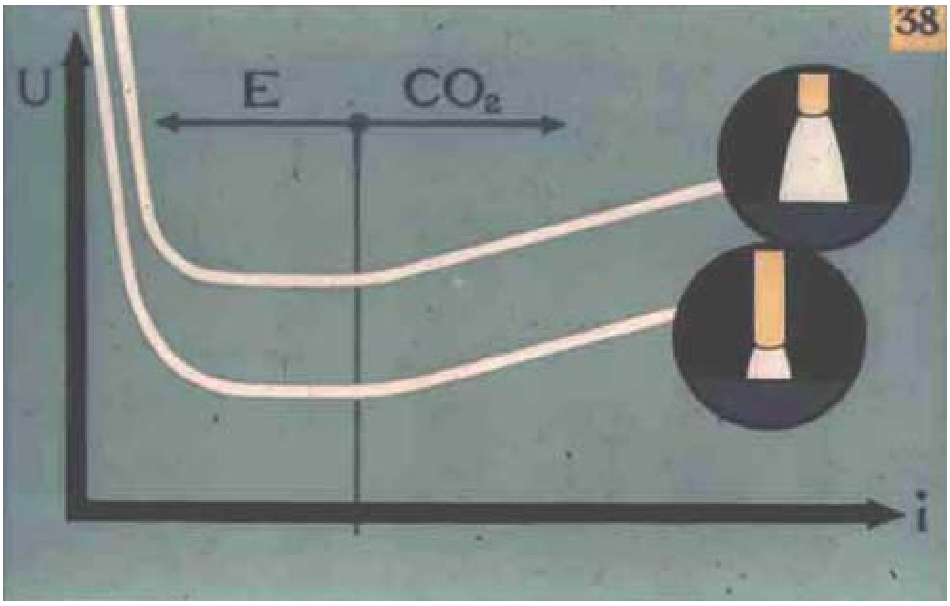
Slide no. 37 Supply of gas



This slide shows the CO_2 gas cylinder and no−freeze CO_2 regulator. Adjusting means provided on the cylinder and regulator are marked in yellow.

NOTE: Give a detailed explanation of how to handle the regulator and connect the latter to the cylinder valve. Be sure to discuss the applicable safety regulations.

Slide no. 38 Arc characteristic curves



This slide shows the behavior of arc characteristic curves. Essentially, the behavior of arc voltage−arc current characteristic curves is determined by a number of influential variables such as shielding medium, type of electrode wire, and ionization.

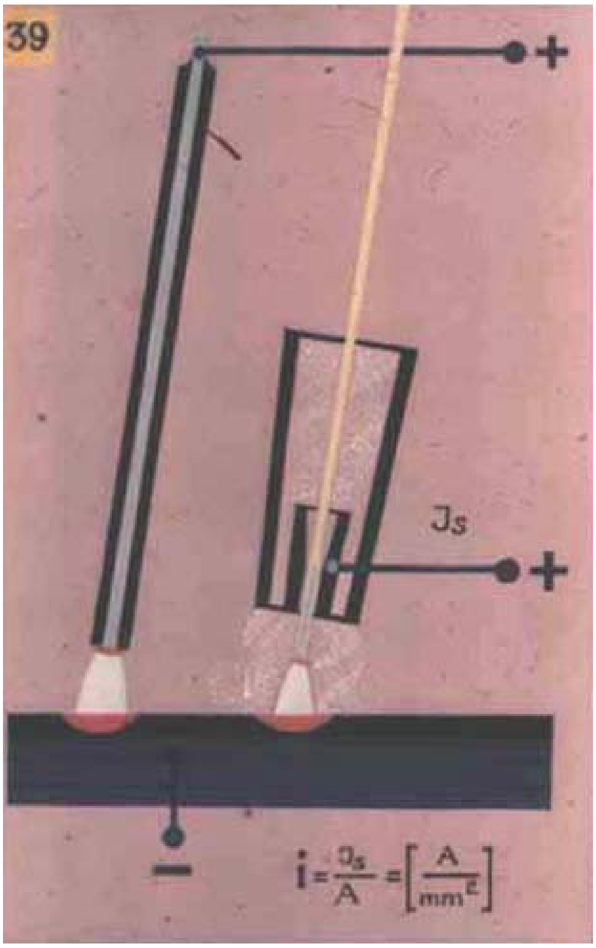
The behavior shown in this slide can be considered as being typical of general welding conditions, with the curve showing a drooping to flat behavior in the range of low welding current densities and a rising behavior in the case of high weld current densities.

The typical ranges shown in this slide are obtained for the individual processes of welding.

It is important to note here that the behavior of the arc characteristic curve varies as the length of the arc changes.

NOTE: The steep slope of arc voltage–arc current characteristic curves, which can be observed in the range of low welding current densities, is of no consequence to the electric arc used for welding purposes.

Slide no. 39 Current density



In this slide, electrodes for electric arc welding and gas metal–arc CO_2 welding are compared.

For electric arc welding, large cross–section electrodes and a long wire extension are used.

