Fusion Welding

1. Energy source

Classification of Fusion welding based on energy source

Energy source	Types of welding
Chemical	Oxy fuel gas welding, Exothermic welding/ Thermite welding, Reaction brazing/Liquid phase bonding
Radiant energy	Laser beam welding, Electron beam, Infrared welding/ brazing, Imaging arc welding, Microwave welding,
Electric-Perm. electrode arc	Gas tungsten arc welding, plasma arc welding, Carbon arc welding, atomic hydrogen welding, Stud arc welding
Electric-Consumable electrode	Gas metal arc welding, Shielded metal arc welding, Submerged arc welding, Electrogas welding, Electroslag welding, Flux cored arc welding
Electric-Resistance	Resistance spot, resistance seam, projection welding, flash/ upset welding, Percussion, Induction welding

ARC WELDING

Class: Fusion Welding

Energy Source: Electrical type - Electrical arc

ARC WELDING (AW)

A group of welding processes producing coalescence of workpieces by melting them with an arc. The processes are used with or without the application of pressure and with or without filler metal. AWS A3.0M/A3.0:2010

WELDING ARC

A controlled electrical discharge between the electrode and the workpiece formed and sustained by the establishment of a gaseous conductive medium, called an arc plasma.

ARC WELDING ELECTRODE

A component of the welding circuit through which current is conducted and that terminates at the arc.

ARC WELDING GUN

A device used to transfer current to a continuously fed consumable electrode, guide the electrode, and direct the shielding gas. See Figure B.38.

ARC WELDING TORCH

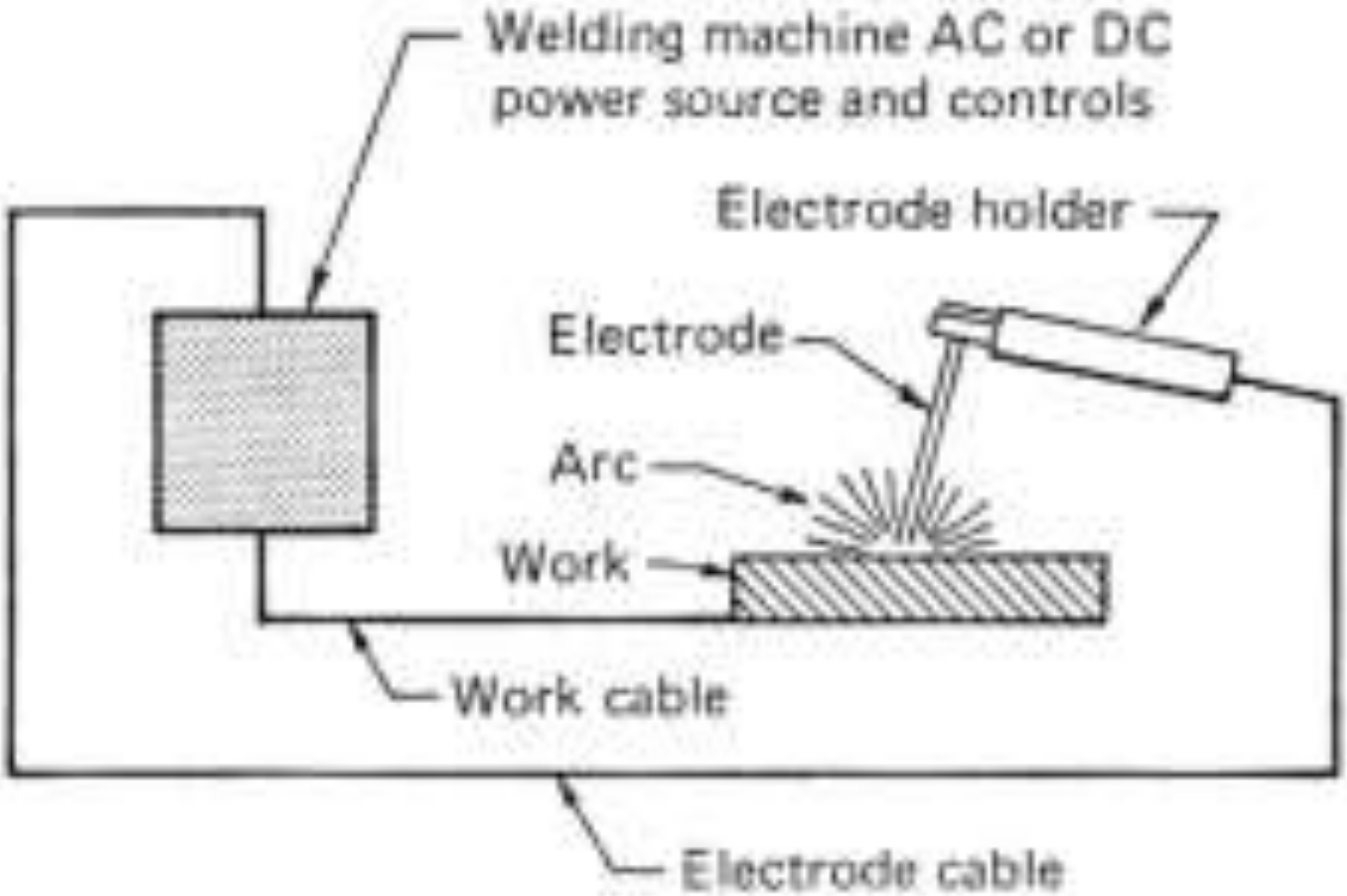
A device used to transfer current to a fixed welding electrode, position the electrode, and direct the shielding gas. See Figures B.35 and B.36.

ARC TIME

The time during which an arc is maintained in making an arc weld.

ARC VOLTAGE, *ARC WELDING.*

The electrical potential between the electrode and workpiece.



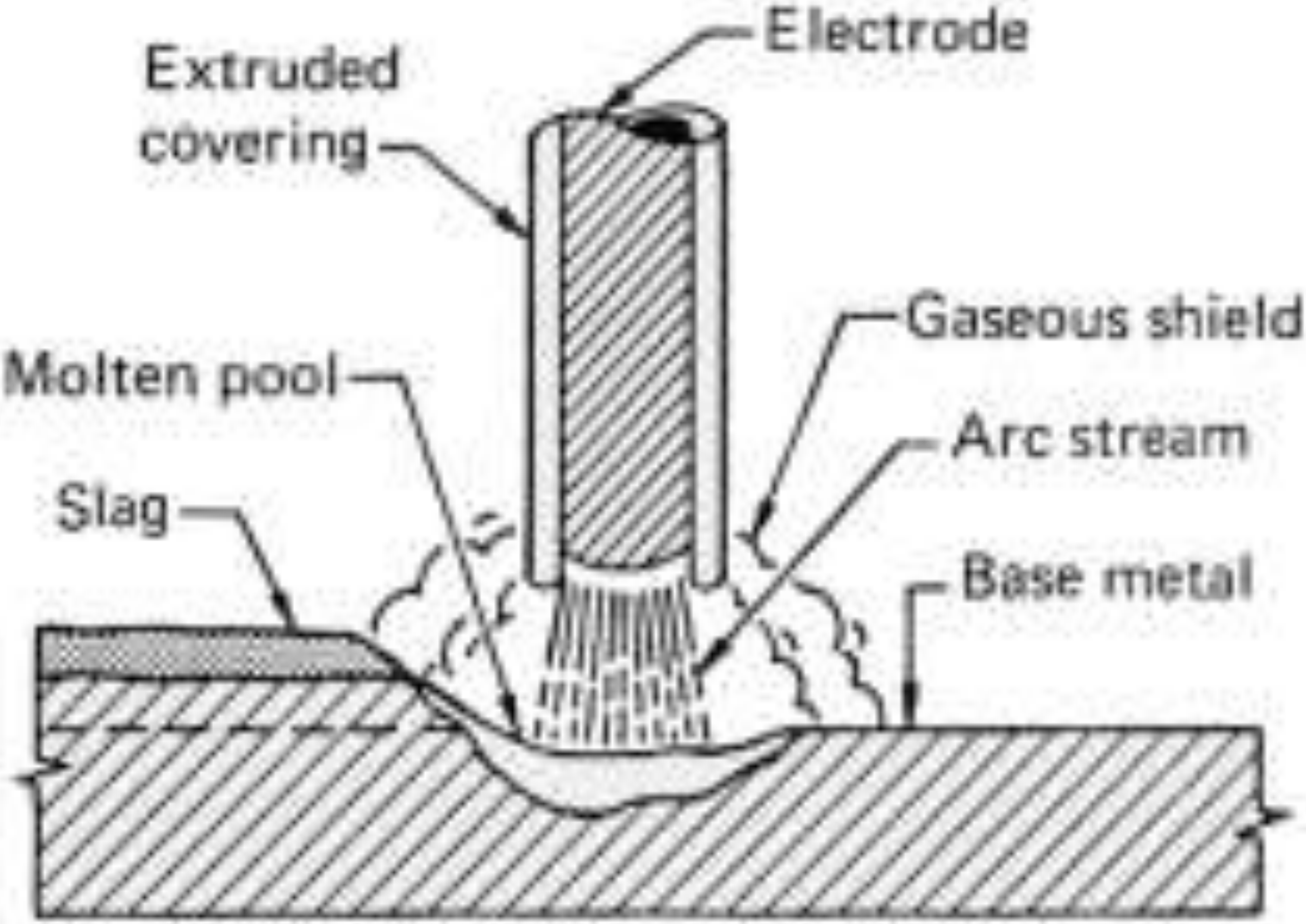
http://www.lincolnelectric.com/en-us/support/process-and-theory/Pages/arc-welding-detail.aspx

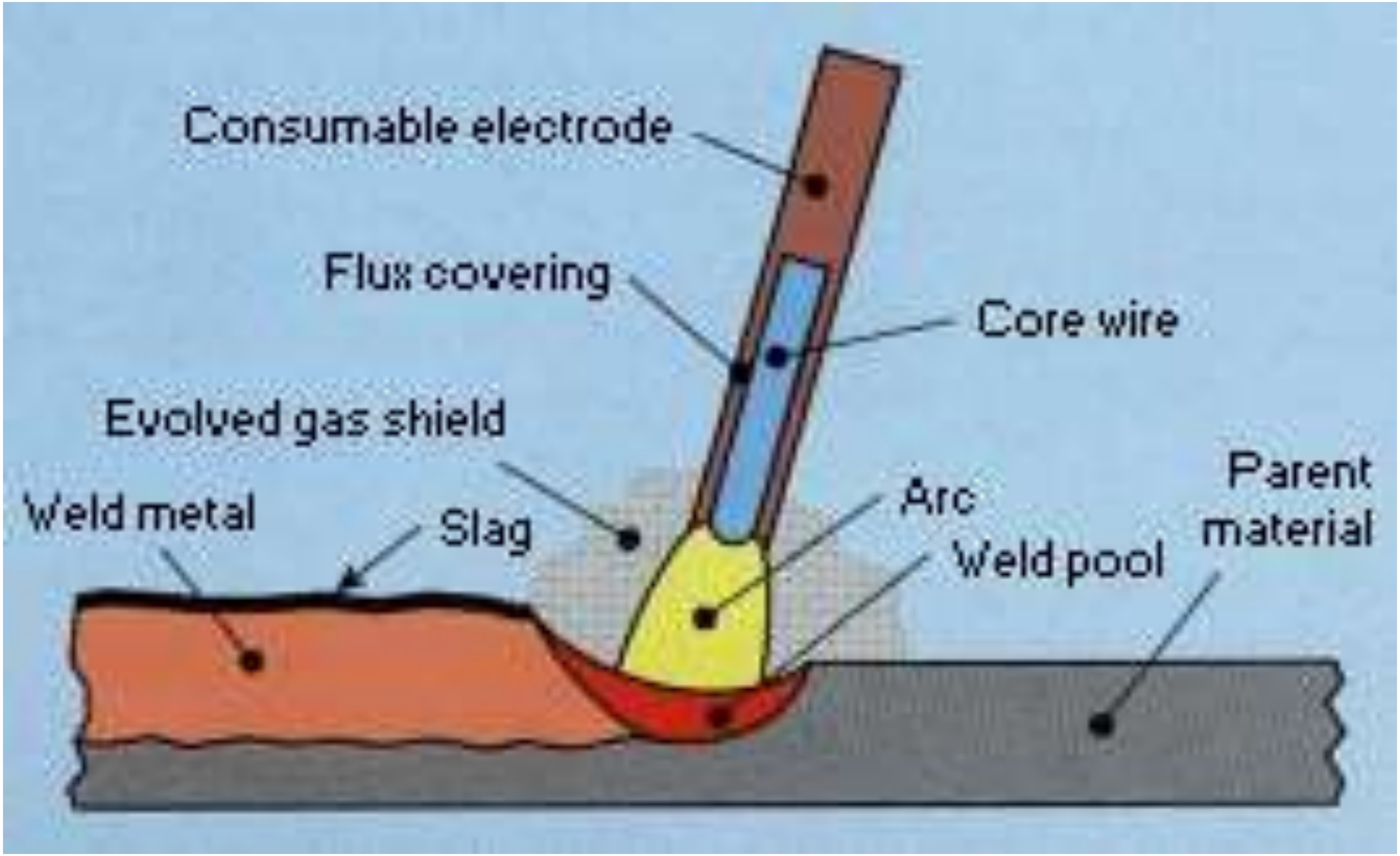
Arc welding is one of several fusion processes for joining metals. By applying intense heat, metal at the joint between two parts is melted and caused to intermix – directly, or more commonly, with an intermediate molten filler metal. Upon cooling and solidification, a metallurgical bond is created.

In arc welding, the intense heat needed to melt metal is produced by an electric arc. The arc is formed between the base (parent) metal and an electrode (stick or wire) that is guided along the joint. The electrode

either can be a rod with the purpose of simply carrying the current between the tip and the work.

or it may be a specially prepared rod or wire that not only conducts the current but also melts and supplies filler metal to the joint.


Electrode
Extruded covering
Gaseous shield
Molten pool
Arc stream
Slag
Base metal


Consumable electrode
Flux covering
Core wire
Evolved gas shield
Weld metal
Slag
Arc
Parent
material
Weld pool

An arc is an electric current flowing between two electrodes through an ionized column of gas. A negatively charged **cathode** and a positively charged **anode** create the intense heat of the welding arc. Negative and positive ions are bounced off of each other in the plasma column at an accelerated rate.

In welding, the ***arc not only provides the heat*** needed to melt the electrode and the base metal, but under certain conditions must also supply the means to ***transport the molten metal from the tip of the electrode to the work***.

So, **electrode** may be

- ***consumable***
- ***non-consumable*** (carbon, tungsten TIG)

If an electrode is ***consumable***, the tip melts under the heat of the arc and molten droplets are detached and transported to the work through the arc column. Any arc welding system in which the electrode is melted off to become part of the weld is described as ***metal-arc***.

In case of carbon or tungsten (TIG) welding there are no molten droplets to be forced across the gap and onto the work. Filler metal is melted into the joint from a separate rod or wire.

More of the heat developed by the arc is transferred to the weld pool with ***consumable electrodes***. ***This produces higher thermal efficiencies and narrower heat-affected zones.***

Arc welding may be done with

- direct current (DC) with the electrode
  - ✓ positive
  - ✓ negative
- alternating current (AC).

The choice of current and polarity depends on

- ✓ the process,
- ✓ the type of electrode,
- ✓ the arc atmosphere,
- ✓ the metal being welded.

Технология дуговой сварки
Technology of Arc Welding

WELDING ARC

A controlled electrical discharge between the electrode and the workpiece formed and sustained by the establishment of a gaseous conductive medium, called an arc plasma.

ELECTRODE

A component of the secondary circuit terminating at the arc, molten conductive slag, or base metal. See consumable electrode, cutting electrode, nonconsumable electrode, resistance welding electrode, tungsten electrode, and welding electrode.

WELDING ELECTRODE

A component of the welding circuit through which current is conducted and that terminates at the arc, molten conductive slag, or base metal.

See also arc welding electrode, bare electrode, carbon electrode, composite electrode, covered electrode, electroslag welding electrode, emissive electrode, flux cored electrode, lightly coated electrode, metal cored electrode, metal electrode, resistance welding electrode, stranded electrode, and tungsten electrode.

ARC WELDING ELECTRODE

A component of the welding circuit through which current is conducted and that terminates at the arc.

WELD POOL

The localized volume of molten metal in a weld prior to its solidification as weld metal.

WELDING ARC INITIATION

WELDING ROD

A form of welding filler metal, normally packaged in straight lengths, that does not conduct the welding current. See Figure B.36.

WELDING WIRE

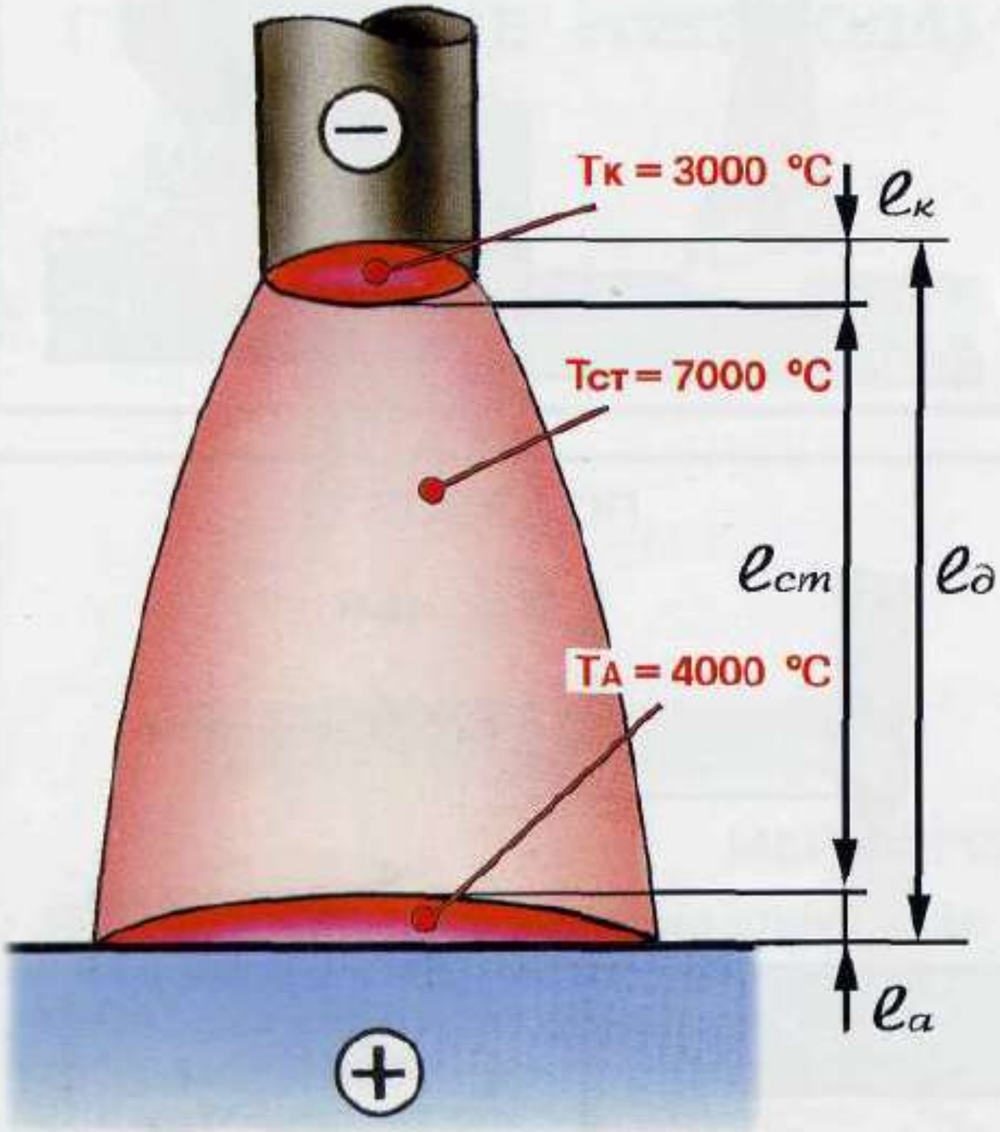
A form of welding filler metal, normally packaged as coils or spools, that may or may not conduct electrical current depending upon the welding process with which it is used. See Figure B.36. See also welding electrode and welding rod.

CUTTING ELECTRODE.

A nonfiller metal electrode used in arc cutting. See also carbon electrode, metal electrode, and tungsten electrode.

ELECTRIC ARC

СТРОЕНИЕ И ХАРАКТЕРИСТИКИ



$\ell_к$ - катодная область

$\ell_а$ - анодная область

$\ell_{ст}$ - столб дуги

$\ell_д$ - длина дуги

$$\ell_д = \ell_а + \ell_к + \ell_{ст}$$

$$\ell_а \approx \ell_к = 10^{-5} \div 10^{-3} см$$

ТЕПЛОВАЯ МОЩНОСТЬ ДУГИ

$$Q = 0{,}24\, k\, I_{св}\, U_д ,$$

где Q - тепловая мощность, кал/с;

0,24 - коэффициент перевода электрических величин в тепловые, кал/Вт · с;

k - коэффициент снижения мощности дуги при сварке на переменном **токе** (0,7-0,97);

$I_{св}$ - сварочный ток, А;

$U_д$ - напряжение на дуге, В

ELECTRIC ARC

http://www.thermopedia.com/content/717/

Svirchuk, Ye.S.