For gas metal–arc CO_2 welding, small–section electrodes and a short extension are used.

The current density is obtained from the weld amperage to electrode cross section are:

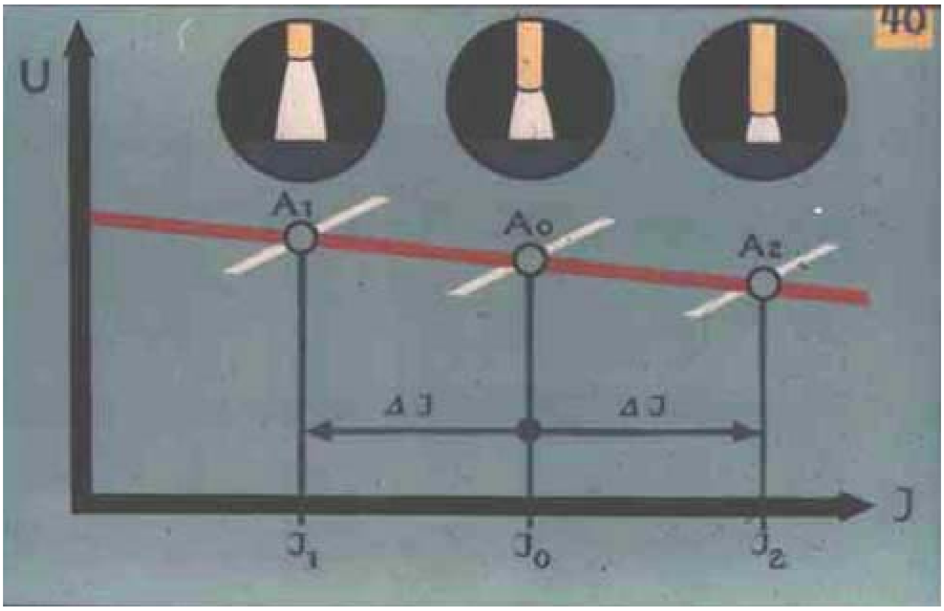
$$i = \frac{I_s}{A}\left[\frac{A}{mm^2}\right]$$

The short electrode extension used in gas metal–arc CO_2 welding allows welding to be carried out at substantially higher current densities. This provides for high efficiency of metal deposition.

By electrode extension is understood the length of electrode that extends beyond the contact tip or the amount of electrode stickout.

NOTE: In electric arc welding, any increase in current density would result in the length of electrode sticking out of the contact tip becoming excessively hot and, thus, useless.

Slide no. 40 Operating points in CO gas−shielded arc welding

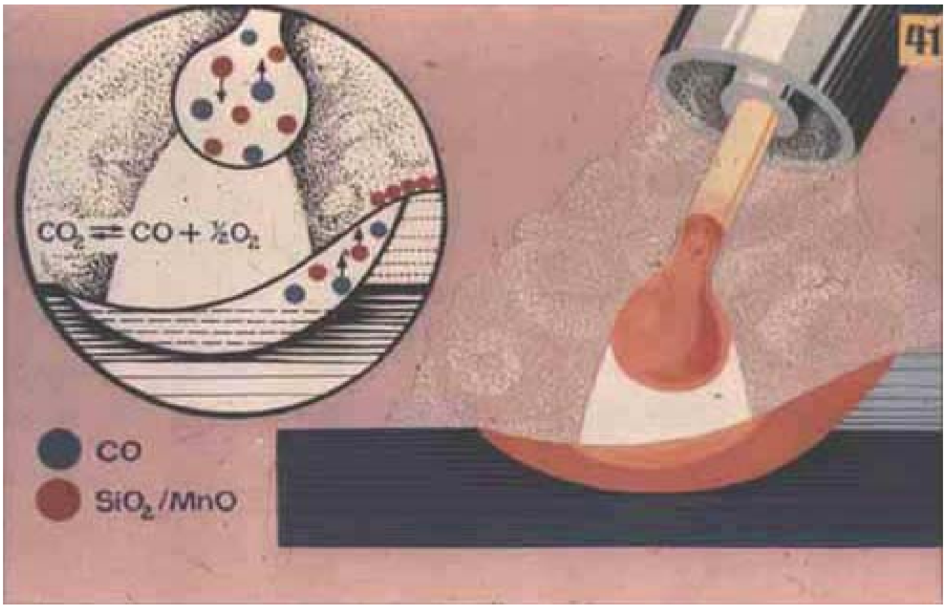


This slide shows the relations between volt−ampere and arc characteristics in CO_2−shielded welding. An average weld current (I_0) is obtained for an average operating point (A_0). A change in average arc length results in a longer length of the arc (A_1, with I_1) or in a shorter length of the arc (A_2 with I_2).

A change in amperage by ?I results in different rates of burn−off, with a lower amperage, I_1, causing a lower electrode current density and, consequently, a lower burn−off rate and a high amperage, I_2, causing a high electrode current density and, hence, a high metal deposition speed.

Since filler metal is fed at a constant rate in gas metal−arc CO_2 welding, arc length regulation (?I regulation) is assured by the processes described above. In addition, a constant rate of wire feed insures that the wire feed and weld deposit speeds are in equilibrium during the operation of welding.

Slide no. 41 Splitting−up of CO shielding gas



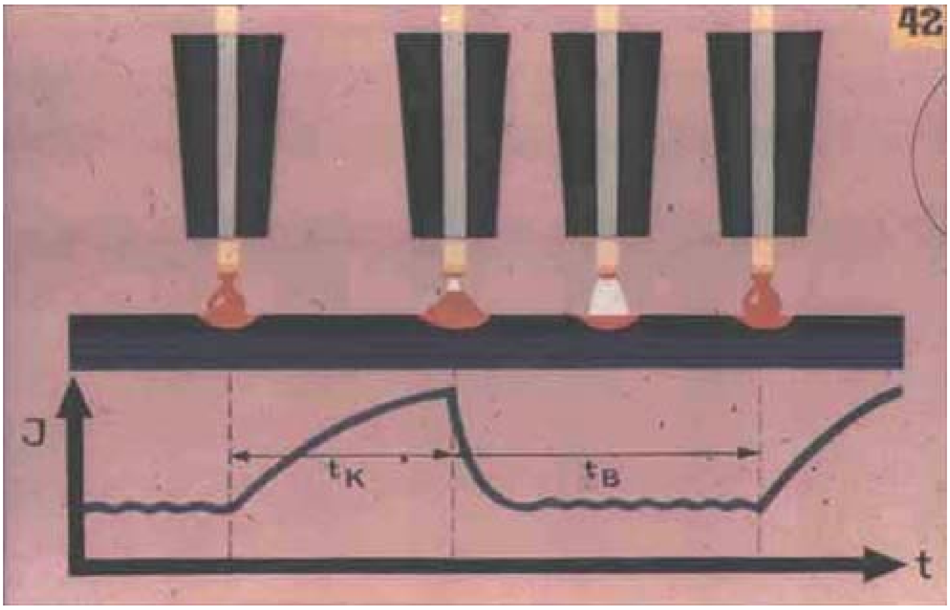
This slide will call the student's attention to an important process proceeding during the operation of gas metal−arc CO_2 welding.

CO_2 shielding gas is not usually capable of completely fulfilling the function of protecting the pool of molten weld metal from adverse influences.

CO_2 gas is split up into carbon monoxide and oxygen, with the latter reacting with carbon, manganese, and silicon in the puddle of molten metal. In addition to the formation of CO, there will be observed SiO_2 and MnO losses during arc transfer. To insure that the molten metal will have similar values to those of the base−plate material, it is necessary that an adequate amount of deoxidizing elements be introduced via the welding filler metal.

NOTE: Therefore, special fillers have to be used for gas metal−arc CO_2 welding. Unsuitable weld filler materials will lead to formation of weld porosity. Also, rust and moisture will have adverse effects upon weld metal.

Slide no. 42 Transfer of metal in CO gas−shielded welding



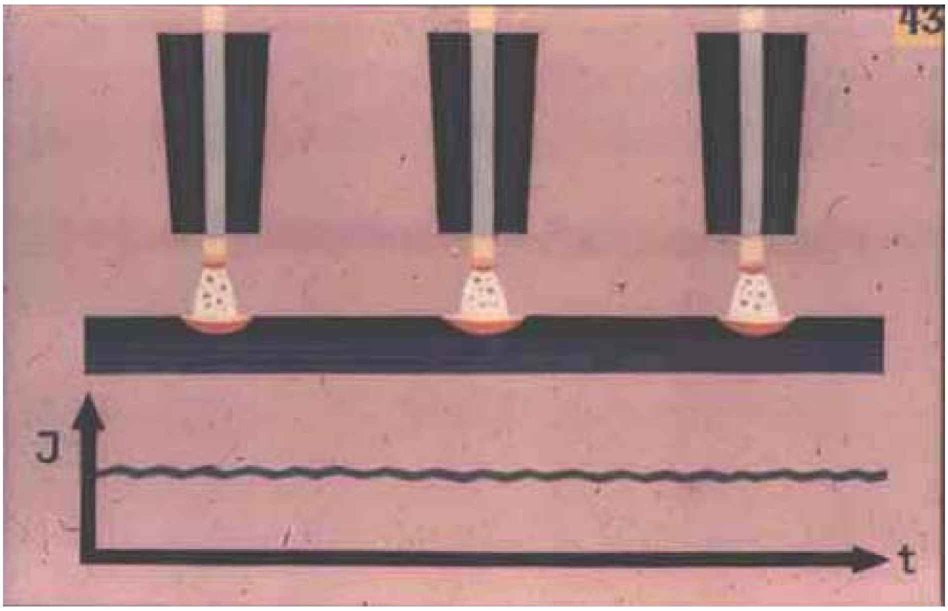
In gas metal−arc CO_2 welding, metal transfer is, in general, in the form of dip, i.e., by the short−circuiting mode.