DOI: 10.1615/AtoZ.e.electric_arc

An electric arc is a form of a self-maintained gas discharge—i.e., a discharge which does not need an external gas ionization source for continuous burning. An electric arc burns between two electrodes: positive (anode) and negative (cathode). If an electric arc is fed from an (AC) power source with a given frequency, then the cathode and anode replace each other at the same frequency. The term “arc” is due to the fact that a sufficiently long discharge between the horizontal electrodes has an arc shape, caused by free-convective vertical gas motion. A long electric arc can be divided into three areas: a conducting column, the properties of which at some length apart from the electrodes are independent of physical phenomena near the electrodes; and two areas near the electrodes, namely, the near-anode and near-cathode areas. In near-electrode areas, a noticeable increase of electric field strength usually occurs compared with an electric arc column. Voltage drops in these areas are called cathode and anode voltage drops. Their values usually don’t exceed 10 volts.

In an electric arc column, gas is heated to a high temperature and its electrical conductivity is attributed mainly to thermal ionization processes. At pressures higher than atmospheric pressure, gas in an electric arc column is usually in local thermodynamic equilibrium state.

An electric arc which burns in a large gas volume and isn’t affected by external factors (e.g., by gas flow or applied magnetic field) is called a free-burning arc. Such an arc usually rapidly and randomly moves and changes its shape. In special devices, particularly in plasmatrons, it is possible to have a stationary electric arc (e.g., arc burning in a narrow, cylindrical, insulating channel) or to arrange its motion in an ordered fashion. Such electric arcs are called stabilized arcs.

The dependence of electric arc voltage on its current is called *current-voltage characteristic* (CVC). CVCs are classified into the static CVC, which is based on stationary current and voltage values and dynamic CVC’s, which connect the corresponding instantaneous values.

The CVC of most direct current (DC) electric arcs is such that a current rise leads to a voltage decrease (drooping characteristic, see **Figure 1**, curve 1) or to a constant voltage (independent characteristic). Thus, an electric arc doesn’t follow **Ohm’s Law** and represents a nonlinear element of an electric circuit. To keep a stable electric arc burning, an additional resistor is connected in series with an arc to increase a power source’s own CVC slope (see **Figure 1**: curve 2 is a CVC of a power source without resistor; curve 3 is a CVC of a power source with resistor). Point A corresponds to unstable electric arc burning because with an occasional increase of current I_a by a magnitude of ΔI, a positive potential difference, ΔV, arises which causes further current increases until point B is reached. This corresponds to stable arc burning at current I_b. An additional resistor substantially decreases the energy efficiency of an electric arc device. To avoid this disadvantage, special power sources are sometimes used. Certain stabilized electric arcs have rising CVCs; in this case, it is possible to substantially decrease resistor magnitude or to entirely remove it from a feeding circuit.

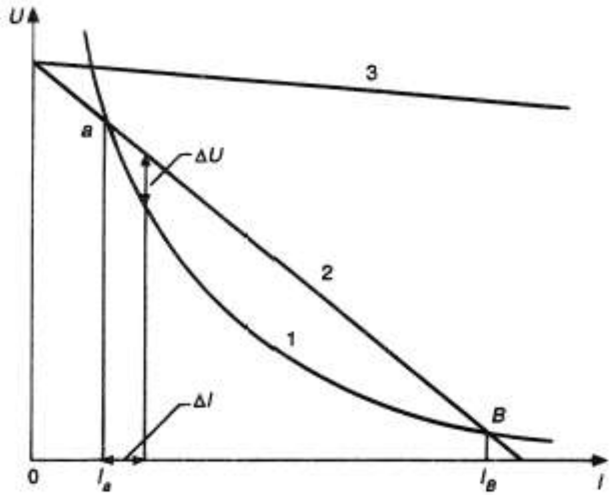


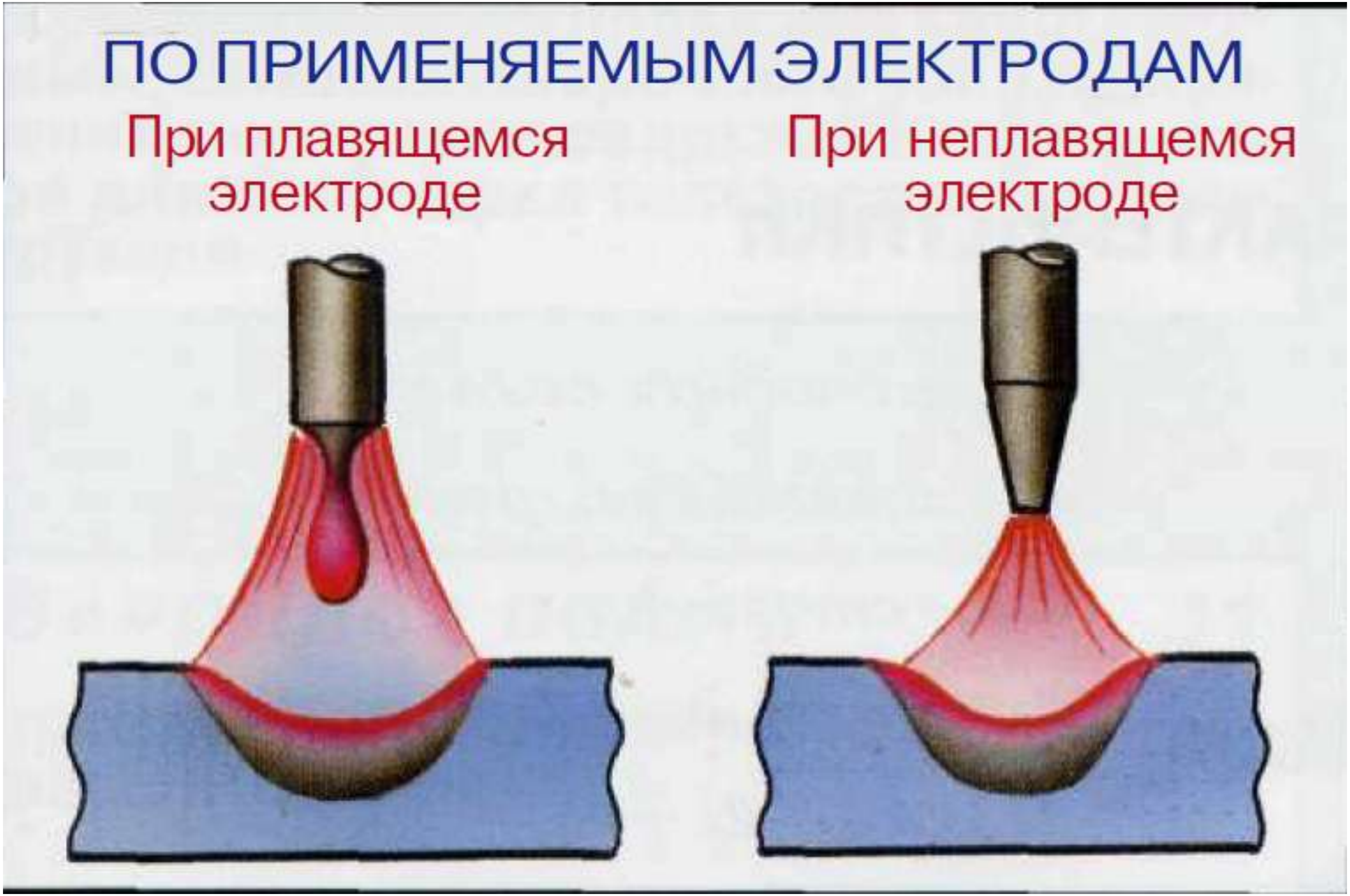
Figure 1. Current-voltage characteristics for electric arcs (1 - “drooping” characteristic, 2 - CVC for power source without resistor, 3- CVC with resistor).

For alternating current (AC) electric arcs, current-time dependence during each half-period is near sinusoidal; voltage-time dependence usually has a near-rectangular shape, with characteristic sharp voltage peak at the point of origin (so-called ignition peak). A dynamic AC CVC has a loop shape that indicates a hysteresis phenomenon caused by thermal inertia of the electric arc column. A CVC, plotted by the effective values of current and voltage, has the same shape as a DC arc under the same conditions. That is why for stable AC arc burning, an induction coil is connected to a circuit in series with arc (more seldom a resistor is used). An advantage of an induction coil over a resistor is that the coil has a low resistance and consequently doesn’t influence an electric arc device’s efficiency. On the other hand, this leads to a significant decrease in power factor.

An electric arc is a powerful, highly-concentrated source of heat and light. These electric arc properties determine the main areas of its application. Electric arcs are widely used in various welding devices, in steel-melting arc furnaces and in plasmatrons. Arc light sources are used in various lighting devices (e.g., in floodlights). In cinematographic projection equipment, high-pressure *xenon arc* lamps are used. The light spectrum of a xenon electric arc is close to sunlight, which is why such lamps provide “white” light and correct color transmission.

PROCESSES IN ELECTRIC ARC

KINDS OF ARC WELDING
by electrode type



CONSUMABLE ELECTRODE

An electrode providing filler metal.

BARE ELECTRODE

A filler metal electrode produced as a wire, strip, or bar with no coating or covering except one incidental to its manufacture or preservation.

COVERED ELECTRODE

A composite filler metal electrode consisting of a bare or metal cored electrode with a flux covering sufficient to provide a slag layer and/or alloying elements. See also lightly coated electrode.

NONCONSUMABLE ELECTRODE

An electrode that does not provide filler metal. See Figures B.35 and B.36.

CARBON ELECTRODE

A nonfiller metal electrode used in arc welding and cutting, consisting of a carbon or graphite rod, which may be coated with copper or other materials.

TUNGSTEN ELECTRODE

A nonfiller metal electrode used in arc welding, arc cutting, and plasma spraying, made principally of tungsten.

METAL CORED ELECTRODE

A composite tubular filler metal electrode consisting of a metal sheath and a core of various powdered materials, producing no more than slag islands on the face of a weld bead.

METAL ELECTRODE

A filler or nonfiller metal electrode used in arc welding and cutting that consists of a metal wire or rod manufactured by any method and either bare or covered.

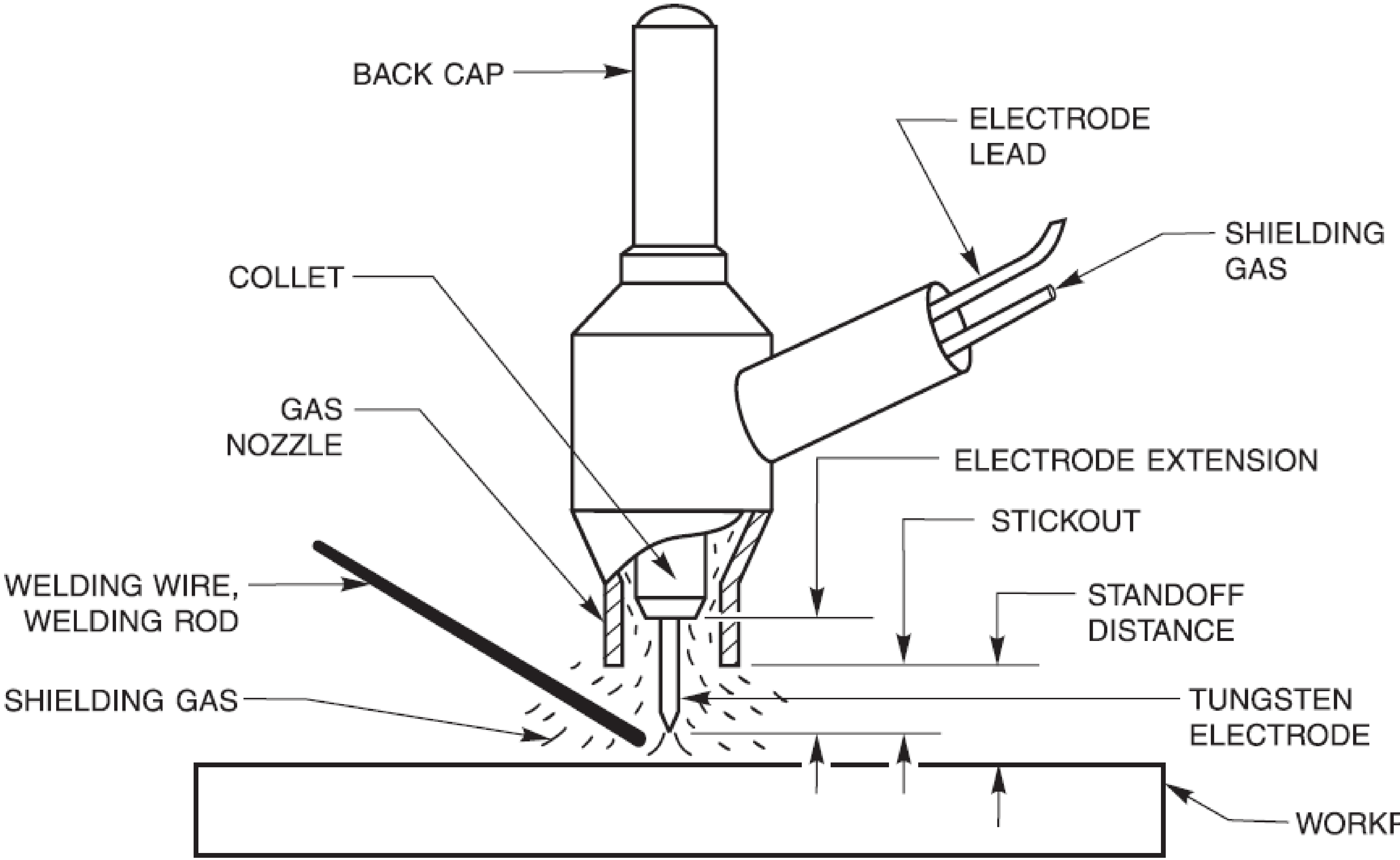


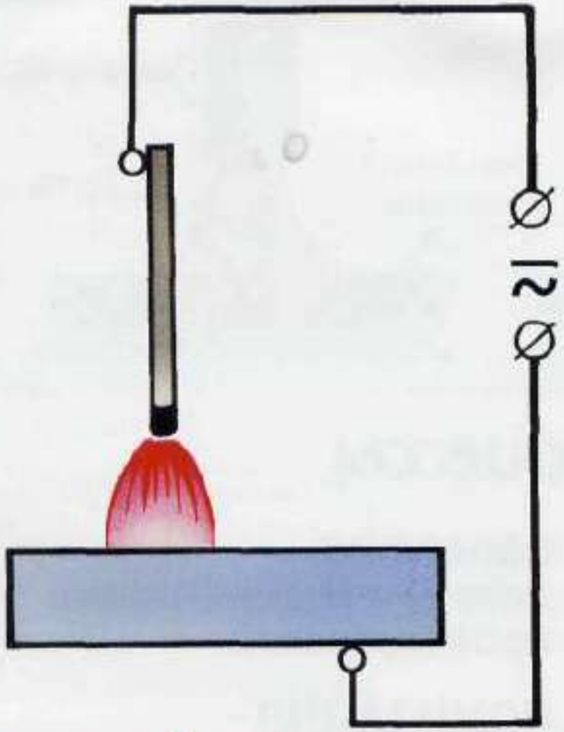
Figure B.36—Gas Tungsten Arc Welding Torch Nomenclature

KINDS OF ARC WELDING by electrode type

КЛАССИФИКАЦИЯ СВАРОЧНОЙ ДУГИ

ПО ПОДКЛЮЧЕНИЮ К ИСТОЧНИКУ ПИТАНИЯ

Прямого действия

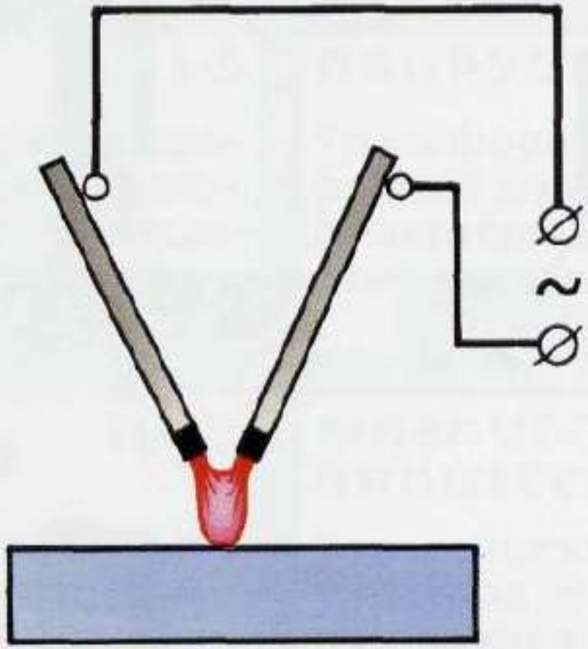


ДУГОВОЙ РАЗРЯД - МЕЖДУ ЭЛЕКТРОДОМ И ИЗДЕЛИЕМ

ИСПОЛЬЗУЕТСЯ:

- при дуговой сварке покрытыми электродами
- при сварке неплавящимся электродом в защитных газах
- при сварке плавящимся электродом под флюсом или в защитных газах

Косвенного действия

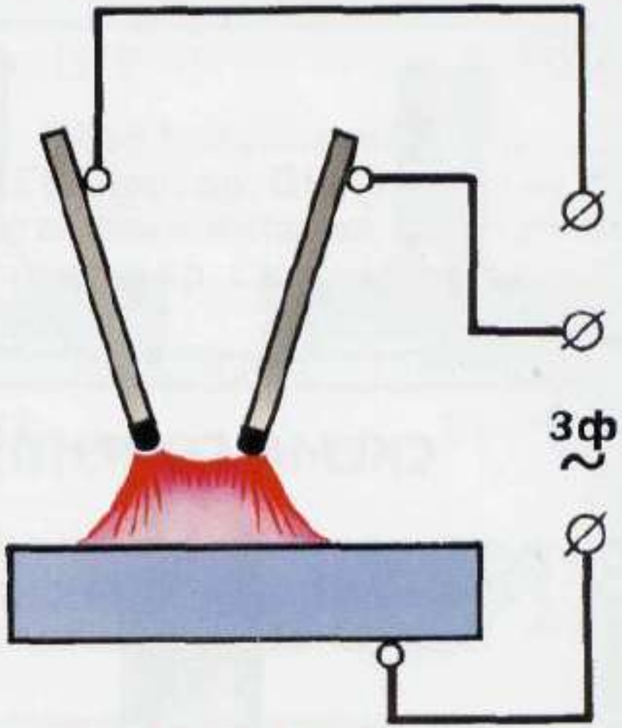


ДУГОВОЙ РАЗРЯД - МЕЖДУ ДВУМЯ ЭЛЕКТРОДАМИ

ИСПОЛЬЗУЕТСЯ:

- при специальных видах сварки и атомно-водородной сварке и наплавке

Комбинированная



ДВА ДУГОВЫХ РАЗРЯДА- МЕЖДУ ЭЛЕКТРОДАМИ И ИЗДЕЛИЕМ, А ТРЕТИЙ- -МЕЖДУ ЭЛЕКТРОДАМИ

ИСПОЛЬЗУЕТСЯ:

- при сварке **спиралешовных** труб на станках автоматической сварки под флюсом

KINDS OF ARC WELDING by arc constricting

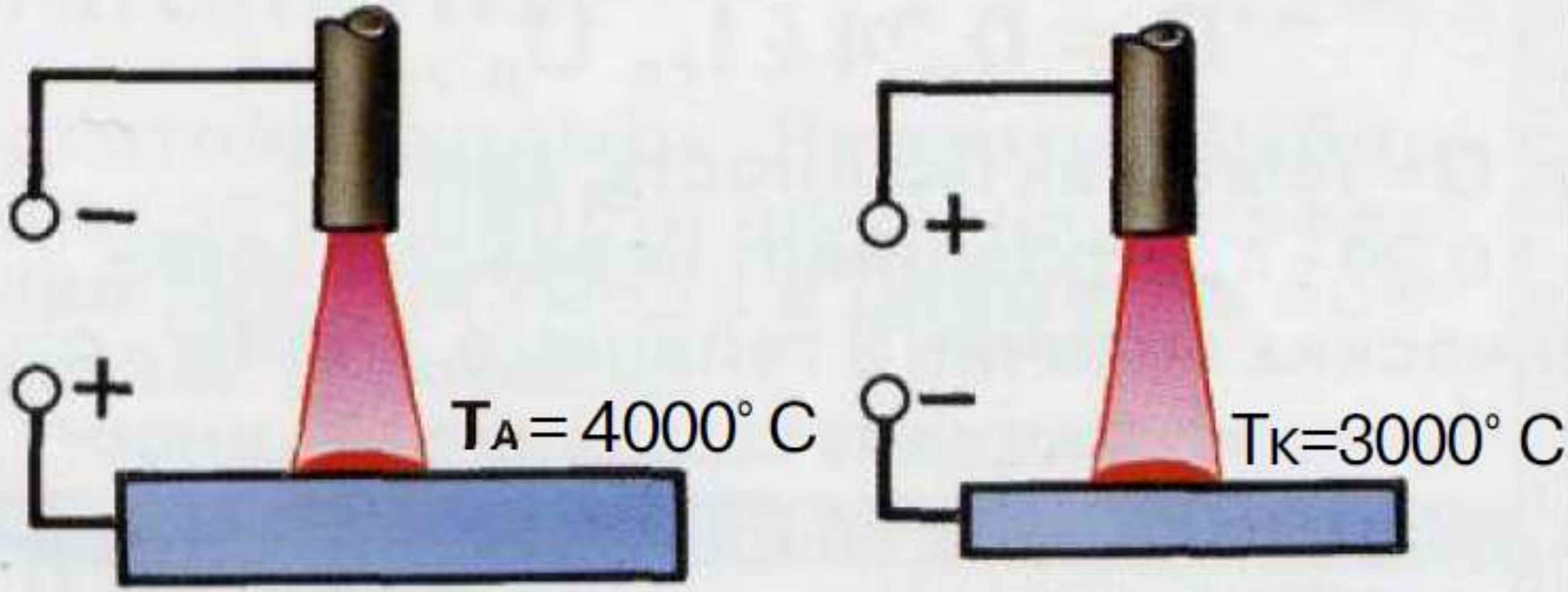
non-constricted (free)

constricted

KINDS OF ARC WELDING by arc of DC polarity

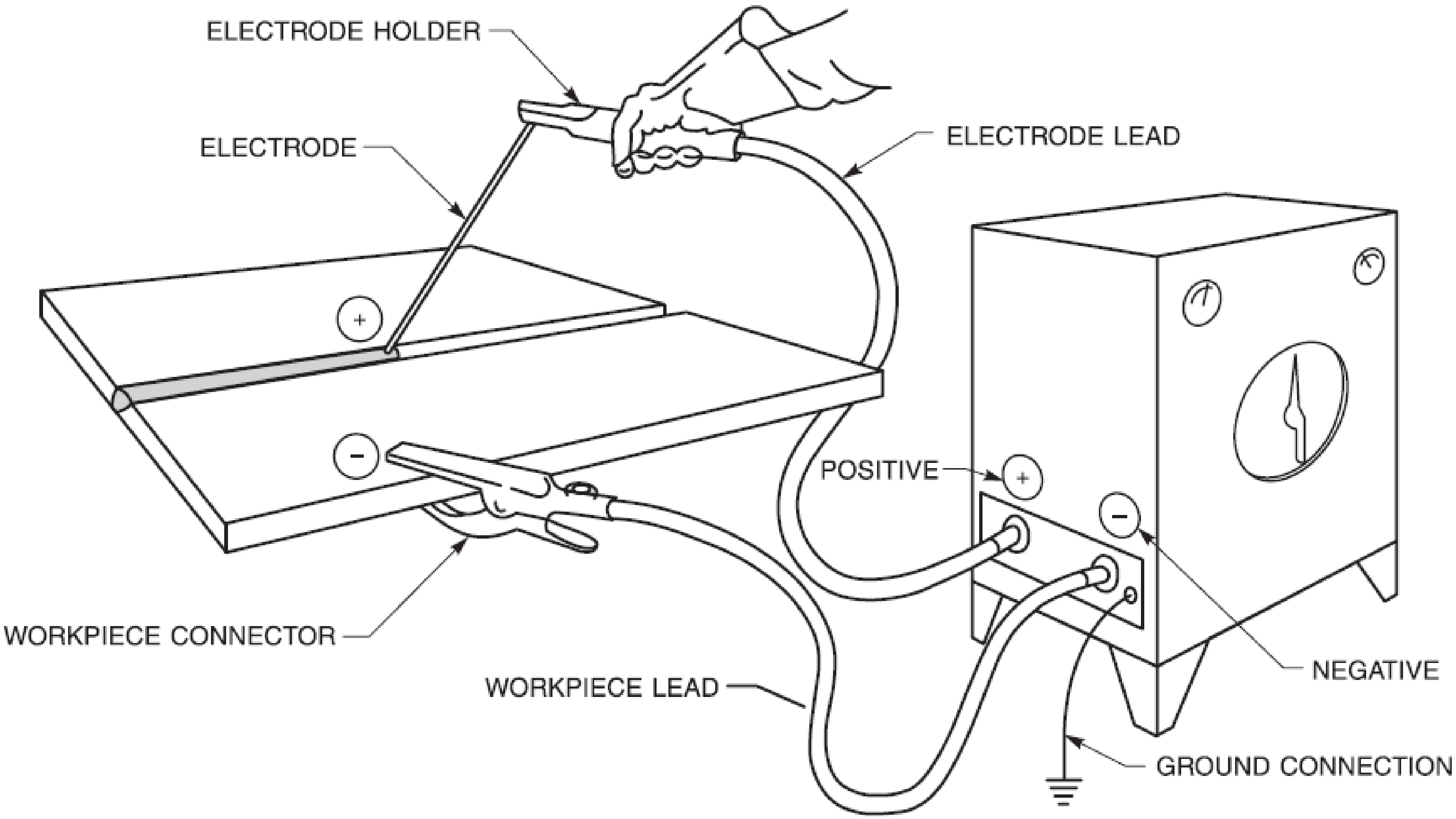
ПО ПОЛЯРНОСТИ ПОСТОЯННОГО ТОКА

Прямая Обратная



При обратной полярности температура на поверхности металла ниже. Используют при сварке тонкой или высоколегированной стали

DCEN (DCSP) DCEP (DCRP)



(A) DIRECT CURRENT ELECTRODE POSITIVE

DIRECT CURRENT ELECTRODE POSITIVE (DCEP)

The arrangement of direct current arc welding leads in which the electrode is the positive pole and the workpiece is the negative pole of the welding arc. See Figure B.34(A).

Also may be called:

DIRECT CURRENT reverse polarity (DCRP)

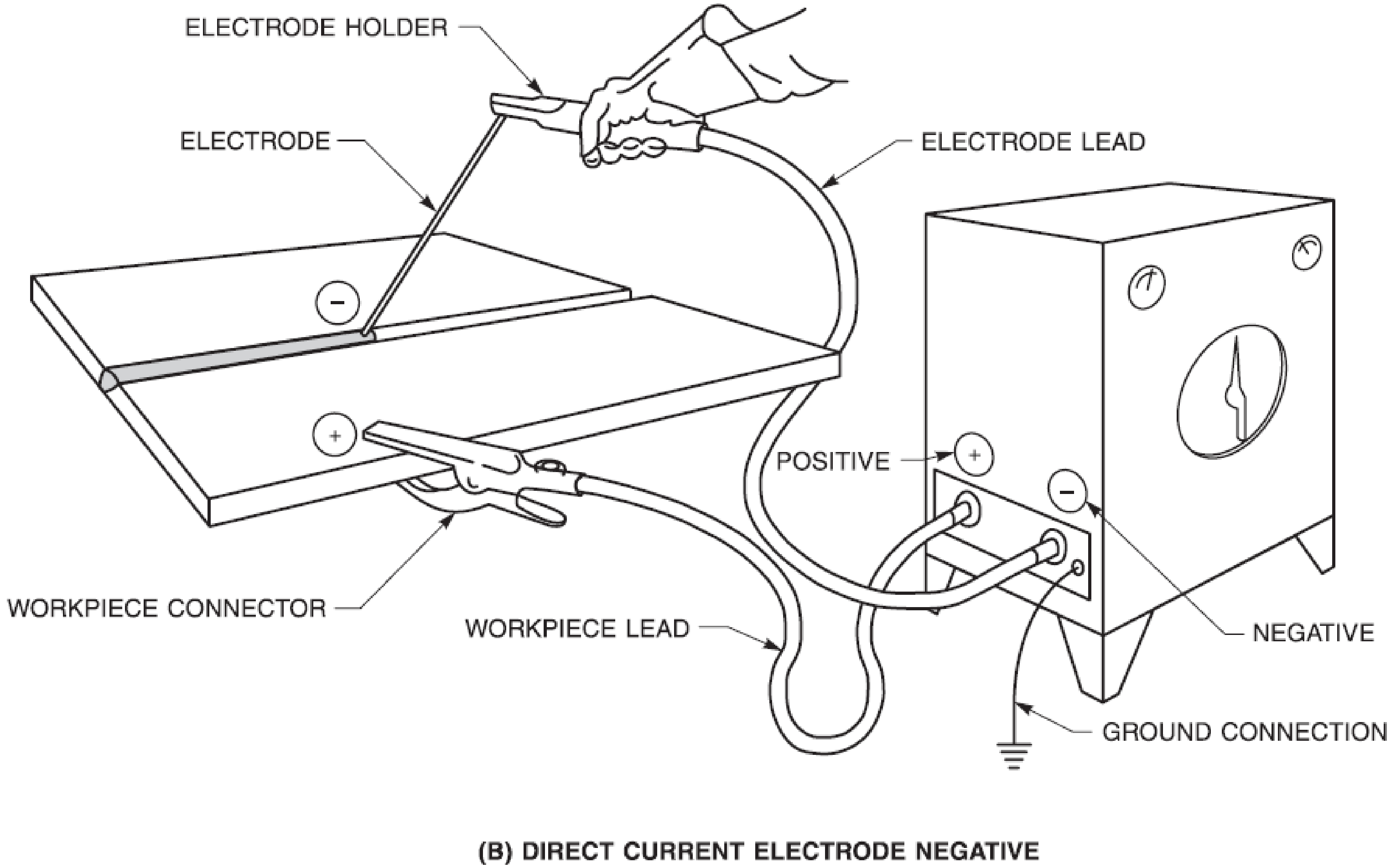


Figure B.34—Welding Current Polarity

DIRECT CURRENT ELECTRODE NEGATIVE (DCEN).

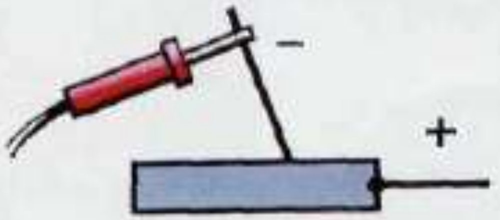
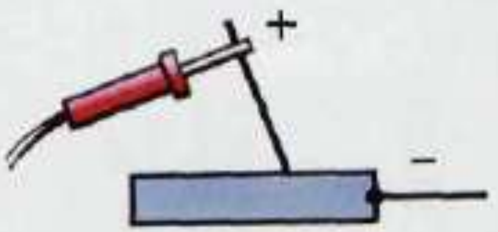
The arrangement of direct current arc welding leads in which the electrode is the negative pole and workpiece is the positive pole of the welding arc. See Figure B.34(B).

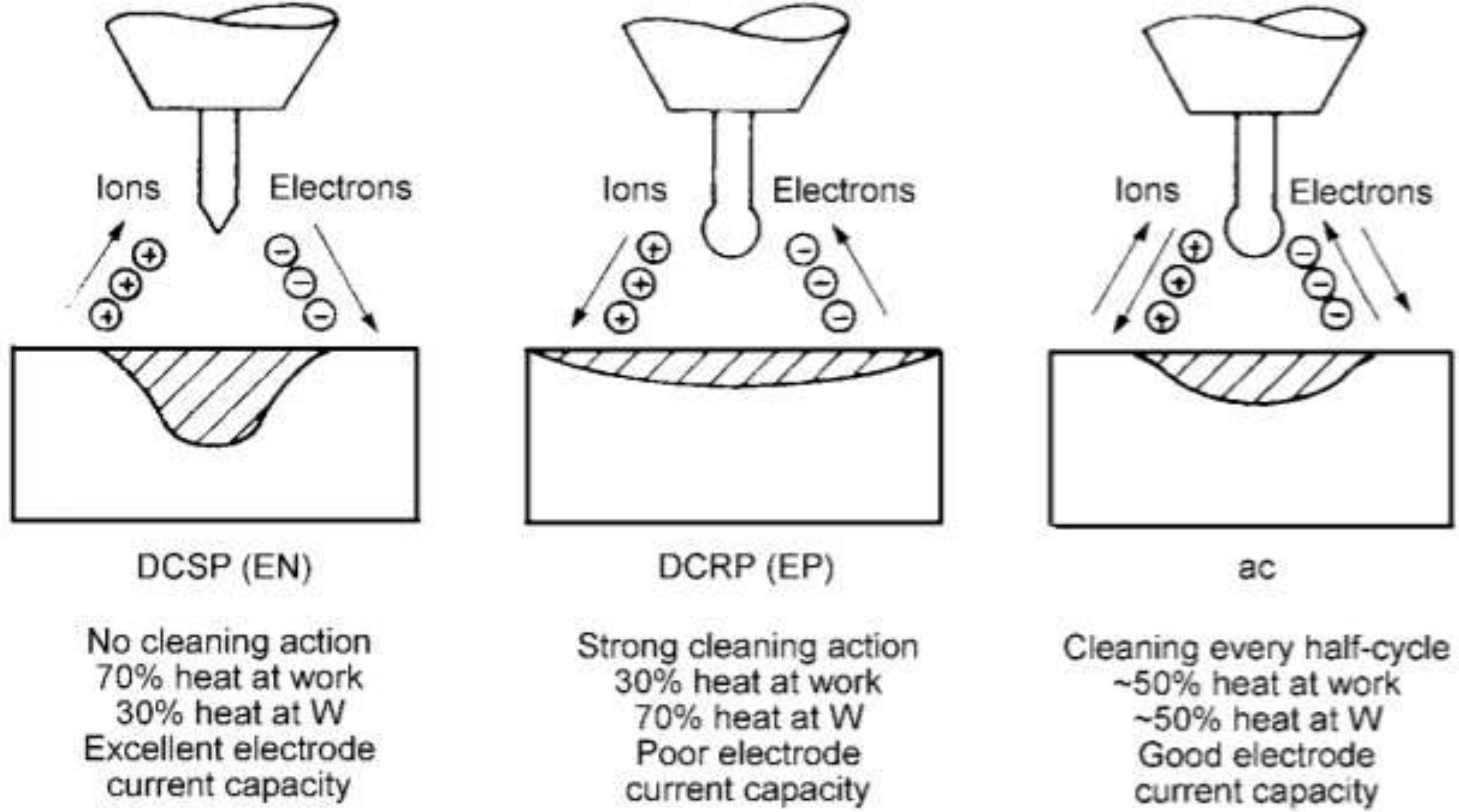
Also may be called:

DIRECT CURRENT straight polarity (DCSP).

WELDING BY DIFFERENT TYPES OF CURRENT

РОД И ПОЛЯРНОСТЬ ТОКА

	– ПОСТОЯННЫЙ	~ ПЕРЕМЕННЫЙ
Прямая 	• Сварка с глубоким проплавлением основного металла • Сварка низко- и среднеуглеродистых и низколегированных сталей толщиной 5 мм и более электродами с фтористо-кальциевым покрытием: **УОНИ-13/45, УОНИ-13/55** и др. • Сварка чугуна	• Сварка низкоуглеродистых и низколегированных сталей (типа 09ГС) в строительно-монтажных условиях электродами с **рутиловым** покрытием • Сварка при возникновении магнитного дутья • Сварка толстолистовых конструкций из низкоуглеродистых сталей
Обратная 	• Сварка с повышенной скоростью плавления электродов • Сварка низколегированных низкоуглеродистых сталей (типа **16Г2АФ**), средне- и высоколегированных сталей и сплавов • Сварка тонкостенных листовых конструкций	



ARC BLOW

The deflection of an arc from its normal path due to magnetic forces

ПРИЧИНЫ отклонения ДУГИ

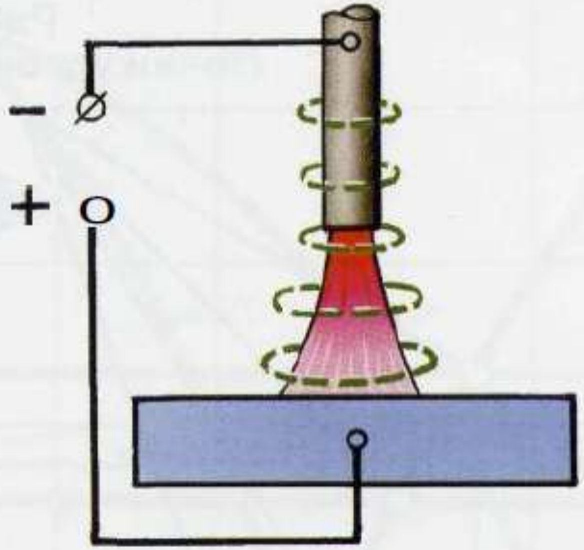
МАГНИТНОЕ ДУТЬЕ

ф При несимметричном относительно дуги подводе тока к изделию дуга из-за воздействия магнитных полей искривляется

- Отклонение дуги может быть вызвано также присутствием ферромагнитных масс вблизи сварки

ф Из-за этого стабильность горения дуги нарушается, затрудняется процесс сварки

Нормальное положение дуги



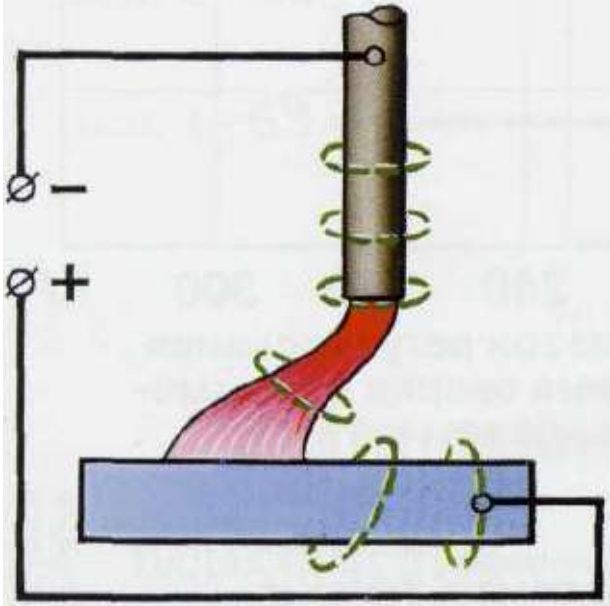
МЕРЫ ПРЕДОТВРАЩЕНИЯ

- Сварка короткой дугой
- Подвод сварочного тока в точке, максимально близкой **к дуге**
- Изменение наклона электрода

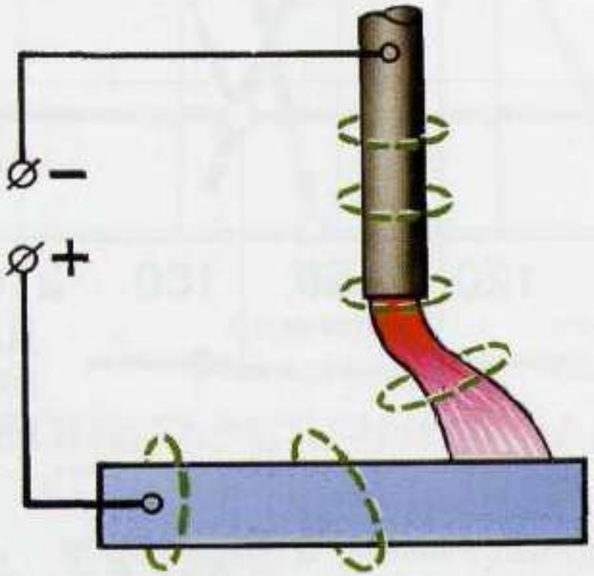
ф Размещение у места сварки компенсирующих ферромагнитных масс

ф Использование трансформаторов или **инверторных** источников питания

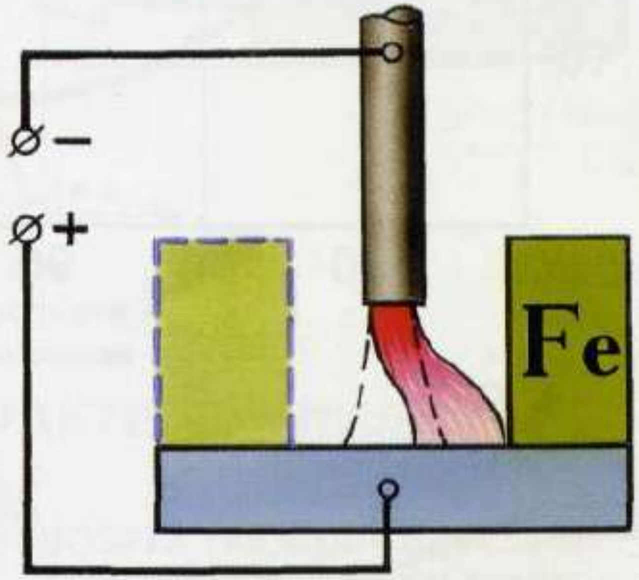
Отклонение влево



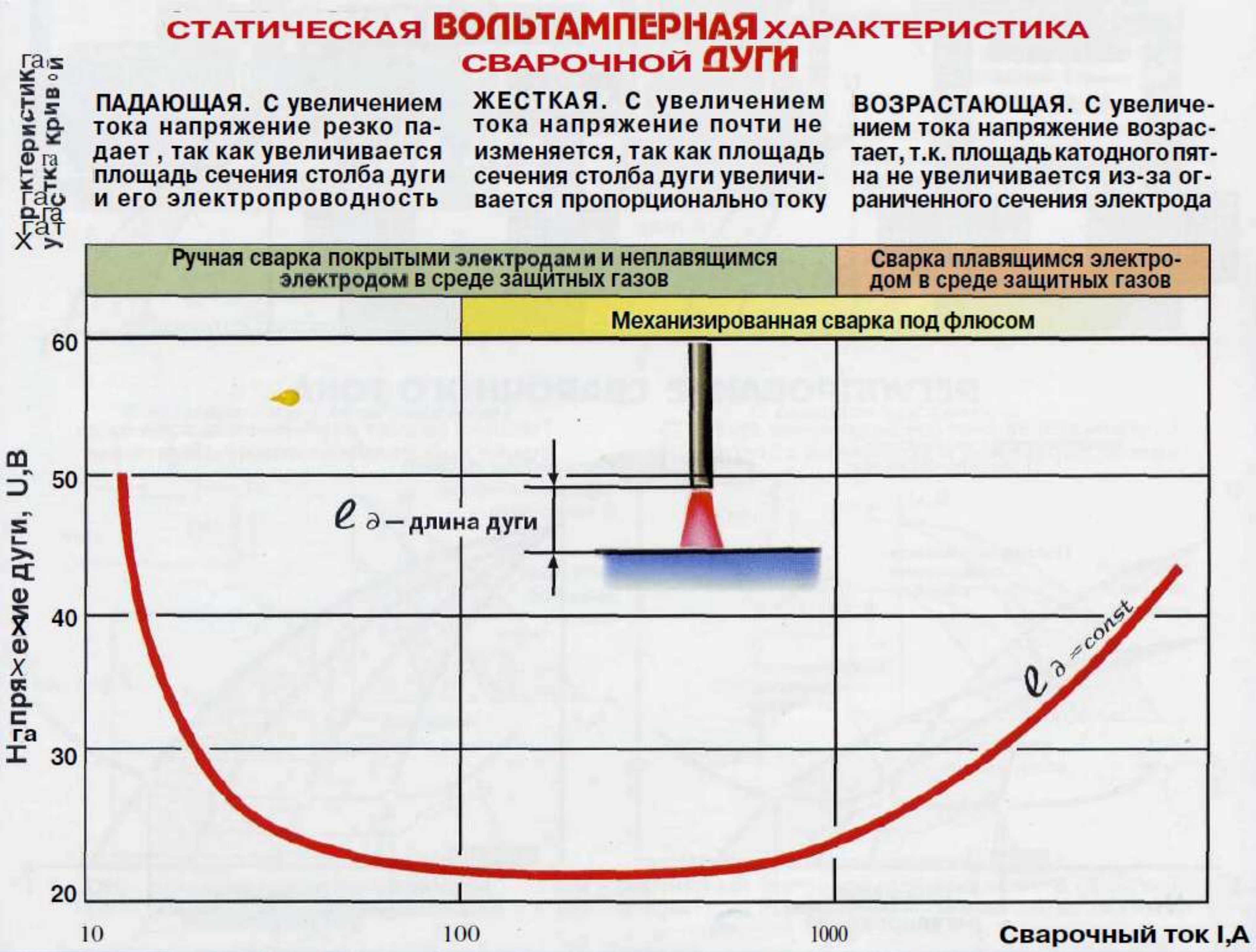
Отклонение вправо



Действие ферромагнитной массы



CURRENT-VOLTAGE CHARACTERISTIC OF ARC



A **current–voltage characteristic** or **I–V curve** (current–voltage curve) is a relationship, typically represented as a chart or graph, between the electric currentthrough a circuit, device, or material, and the corresponding voltage, or potential difference across it.