This slide shows the alternation of arcing and shorting phases. The time of heating during arc operation is followed by short−circuiting, with a high short−circuit current intensity resulting in a drop of filler metal being detached from the electrode. This process is repeated constantly. The number of dips per second is dependent upon such welding parameters as wire size, weld amperage, and weld voltage.

In the case of a wire diameter, welding amperage, and welding voltage less than or equal to 1.2 mm, 200 A, and 20 V, respectively, the arc is generally referred to as a short−circuit transfer arc; here, the number of dips per second will be highest. For a wire size of 0.8 mm, for example, the number of dips recorded was as large as 200 dips/second.

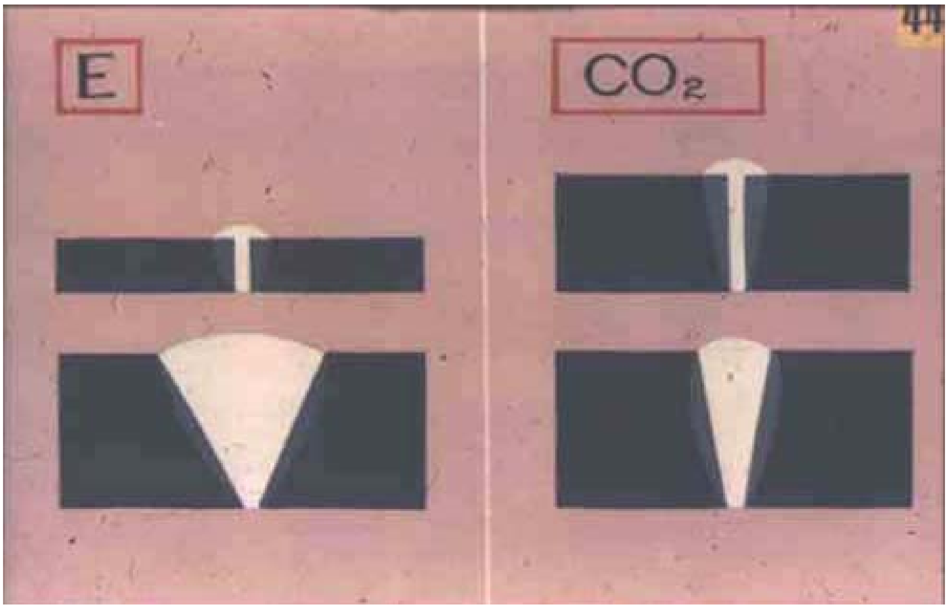
The number of dips becomes smaller as the values of the welding parameters increase, with non−short−circuiting metal transfer being observed for high welding amperages.

Slide no. 43 Spray−transfer−type arc



When using the high−current CO_2 technique, transfer by the spray mode can be observed. Carbon−dioxide−shielded spray transfer arc welding is remarkable especially for high metal deposition efficiency and deep penetration, and it is finding very wide application as a machine welding process.

Slide no. 44 Weld preparation



By comparing joint preparations for electric arc welding and gas metal−arc CO_2 welding it is possible to bring out some important advantages afforded by CO_2 gas−shielded arc welding.

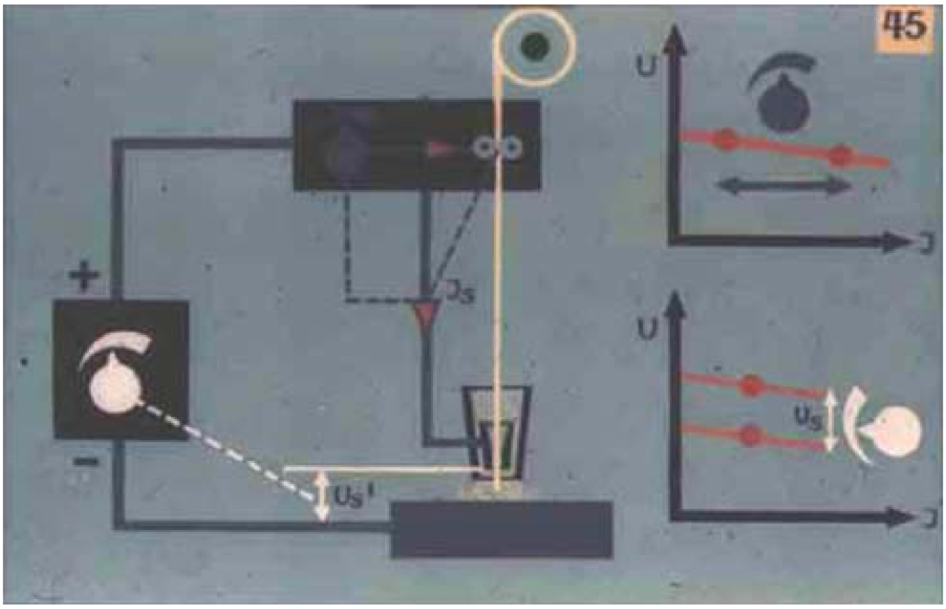
CO_2−shielded welding:	Square butt type weld for larger work thickness, single−V butt weld with a smaller included angle.

This allows the following advantages to be claimed for CO_2 welding:

Shorter time of preparation of square−groove welds and lower consumption of welding filler metal.

This slide also allows the instructor to point out the importance of such parameters as plate or sheet thickness, included angle, and joint−root opening.

Slide no. 45 Selection of parameters



This slide shows where the most important CO_2 welding parameters (U_S and I_S) have to be set.

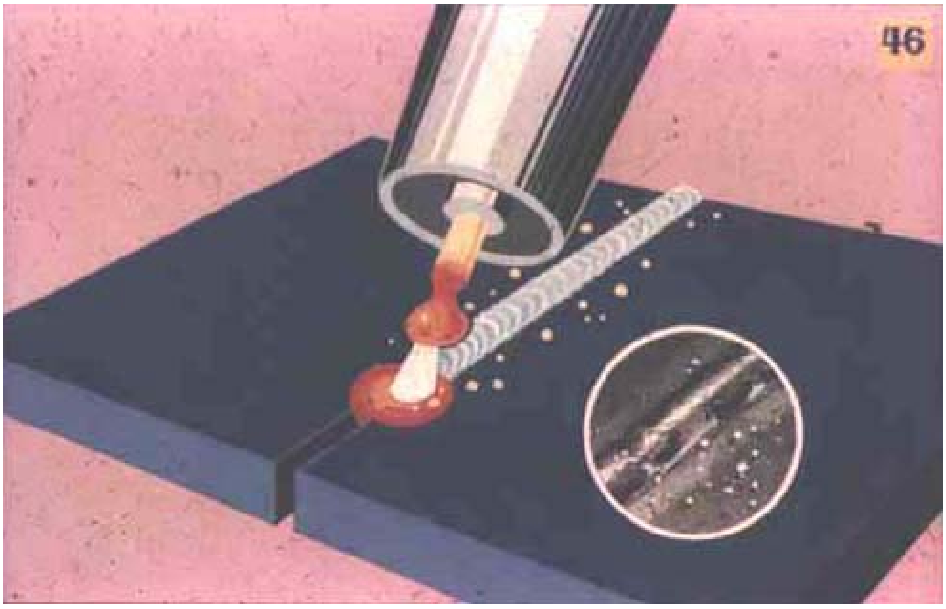
Welding current, I_S:	This is set on the weld unit (potentiometer (blue)). (With electric arc welding, weld current is set on the weld power source.) Amperage increases as wire feed rate increases.
Welding voltage, U_S:	This is set on the welder power unit (potentiometer (white)). Adjustment on the power unit allows a different volt–ampere characteristic to be chosen. This involves a change in voltage.

It is important to note here that efficient gas metal–arc CO_2 welding requires that the welding current, I_S, and the welding voltage, U_S, be properly tuned to each other.

Approximate values:	U_S ? 14 + 0.05 • I_S for amperages up to 600 A.

For mixed shielding gases (e.g., CO_2 + argon), smaller values of U_S have to be chosen.

Slide no. 46 Extremely high weld voltage



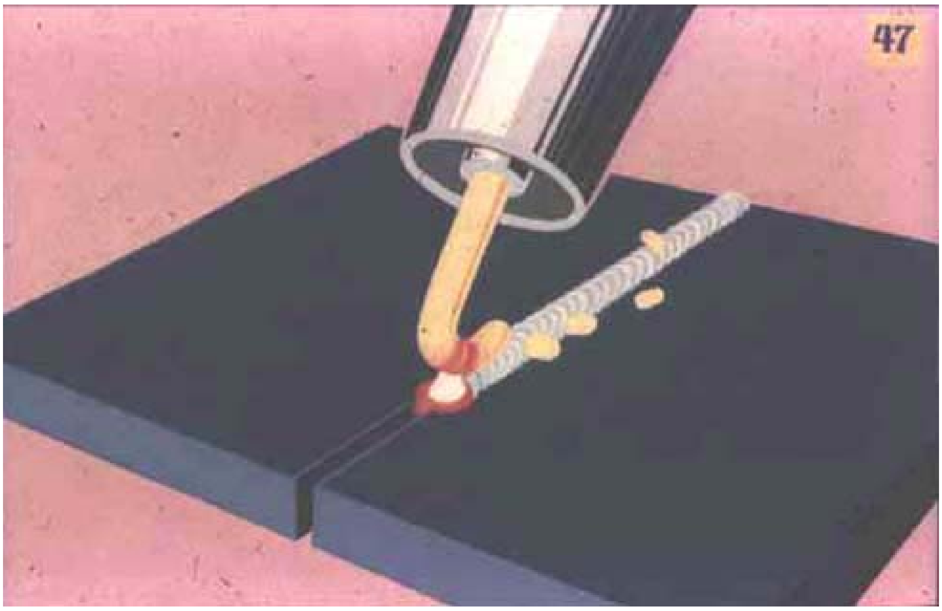
This slide shows the plate surface and the drop of metal when welding at too high a weld voltage.

A long weld arc, formation of large drops, coarse weld ripples, and excessive weld metal spatter are the result of using too high a weld voltage relatively to the weld amperage.