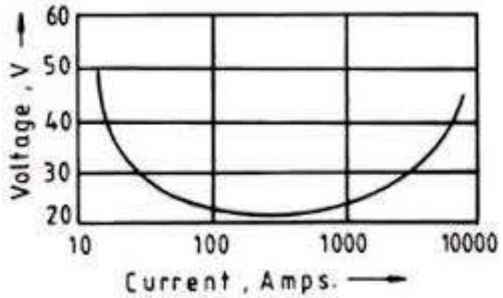


Fig. 3·13 Static volt-ampere characteristic of an electric arc.

For arc stability, arc voltage and current must have a definite relationship to each other. This relationship is known as the static volt-ampere characteristic of the arc and its typical shape is shown in Fig. 3.13. It shows that as the current increases up to about 100A, the arc voltage decreases which is explained on the basis that with the increase in current, in this range, the arc stream broadens while the temperature rises with the result that the arc voltage decreases.

This is known as drooping or negative volt-ampere characteristic. From 100 to 1000 ampere the arc V-I characteristic is nearly flat or very slightly rising. This is because in this range the increase in arc stream cross- section with increase in current remains nearly proportional and hence the current density and the arc voltage remain constant.

This part of the arc is said to have a plateau or flat volt-ampere characteristic. With the further increase in arc current beyond 1000A there is hardly any expansion of arc stream and hence the current density increases and so does the arc voltage. This part of the arc is said to have a positive or rising volt-ampere characteristic.

Fig. 3.14 shows the static V-I characteristic of an argon shielded tungsten arc for the normally used welding current range of up to about 300A and for the arc length range of 1 to 16 mm. It is clearly evident that the static volt- ampere characteristic for such an arc between the workable range is very slightly rising in nature. Fig. 3.15 shows the relationship between the arc length and the arc voltage. It is evident that except for very short arc length of less than0.8 mm the arc voltage is directly proportional to arc length.

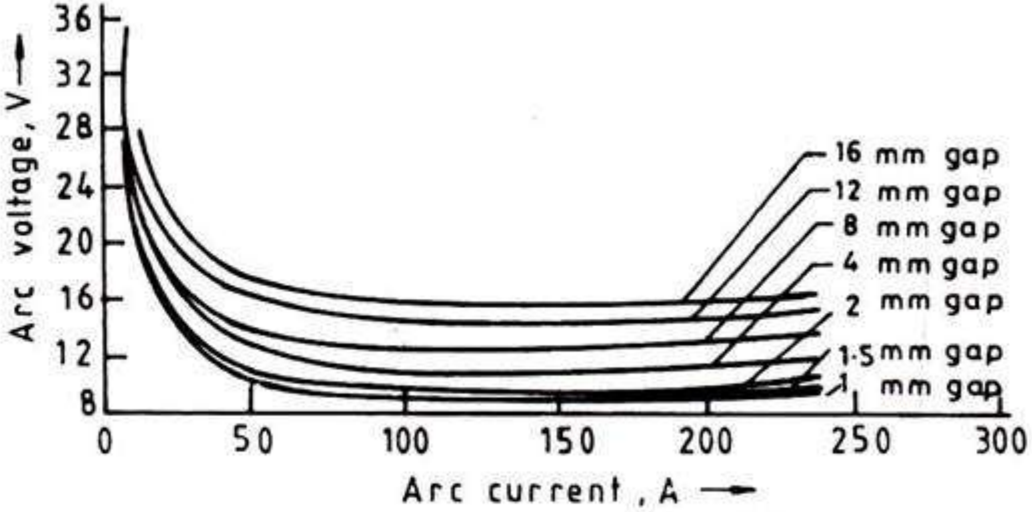
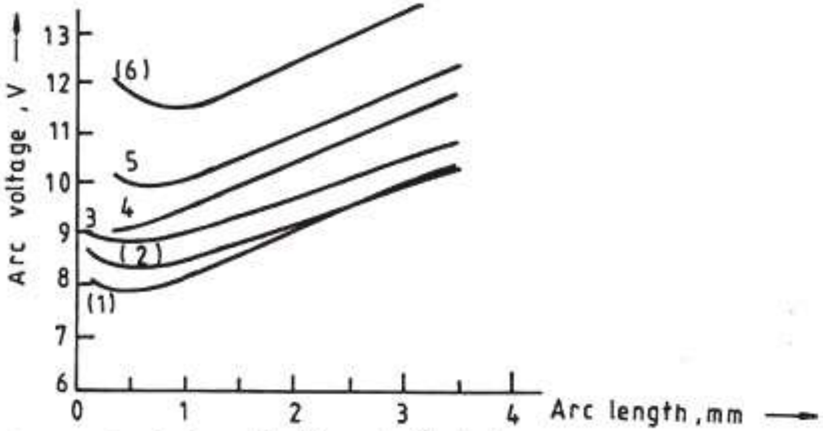


Fig. 3·14 Static volt-ampere characteristic of an argon-shielded tungsten arc.



(1) Only anode melted
(2) Only cathode melted
(3) Anode and cathode unmelted

Electrode : Thoriated tungsten
Diameter : 1·6 mm
Current : 40 A

(4) 100 A
(5) 50 A
(6) 30 A

Electrode : Pure tungsten
Diameter : 3 mm

Fig. 3·15 Arc length versus arc voltage for arcs under different sets of conditions.

http://www.yourarticlelibrary.com/welding/welding-arc/electrical-characteristics-of-an-arc-with-diagram-metallurgy/96458

ARC WELDING PROCESS PARAMETERS

ПАРАМЕТРЫ РЕЖИМА РУЧНОЙ ДУГОВОЙ СВАРКИ

ОСНОВНЫЕ

- Сварочный ток
- Напряжение дуги
- Скорость сварки
- Род и полярность тока

ДОПОЛНИТЕЛЬНЫЕ

- Положение шва в пространстве
- Число проходов
- Температура окружающей среды

СВАРОЧНЫЙ ТОК устанавливают в зависимости от диаметра электрода, а диаметр электрода выбирают в зависимости от толщины свариваемого изделия:

Толщина металла, мм	1-2	3	4-5	6-8	9-12	13-15	16 и более
Диаметр электрода, мм	1,5-2	3	3-4	4	4-5	5	6

ОРИЕНТИРОВОЧНЫЙ РАСЧЕТ СВАРОЧНОГО ТОКА

Диаметр электрода d=3-6ММ	Диаметр электрода d<3мм
I=(20+6d)dk	I=30dk

Коэффициент k	Нижний шов	Вертикальный шов	Потолочный шов
	1	0,9	0,8

WELDING CURRENT

See automatic arc welding current and resistance welding current.

AUTOMATIC ARC WELDING CURRENT

The current in the welding circuit during the making of a weld, but excluding upslope, downslope, and crater fill current. See Figures B.53 and B.54.

ARC VOLTAGE, *arc welding*

The electrical potential between the electrode and workpiece.

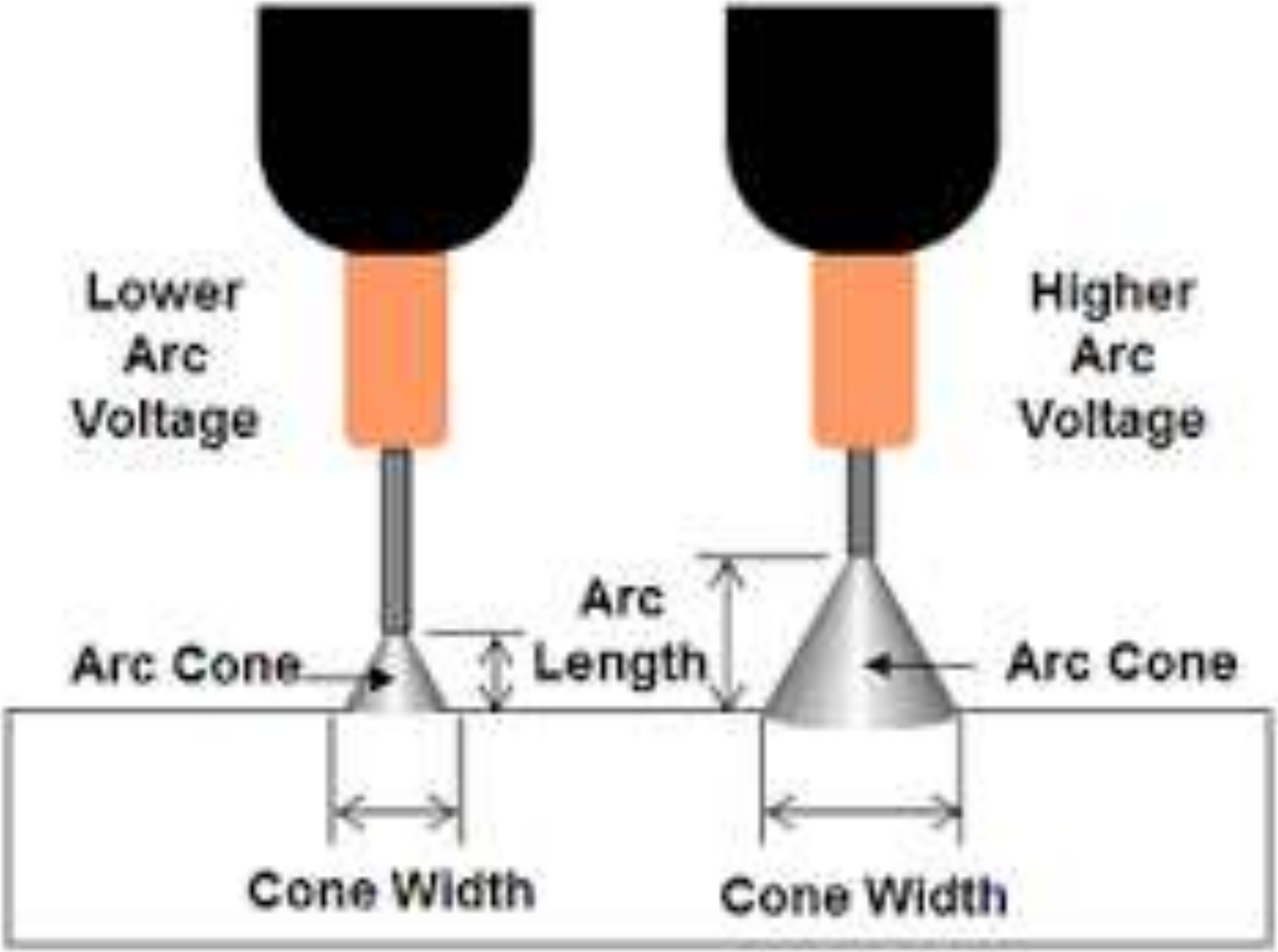
ARC LENGTH

The distance from the tip of the welding electrode to the adjacent surface of the weld pool.

НАПРЯЖЕНИЕ на дуге зависит от ее длины. Оптимальная длина дуги выбирается между минимальной и максимальной. Длинную дугу применять не рекомендуется

Минимальная	Максимальная
$\ell_д=0,5d_э$	$\ell_д=d_э+1$

$d_э$ - диаметр электрода (мм)


Lower
Arc
Voltage
Higher
Arc
Voltage
Arc
Length
Arc Cone
Arc Cone
Cone Width
Cone Width

ELECTRODE EXTENSION, *carbon arc cutting.*

The length of electrode extending beyond the electrode holder or cutting torch.

ELECTRODE EXTENSION, *flux cored arc welding, electrogas welding, gas metal arc welding, and submerged arc welding.*

The length of electrode extending beyond the end of the contact tip. See Figure B.38.

ELECTRODE EXTENSION, *gas tungsten arc welding and plasma arc welding.*

The length of tungsten electrode extending beyond the end of the collet. See Figures B.35 and B.36.

AWS A3.0M/A3.0:2010

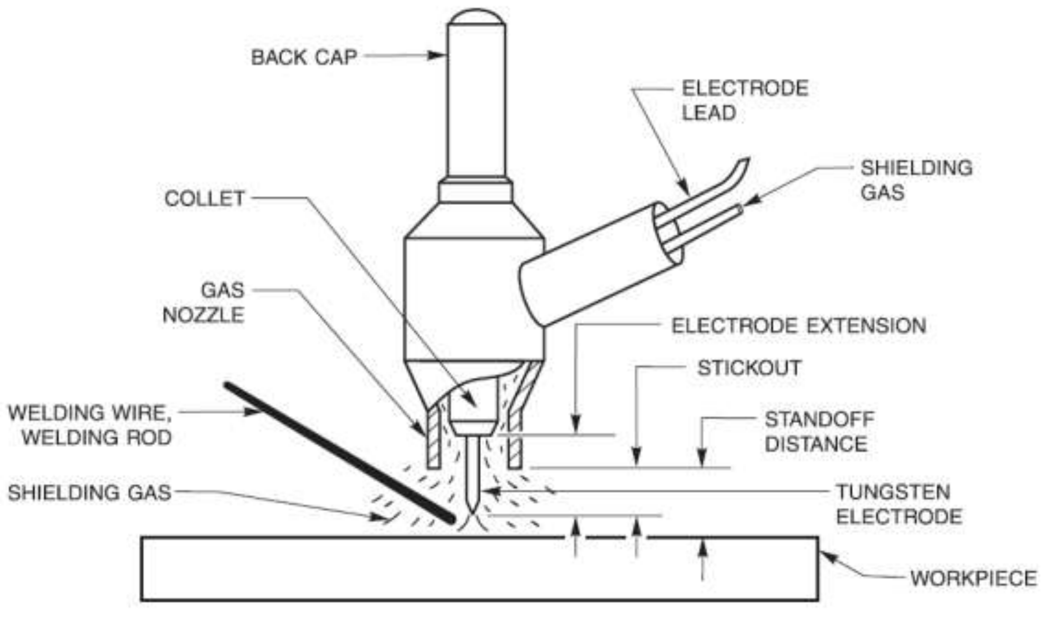


Figure B.36—Gas Tungsten Arc Welding Torch Nomenclature

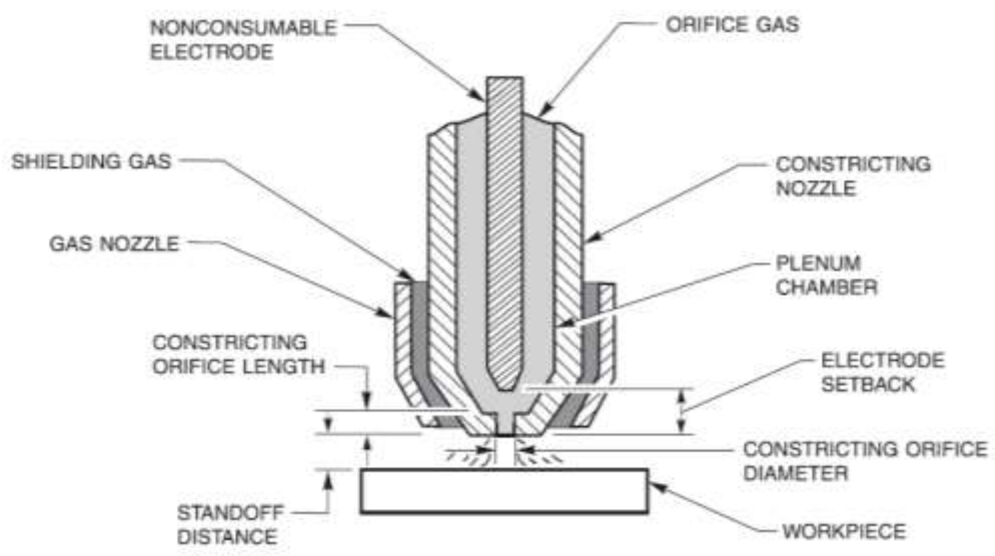
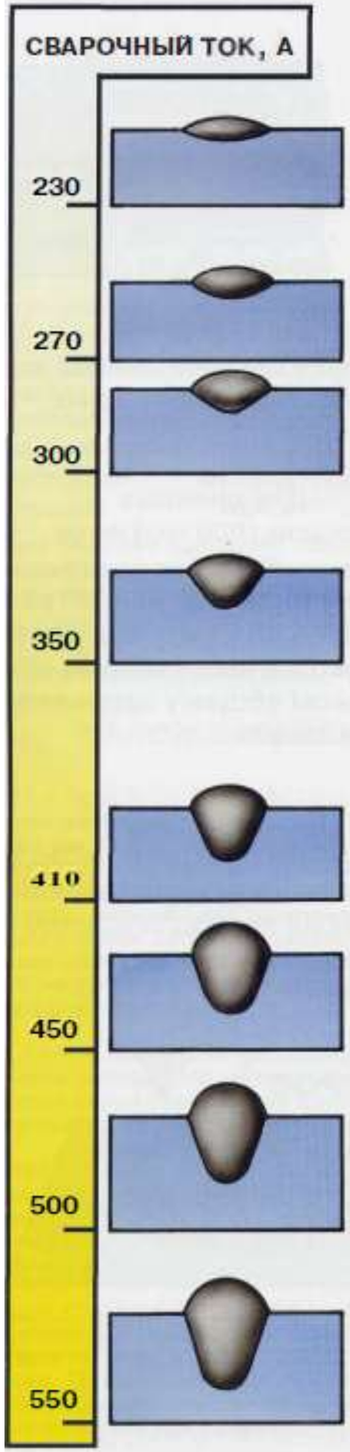
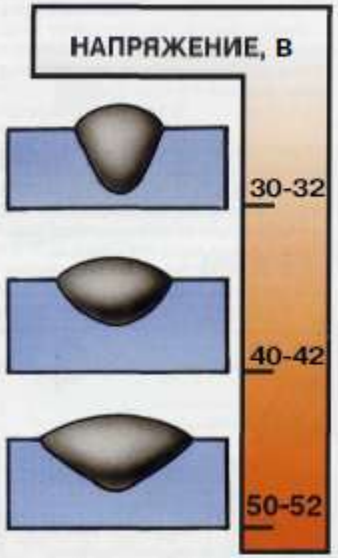
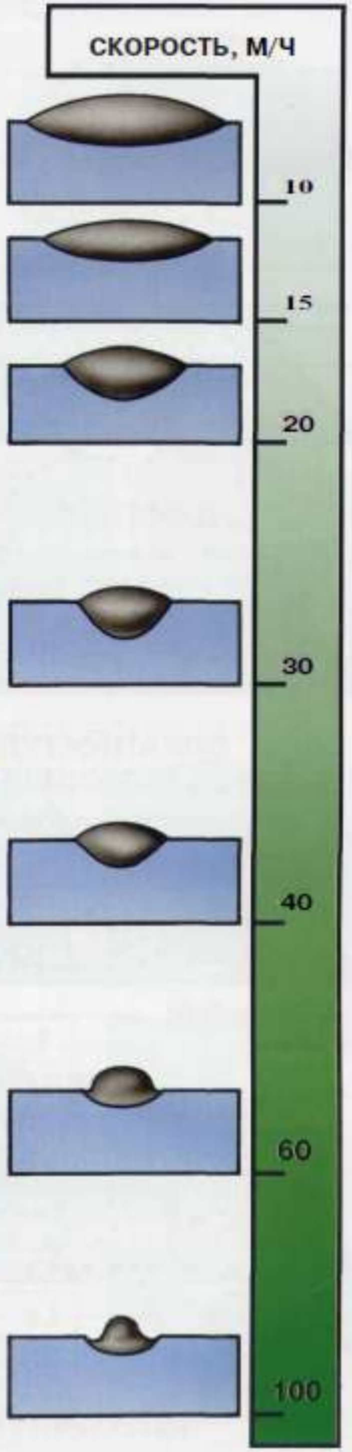


Figure B.35—Plasma Arc Torch Nomenclature

ВЛИЯНИЕ СВАРОЧНОГО ТОКА, НАПРЯЖЕНИЯ ДУГИ И СКОРОСТИ СВАРКИ НА ФОРМУ И РАЗМЕРЫ ШВА





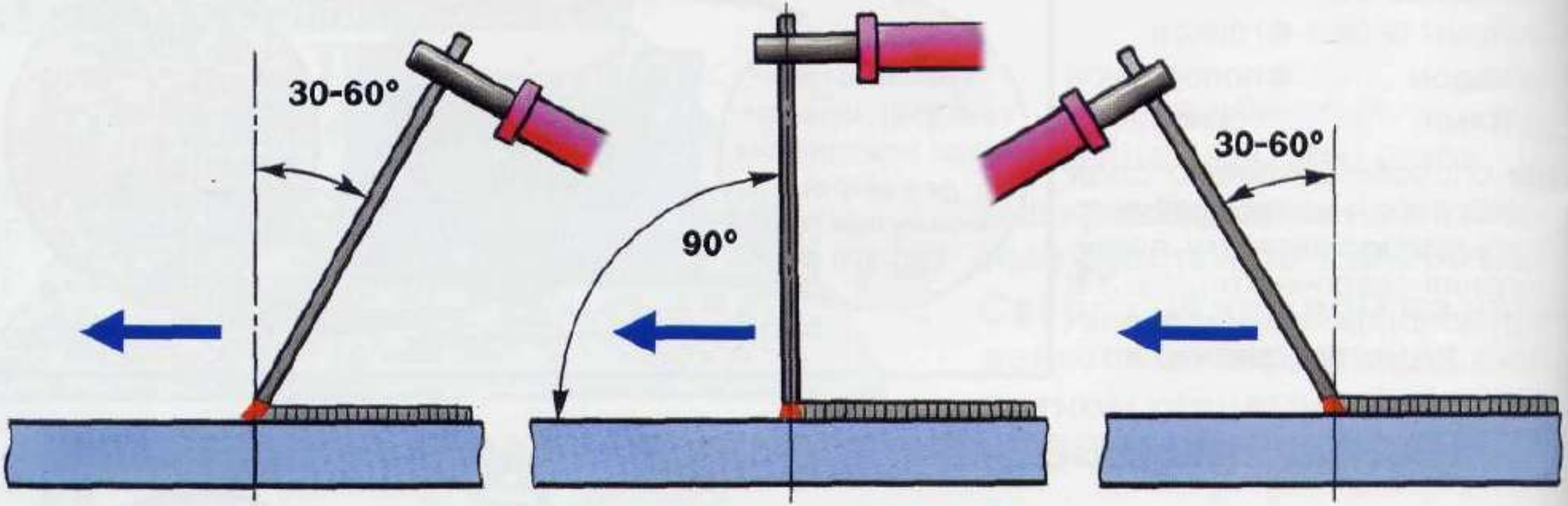


С УВЕЛИЧЕНИЕМ СВАРОЧНОГО ТОКА глубина провара увеличивается, ширина шва почти не изменяется

С ПОВЫШЕНИЕМ НАПРЯЖЕНИЯ ширина шва резко увеличивается, а глубина провара уменьшается. Это важно учитывать при сварке тонкого металла. Несколько уменьшается и выпуклость (усиление) шва. При одном и том же напряжении ширина шва при сварке на постоянном токе (особенно обратной полярности) значительно больше, чем ширина шва при сварке на переменном токе

С УВЕЛИЧЕНИЕМ СКОРОСТИ сначала глубина провара возрастает (до 40-50 м/ч), а затем уменьшается. При этом ширина шва уменьшается постоянно. При скорости более 70-80 м/ч основной металл не успевает прогреваться, и по обеим сторонам шва возможны подрезы

ПОЛОЖЕНИЯ ЭЛЕКТРОДА ПРИ СВАРКЕ



"УГЛОМ ВПЕРЕД"

Горизонтальные, вертикальные, потолочные швы, сварка неповоротных стыков труб

"ПОД ПРЯМЫМ УГЛОМ"

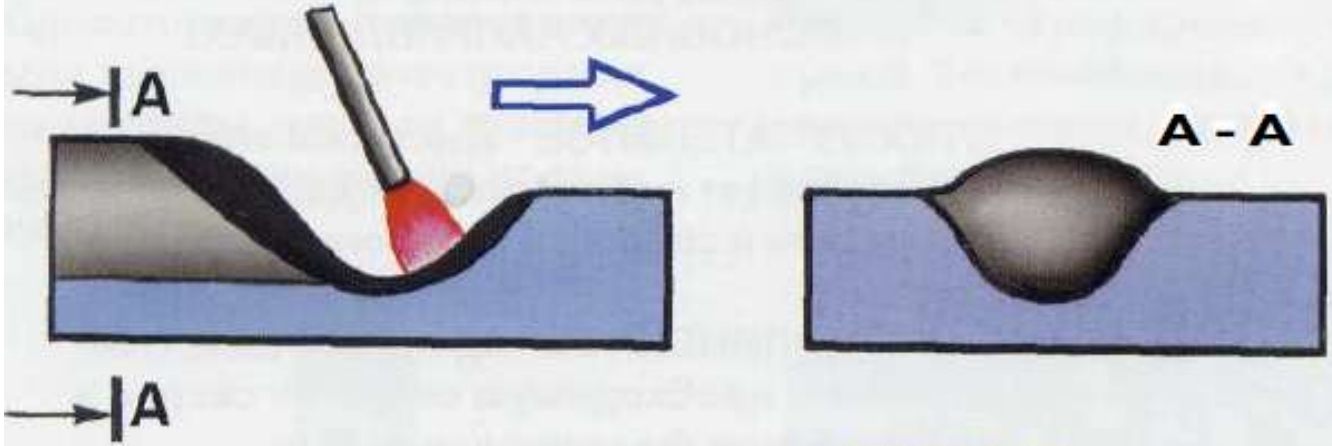
Сварка в труднодоступных местах

"УГЛОМ НАЗАД"

Угловые и стыковые соединения

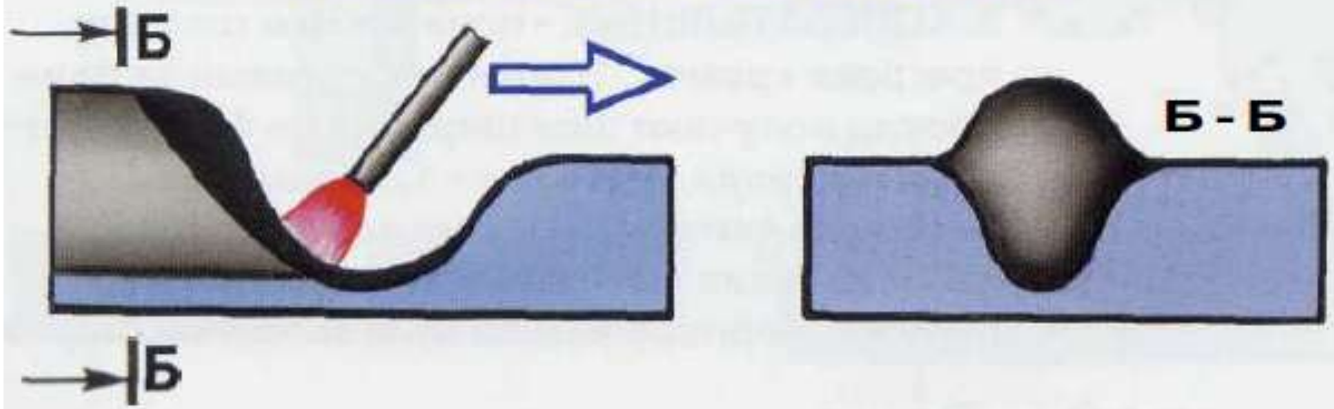
ВЛИЯНИЕ УГЛА НАКЛОНА ЭЛЕКТРОДА И ИЗДЕЛИЯ

СВАРКА УГЛОМ ВПЕРЕД

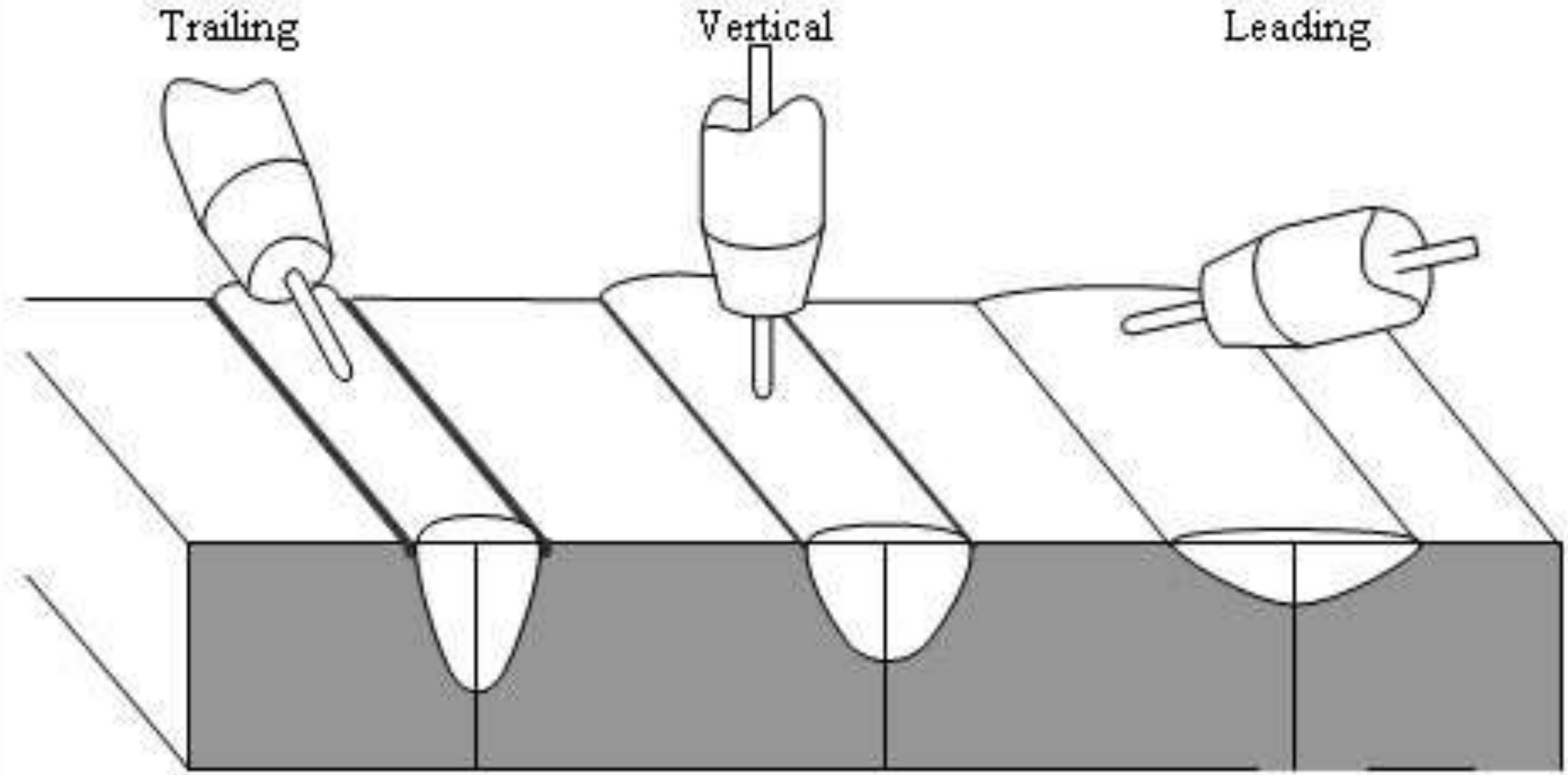


При сварке углом вперед уменьшается глубина провара и высота выпуклости шва, но заметно возрастает его ширина, что позволяет использовать этот способ при сварке металла небольшой толщины. Лучше проплавляются кромки, поэтому возможна сварка на повышенных скоростях

СВАРКА УГЛОМ НАЗАД



При сварке углом назад глубина провара и высота выпуклости увеличиваются, но уменьшается ширина. Прогрев кромок недостаточен, поэтому возможны несплавления и образование пор



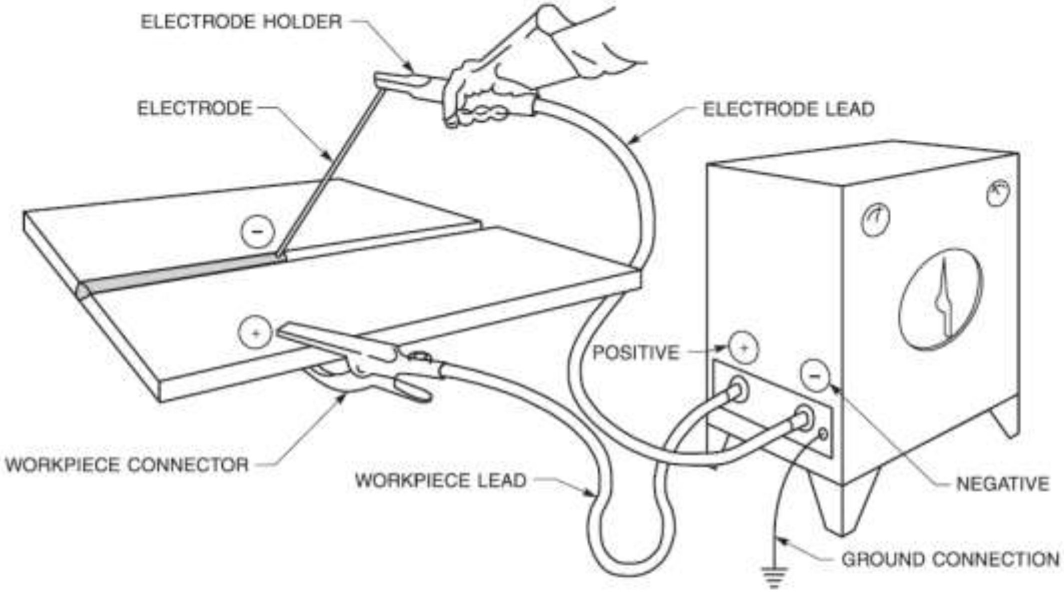
Penetration:	Deep	Moderate	Shallow
Reinforcement:	Maximum	Moderate	Minimum
Tendency to undercut:	Severe	Moderate	Minimum

Effect of electrode angle on butt welds.

1. Energy source

Classification of Fusion welding based on energy source

Energy source	Types of welding
Chemical	Oxy fuel gas welding, Exothermic welding/ Thermite welding, Reaction brazing/Liquid phase bonding
Radiant energy	Laser beam welding, Electron beam, Infrared welding/ brazing, Imaging arc welding, Microwave welding,
Electric-Perm. electrode arc	Gas tungsten arc welding, plasma arc welding, Carbon arc welding, atomic hydrogen welding, Stud arc welding
Electric-Consumable electrode	Gas metal arc welding, Shielded metal arc welding, Submerged arc welding, Electrogas welding, Electroslag welding, Flux cored arc welding
Electric-Resistance	Resistance spot, resistance seam, projection welding, flash/ upset welding, Percussion, Induction welding



(B) DIRECT CURRENT ELECTRODE NEGATIVE

Figure B.34—Welding Current Polarity

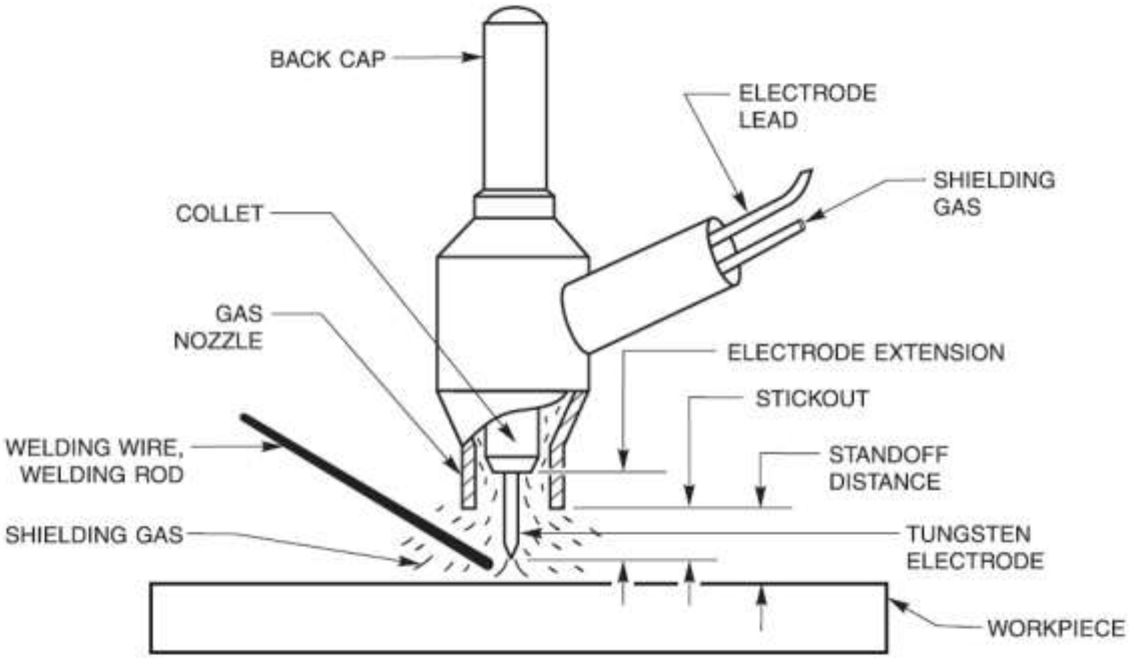
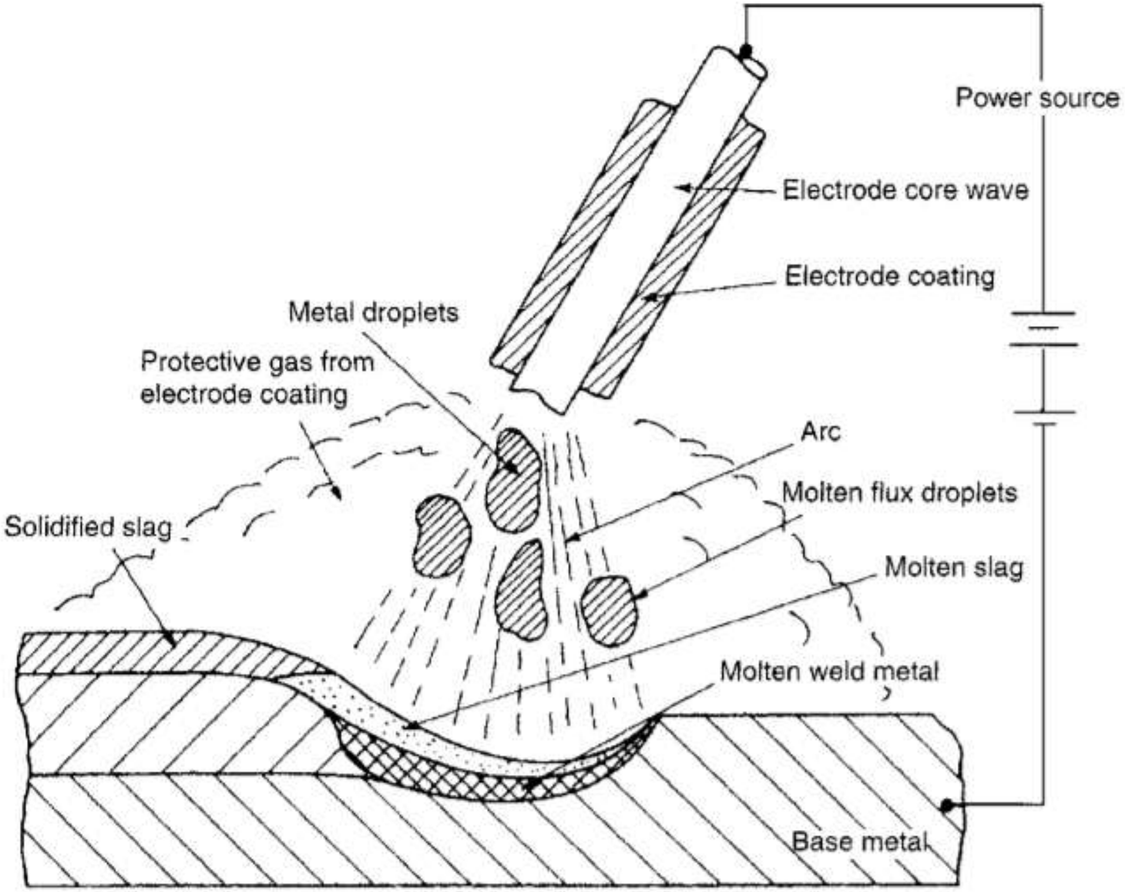
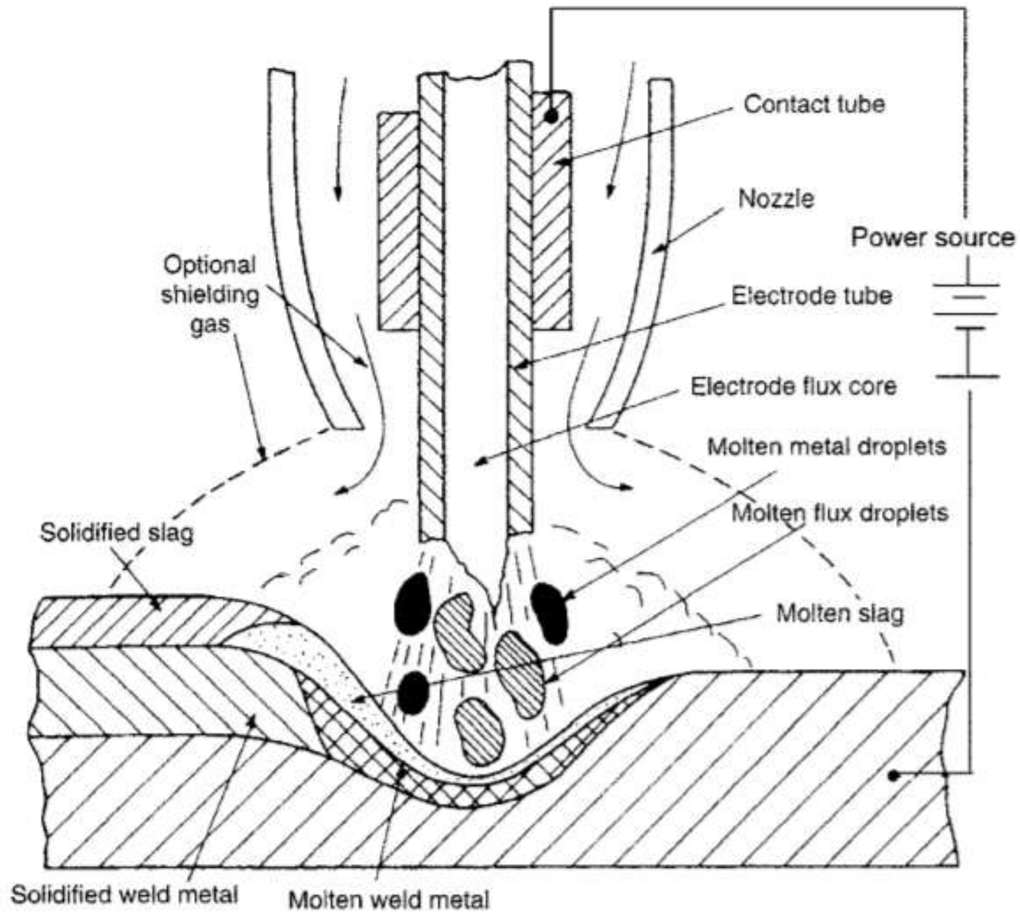