There are two possible ways of remedying this situation:

1. Reduce the weld voltage to a Suitable value, setting being done on the welder power unit.
2. Increase the weld amperage to a suitable value, setting being done on the weld unit.

Slide no. 47 Extremely low weld voltage

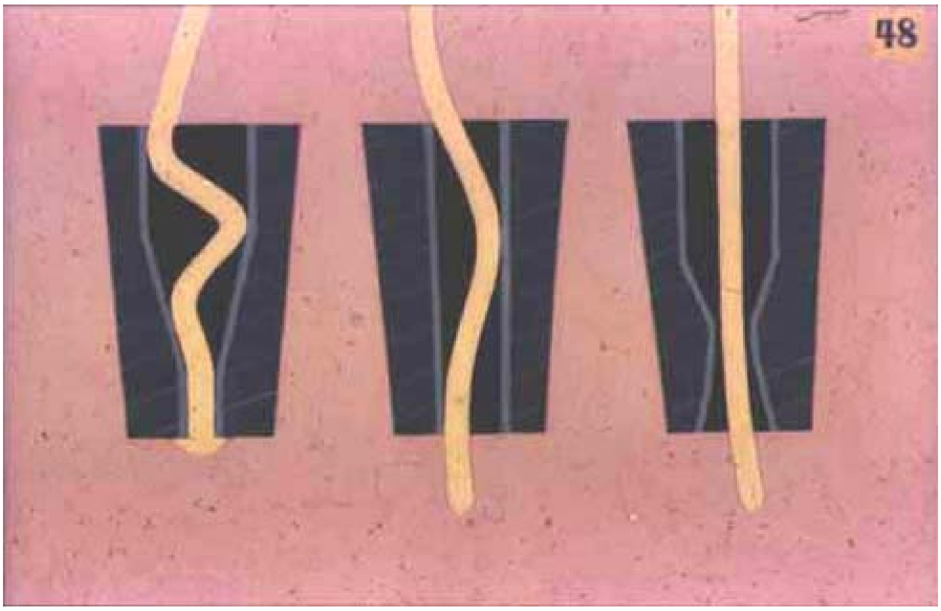


This slide shows that the filler wire will contact the work and buckle when the weld voltage is too low relatively to the weld amperage. This results in irregular welding, with whole pieces of weld wire being melted off.

There are two possible ways of remedying this situation:

1. Increase weld voltage, setting being done on the welder power unit.
2. Decrease weld amperage, setting being done on the weld unit.

Slide no. 48 Contact tips



Contact tips have a decisive influence upon the weld operation. Extremely small tip bores result in the wire surface being worn off by friction, with the filler wire finally sticking fast in the tip, a phenomenon that is known as wire jam−up. In any case, heavy friction between the tip and filler metal wire will result in irregular wire feed which, in turn, causes the operation of welding to become quite irregular.

Shown in the left part are the consequences of such phenomena: Filler wire buckling behind the tip and, occasionally, sticking of the wire to the tip orifice.

NOTE: Such defects can also be observed in these cases where the filler metal wire is heavily deformed and shows formation of burrs because of improperly chosen drive rolls.

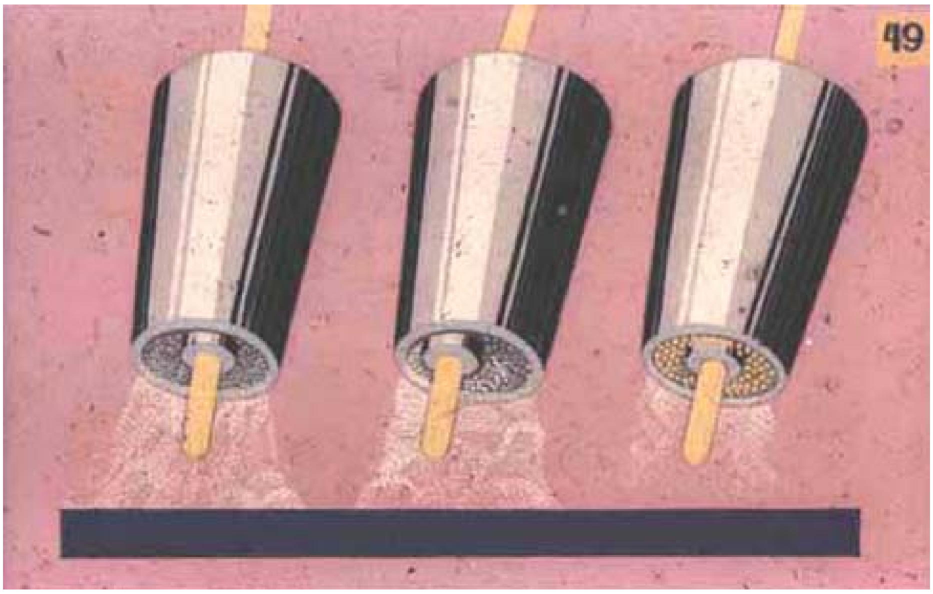
With CO_2−shielded welding, a uniform deposition process requires that the welding current be transmitted in the vicinity of the arc. Major changes of the point of contact in the tip will result in irregular welding.