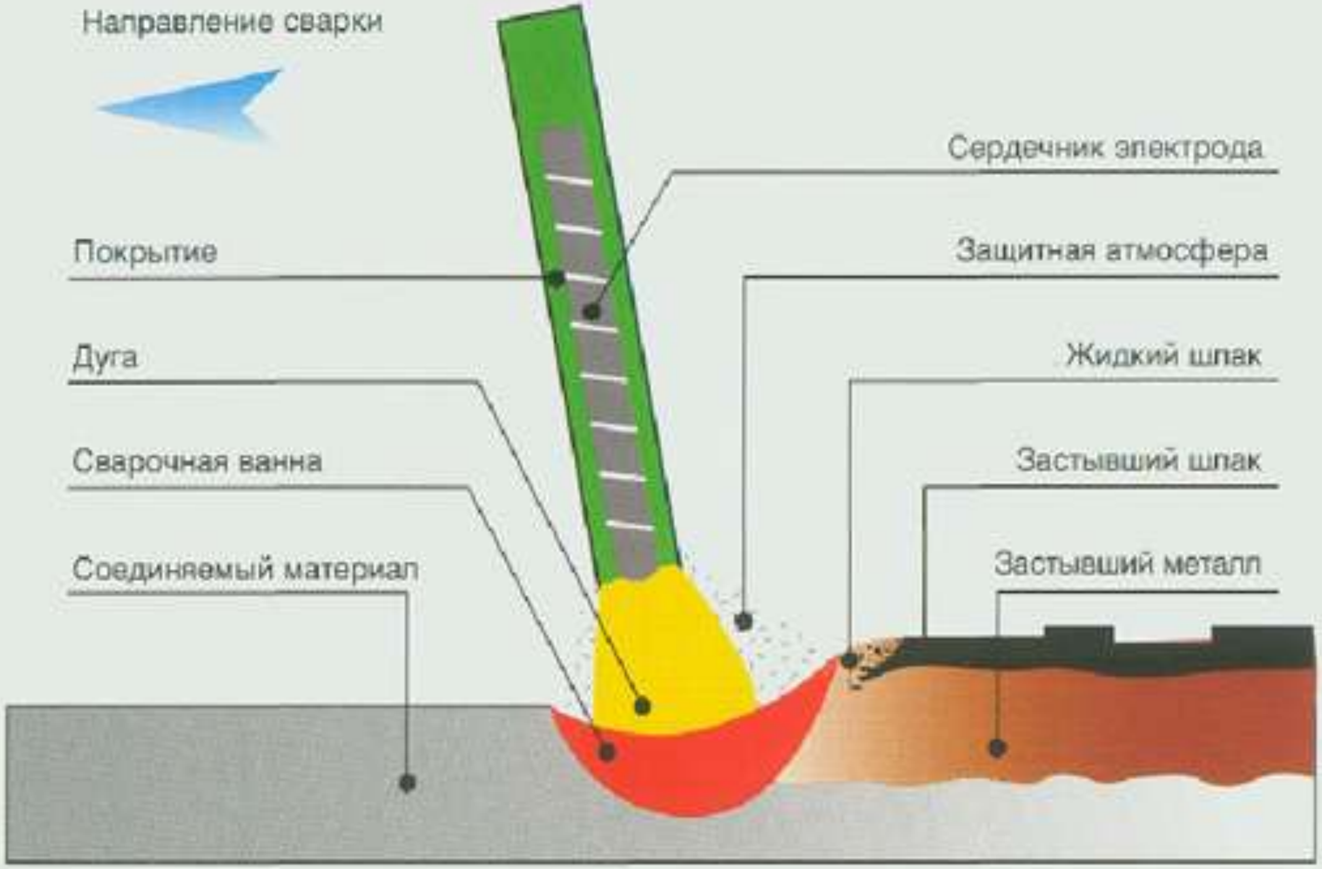
Figure B.36—Gas Tungsten Arc Welding Torch Nomenclature

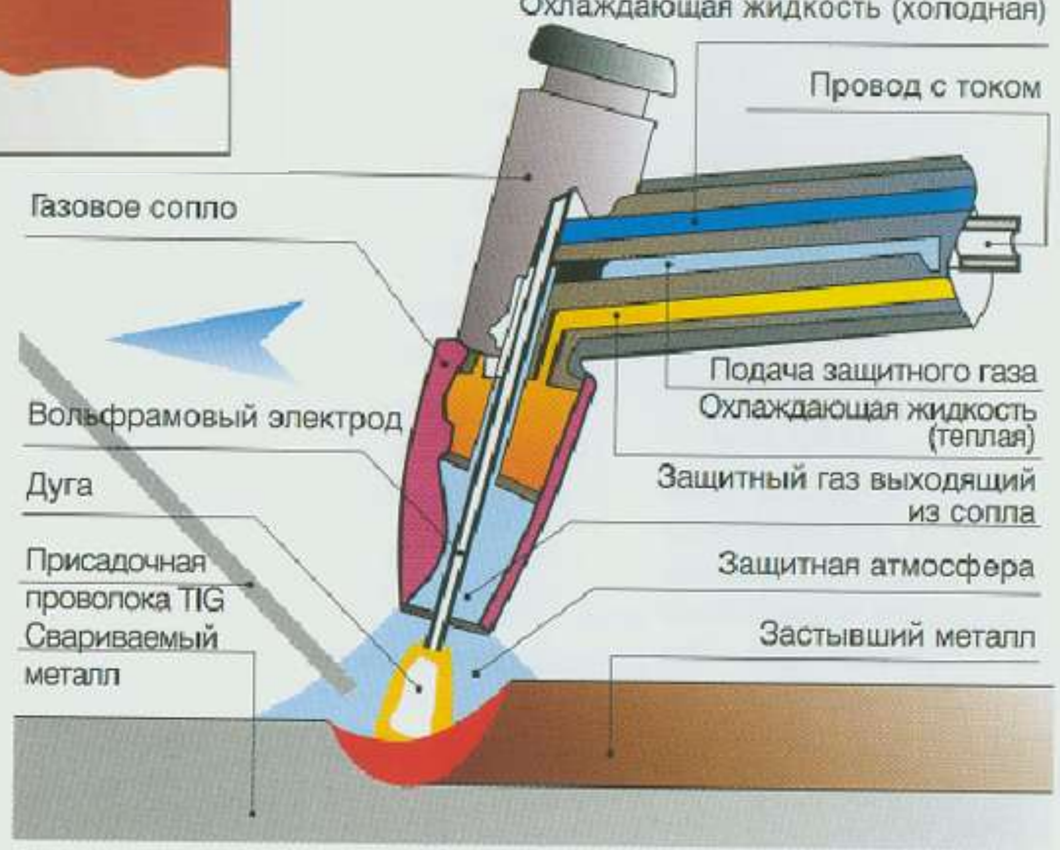

Power source
Electrode core wave
Electrode coating
Metal droplets
Protective gas from
electrode coating
Arc
Molten flux droplets
Solidified slag
Molten slag
Molten weld metal
Base metal

(a)


Contact tube
Nozzle
Power source
Optional
shielding
gas
Electrode tube
Electrode flux core
Molten metal droplets
Solidified slag
Molten flux droplets
Molten slag
Solidified weld metal
Molten weld metal

(b)


Направление сварки
Сердечник электрода
Покрытие
Защитная атмосфера
Дуга
Жидкий шлак
Сварочная ванна
Застывший шлак
Соединяемый материал
Застывший металл


Охлаждающая жидкость (холодная)
Провод с током
Газовое сопло
Подача защитного газа
Охлаждающая жидкость (теплая)
Вольфрамовый электрод
Дуга
Защитный газ выходящий из сопла
Присадочная проволока TIG
Защитная атмосфера
Свариваемый металл
Застывший металл

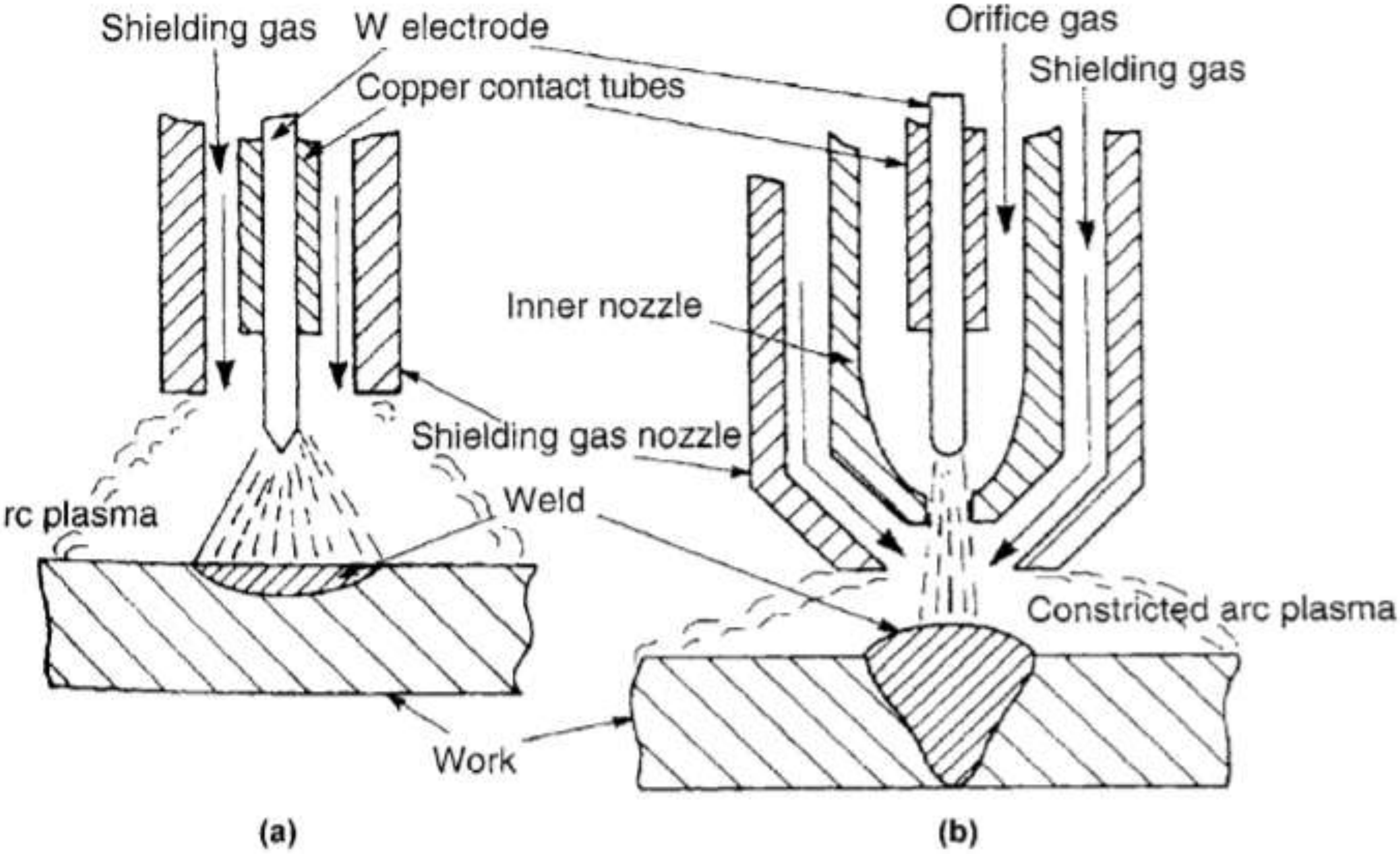
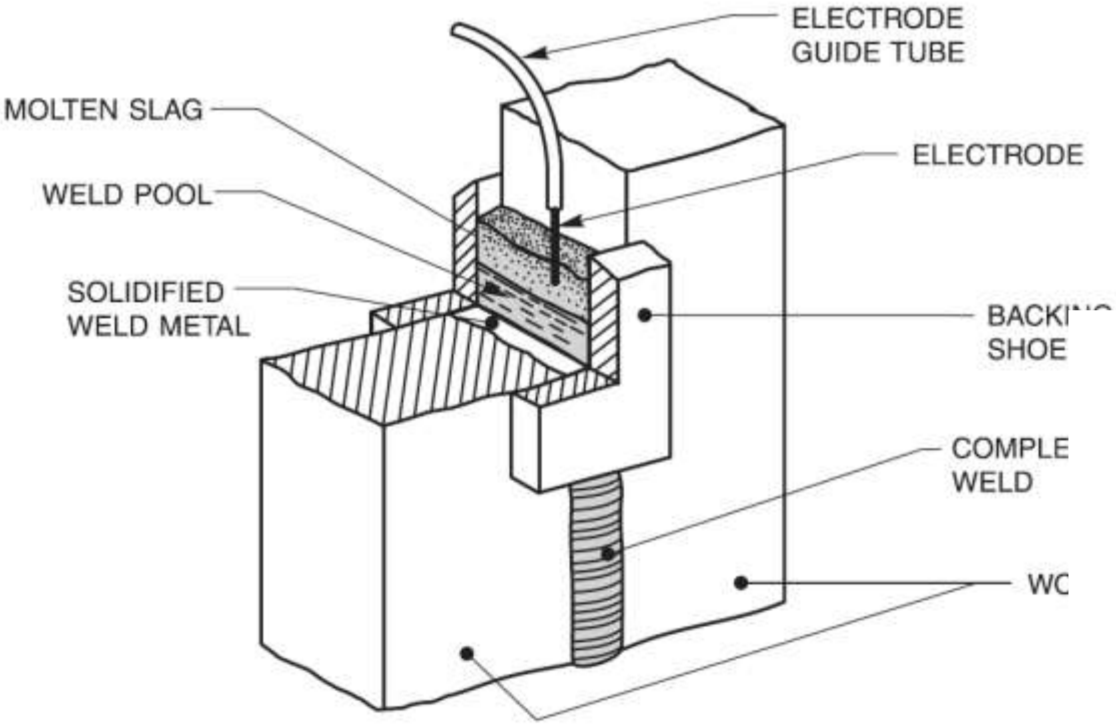
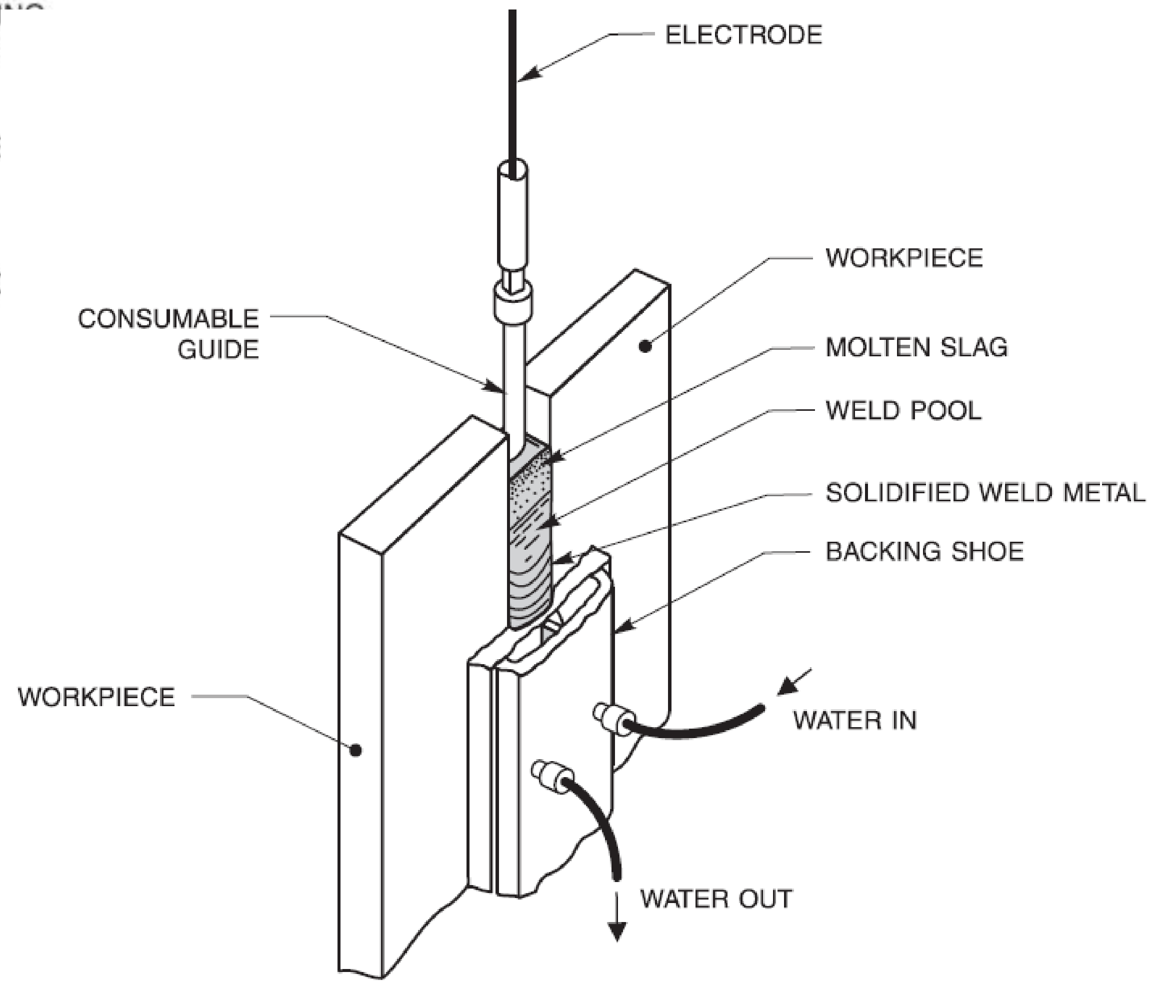


Fig. 7 Schematic illustration comparing (a) gas tungsten arc welding and (b) plasma arc welding processes. Source: Ref 2



(A) ELECTROSLAG WELDING NOMENCLATURE



(B) CONSUMABLE GUIDE ELECTROSLAG WELDING NOMENCLATURE

Figure B.37—Electroslag Welding Process Nomenclature

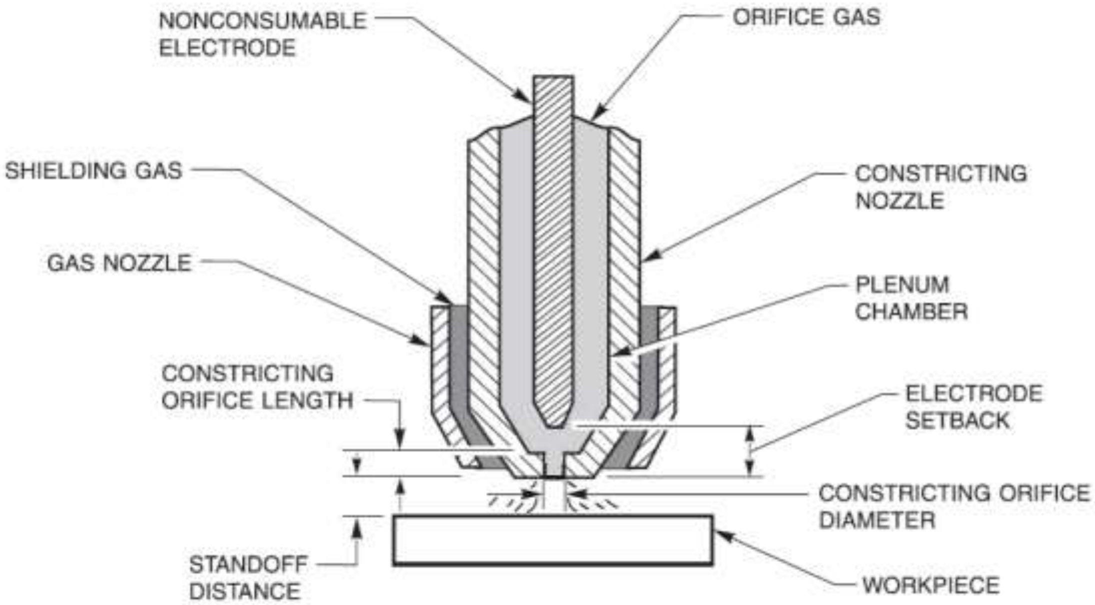
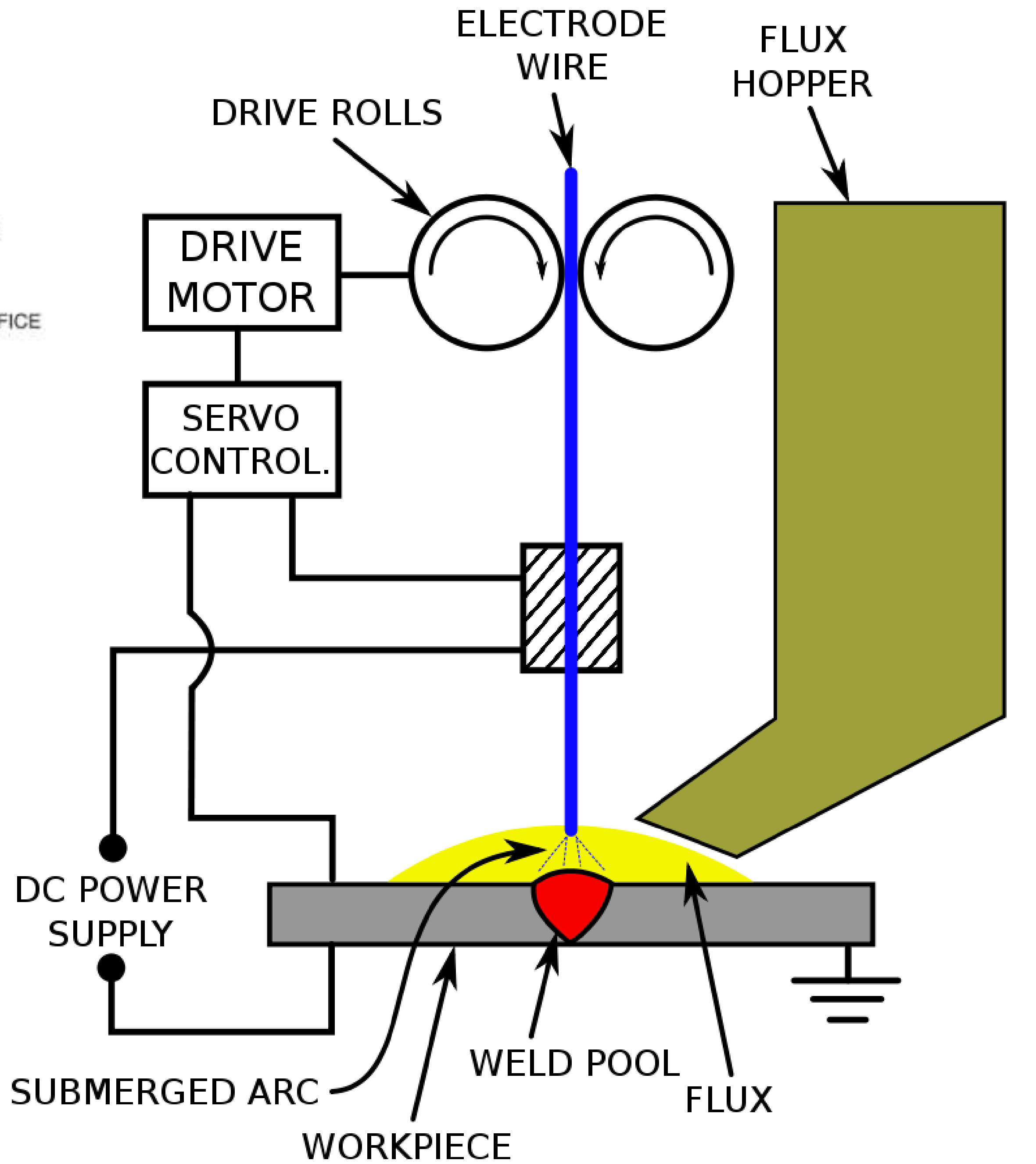


Figure B.35—Plasma Arc Torch Nomenclature



BARE METAL ARC WELDING (BMAW)

An arc welding process using an arc between a bare or lightly coated electrode and the weld pool. The process is used without shielding, without the application of pressure, and filler metal is obtained from the electrode. This is an

SHORT CIRCUIT GAS METAL ARC WELDING (GMAW-S).

A gas metal arc welding process variation in which the consumable electrode is deposited during repeated short circuits.

PULSED GAS METAL ARC WELDING (GMAW-P).

A gas metal arc welding process variation in which the current is pulsed. See also pulsed power welding.

PULSED GAS TUNGSTEN ARC WELDING (GTAW-P).

A gas tungsten arc welding process variation in which the current is pulsed. See also pulsed power welding.

ELECTROGAS WELDING (EGW)

An arc welding process using an arc between a continuous filler metal electrode and the weld pool, employing approximately vertical welding progression with backing to confine the molten weld metal. The process is used with or without an externally supplied shielding gas and without the application of pressure.

METAL TRANSFER PROCESSES IN ARC WELDING AND ARC WELDING ENERGY BALANCE

METAL TRANSFER MODE, *gas metal arc welding*

The manner in which molten metal travels from the end of a consumable electrode across the welding arc to the workpiece. *See also globular transfer, pulsed spray transfer, rotational spray transfer, short circuiting transfer, and spray transfer.*

GLOBULAR TRANSFER, *gas metal arc welding*

The transfer of molten metal in large drops from a consumable electrode across the arc.

See Figure B.39(A). See also short circuiting transfer and spray transfer.

SHORT CIRCUITING TRANSFER, *gas metal arc welding*

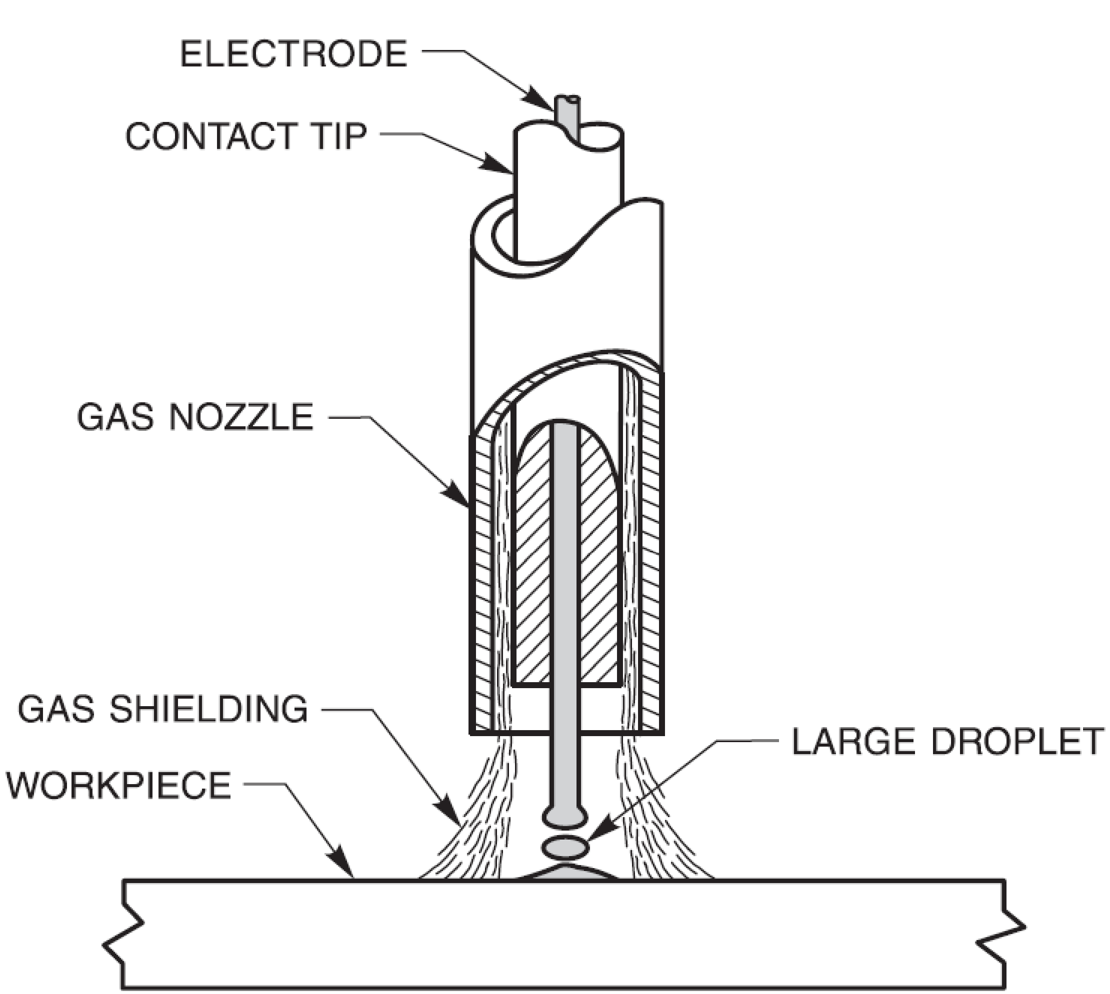
Metal transfer in which molten metal from a consumable electrode is deposited during repeated short circuits.

See Figure B.39(B). See also globular transfer and spray transfer.

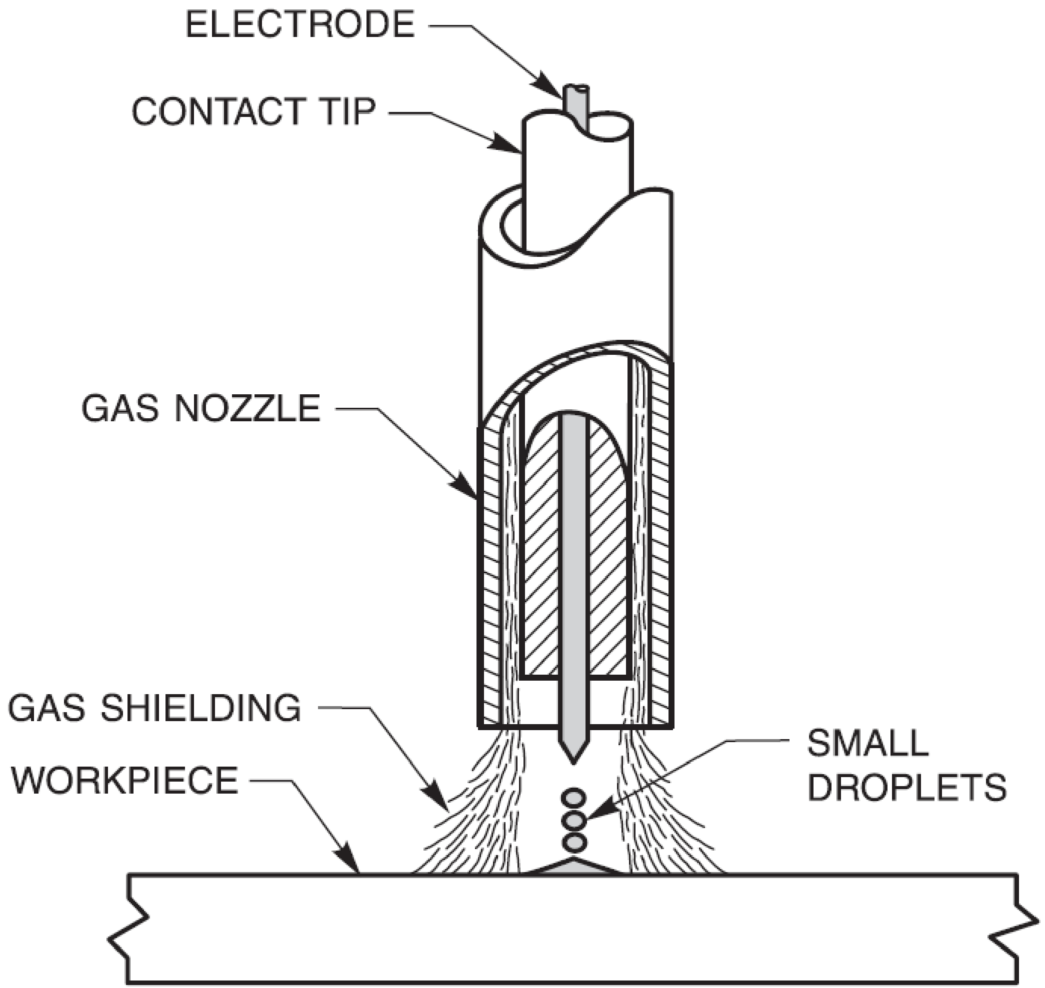
SPRAY TRANSFER, *gas metal arc welding*

Metal transfer in which molten metal from a consumable electrode is propelled *axially* across the arc in small droplets.

See Figure B.39(C). See also globular transfer and short circuiting transfer.



(A) GLOBULAR TRANSFER



(C) SPRAY TRANSFER

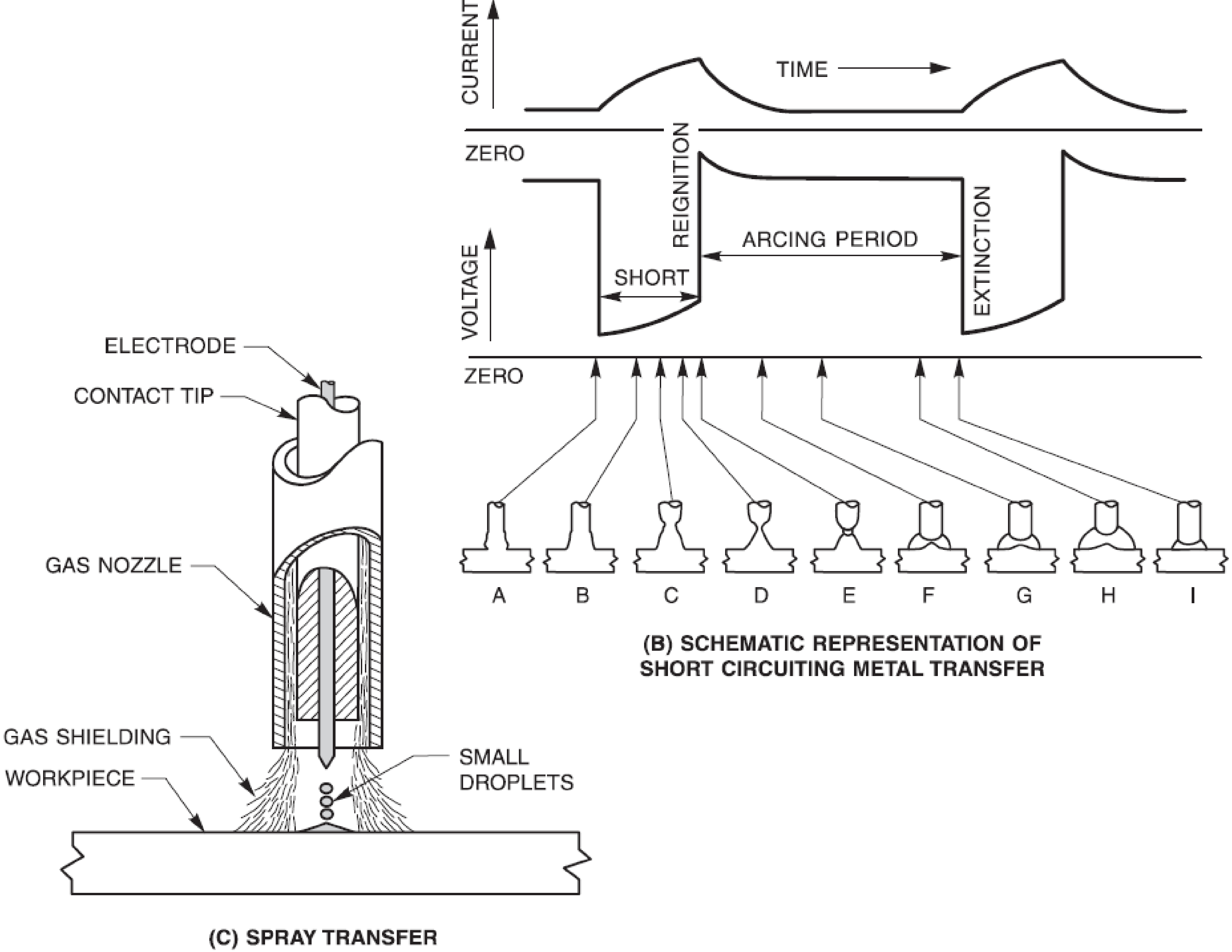
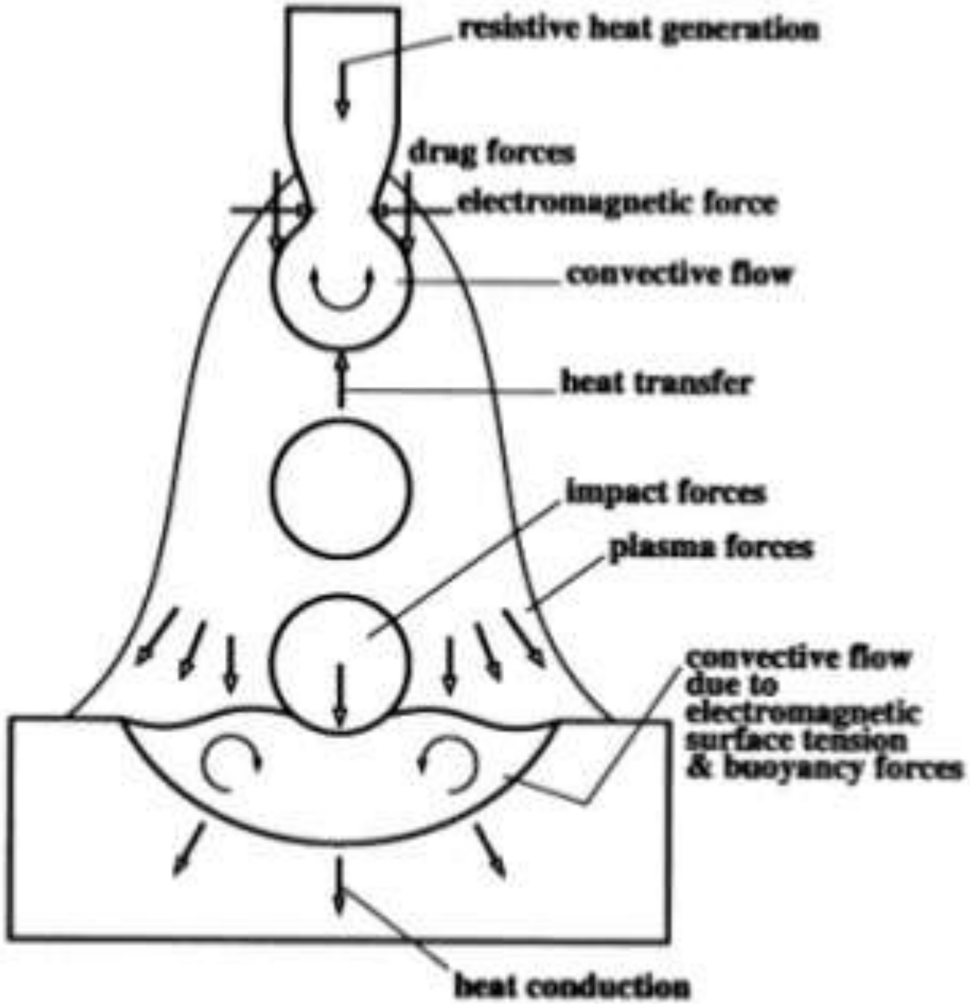