Extremely long contact tips and too large tip orifices lead to different points of contact (center of slide).

Transmission of welding current can be at the beginning or end of the tip. This length, ?l, results in a change of resistance in the wire and in the above−mentioned irregularity of welding.

Such troubles will also usually occur when the bore is heavily worn by friction as a result of prolonged use of the tip. This is shown in the left part of the slide.

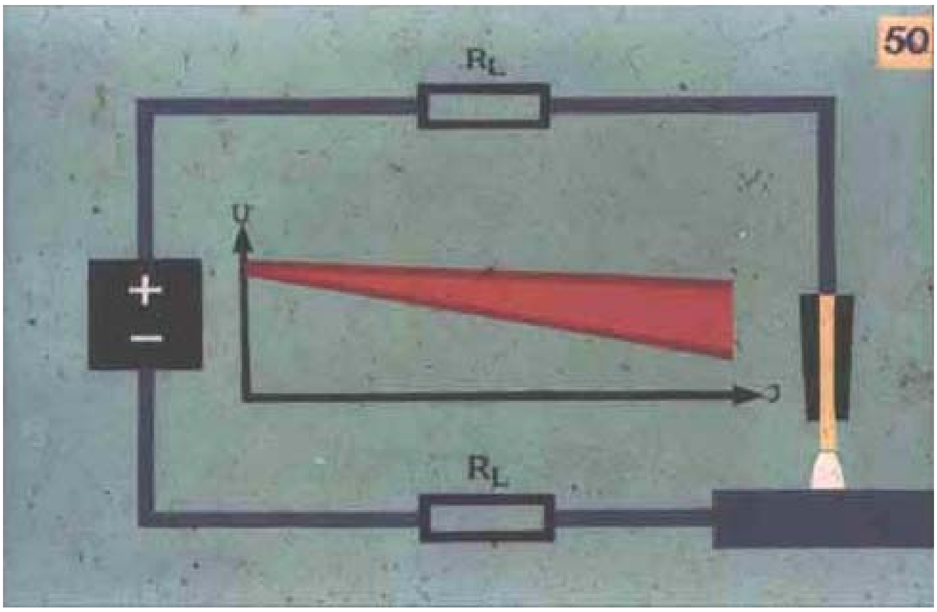
Slide no. 49 Effect of gas nozzle



This slide shows various torch heads having different gas nozzles.

Left:	Contact tip with electrode is in the center of the gas nozzle, with complete gas coverage being insured.
Center:	Gas nozzle is not situated in the center. Inadequate gas shielding results in porosity in the weld metal.
Right:	Gas nozzle narrowed by a ring of spatter resulting in inadequate gas coverage. Remove weld spatter as frequently as possible. For this, use a silicone anti–spatter spray.

Slide no. 50 Effect of welding power lead



The length and cross section of the welding lead may have a substantial effect upon the CO_2 welding operation.

Long lengths and small cross sections of welding power leads tend to cause a change in the volt–ampere characteristic.

This slide shows two characteristics, one being the power source characteristic and the other, the arc characteristic.

It can be seen that the welding characteristic shows a greater slope. The cause of this is the drop of voltage across the welding lead.

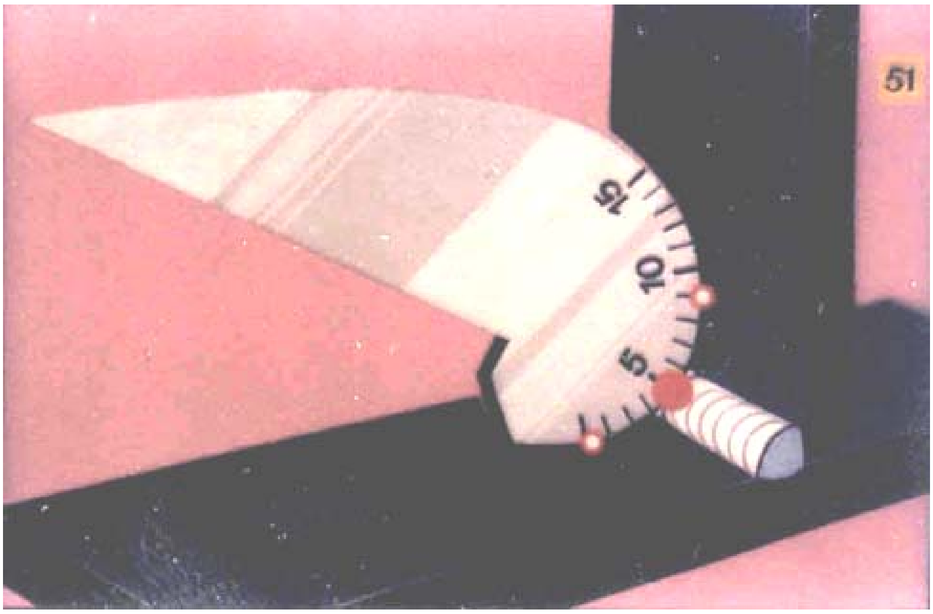
$$U_V = I_S \cdot R_{lead}$$

Since the resistance of the welding power lead is proportional to the length and inversely proportional to the cross section thereof, it is essential that short welding leads having a large cross section be used.

Steeply drooping characteristics tend to cause irregular welding with transfer of coarse filler metal droplets.

Also, long welding leads usually involve unnecessary losses of energy.

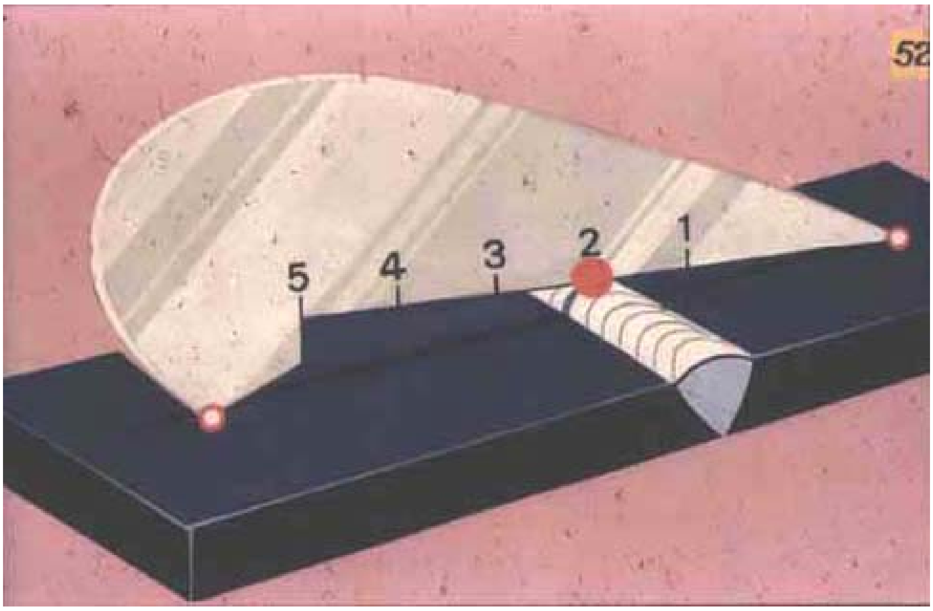
Slide no. 51 Gaging the throat of a fillet weld



This slide shows how a weld gage can be used to determine the throat (“a”) of a fillet weld. The fillet weld gage has been adjusted correctly when the conditions shown in the slide (three–point location) are satisfied.

The result can be read off directly at the contact point opposite the weld surface.

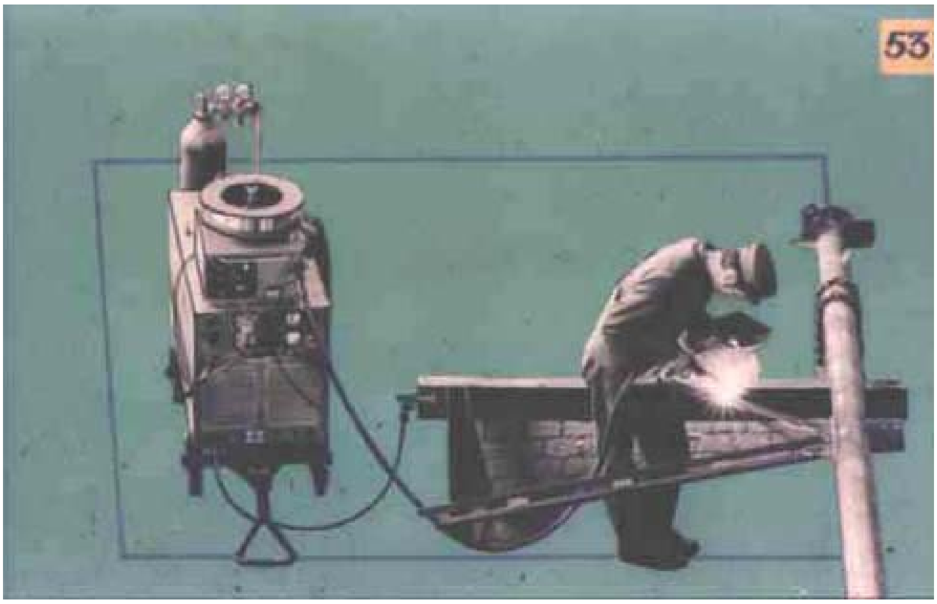
Slide no. 52 Gaging the reinforcement of a V groove weld



This slide shows that the same weld gage can be used to gage the reinforcement of a V groove weld. It is here, too, that three−point location is essential to correct gaging.

The result can be read off directly at the contact point of the scale above the weld surface.

Slides nos. 53 and 54 Application examples



These slides show practical examples of gas metal–arc CO_2 welding. Since all pieces of equipment required for welding can be seen on these slides, it is recommended that slides nos. 53 and 54 be placed so as to be at the beginning of this series of slides on gas metal–arc CO_2 welding.