Figure B.39—Metal Transfer in Gas Metal Arc Welding

Metal transfer in Arc welding
(Consumable electrode)



Metal Transfer Modes

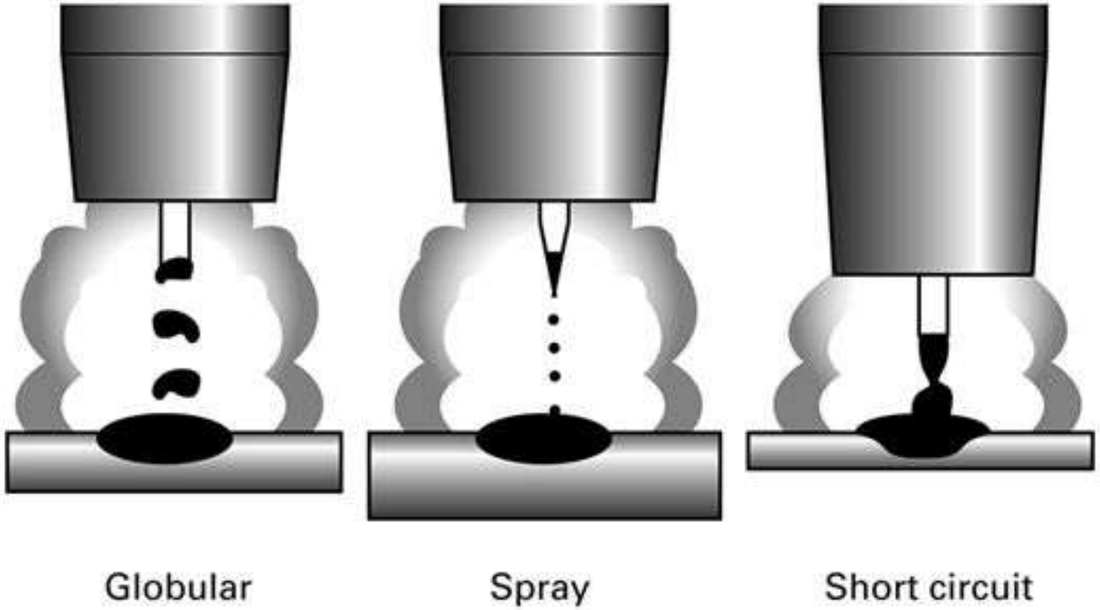


FIGURE 31-9 Three modes of metal transfer during arc welding. *(Courtesy of Republic Steel Corporation, Youngstown, OH)*

As the electrode melts, the arc length and the electrical resistance of the arc length vary. To maintain a stable and satisfactory welding conditions, the electrode must be moved toward the work at a controlled rate.

https://slideplayer.com/slide/232264/ - very simple!
https://slideplayer.com/slide/1709849/

Globular Transfer

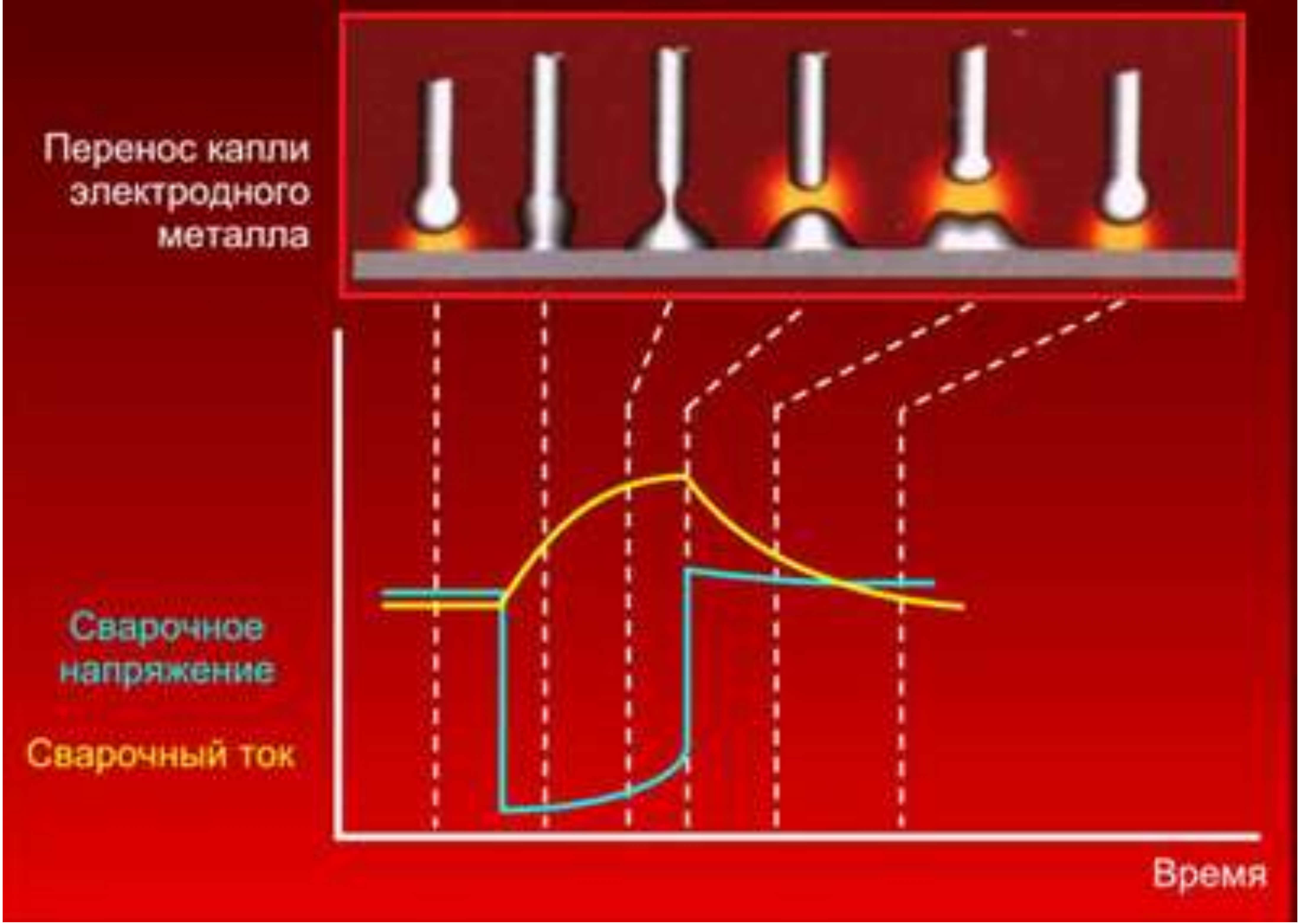
- Welding current and wire speed are increased above maximum for short arc
- Droplets of metal have a greater diameter than the wire being used
- Spatter present
- Welding is most effectively done in the flat position when using globular transfer

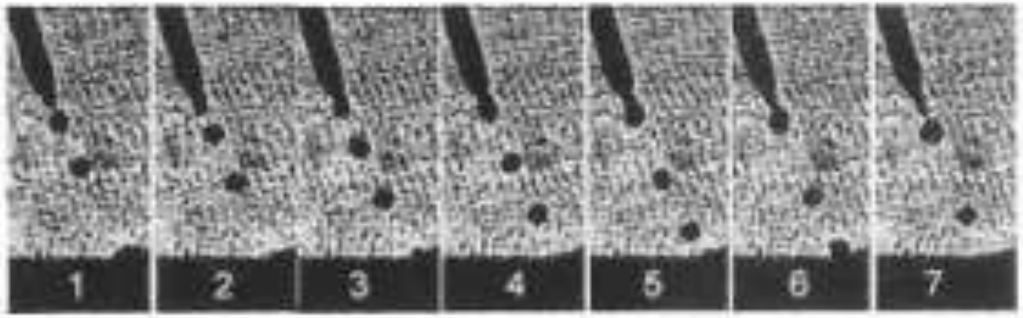
Spray Arc Transfer

- Occurs when the current and voltage settings are increased higher than that used for Globular Transfer
- Used on thick sections of base material, best suited for flat position due to large weld puddle
- Spatter is minimal to none

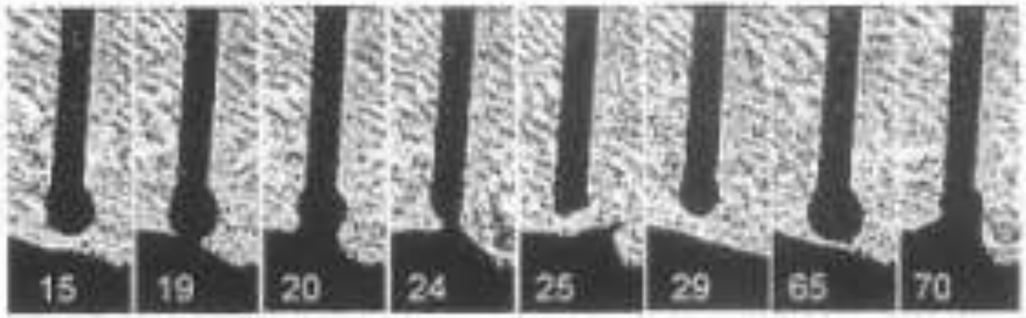
Short Circuit (Short Arc)

- Operates at low voltages and welding current
- Small fast-freezing weld puddle obtained
- Useful in joining thin materials in any position, as well as thick materials in vertical and overhead positions
- Metal transfer occurs when an electrical short circuit is established

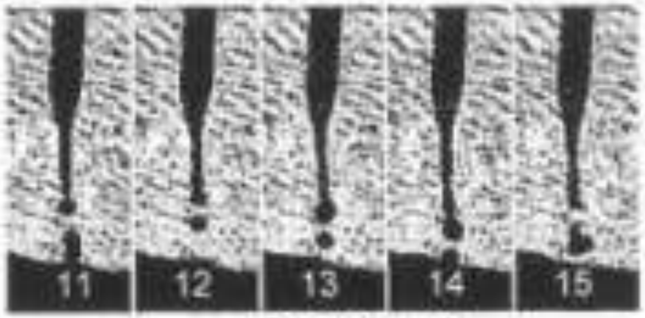

Перенос капли
электродного
металла
Сварочное
напряжение
Сварочный ток
Время



Мелкокапельный

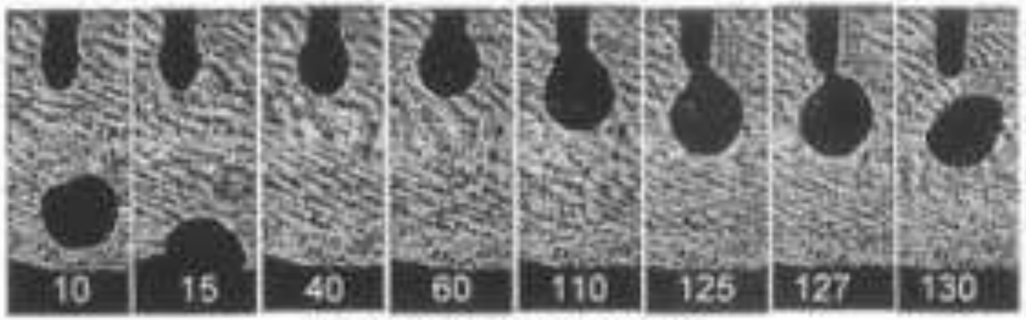


С короткими замыканиями

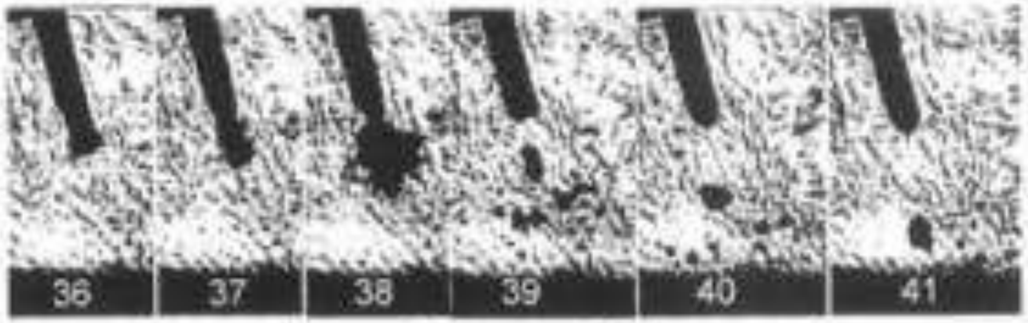


Струйный

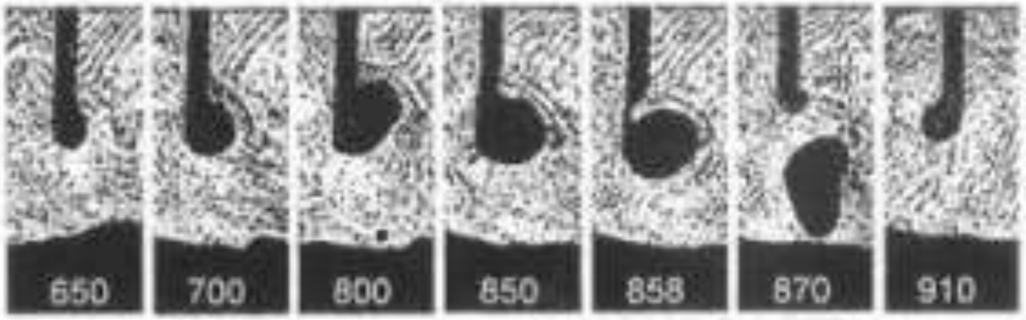

Струйно-вращательный



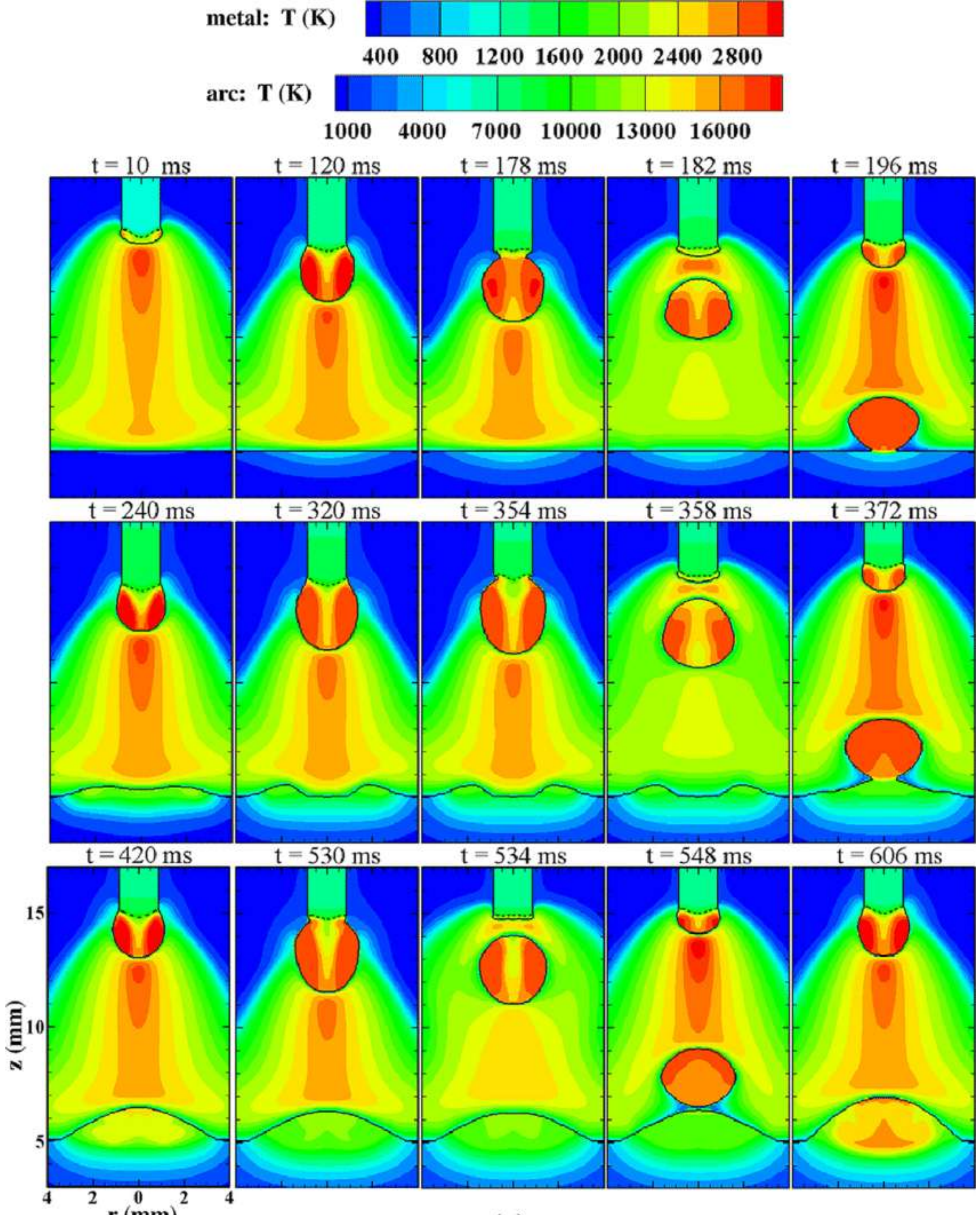
Крупнокапельный



Взрывной

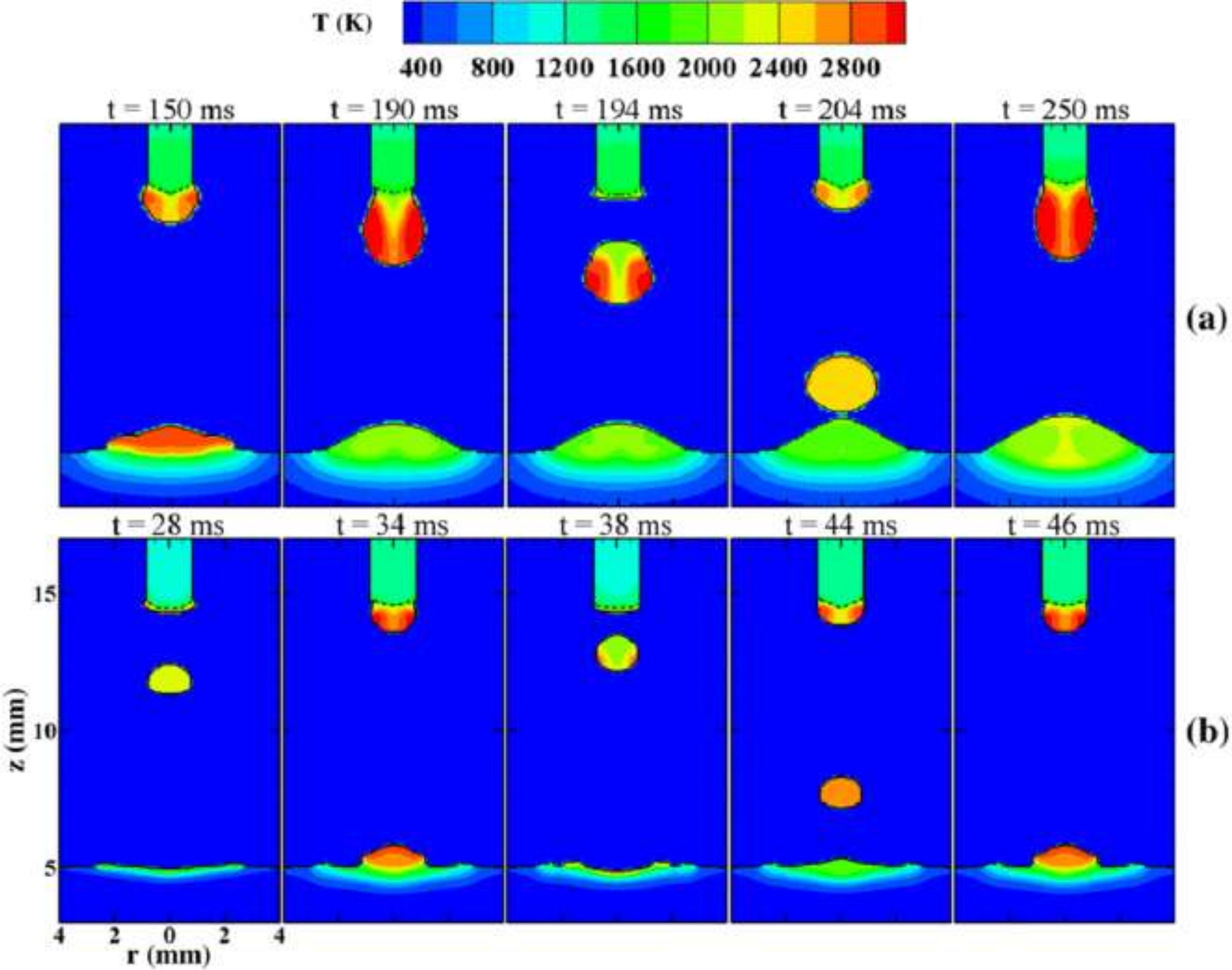


Крупнокапельный отклонённый

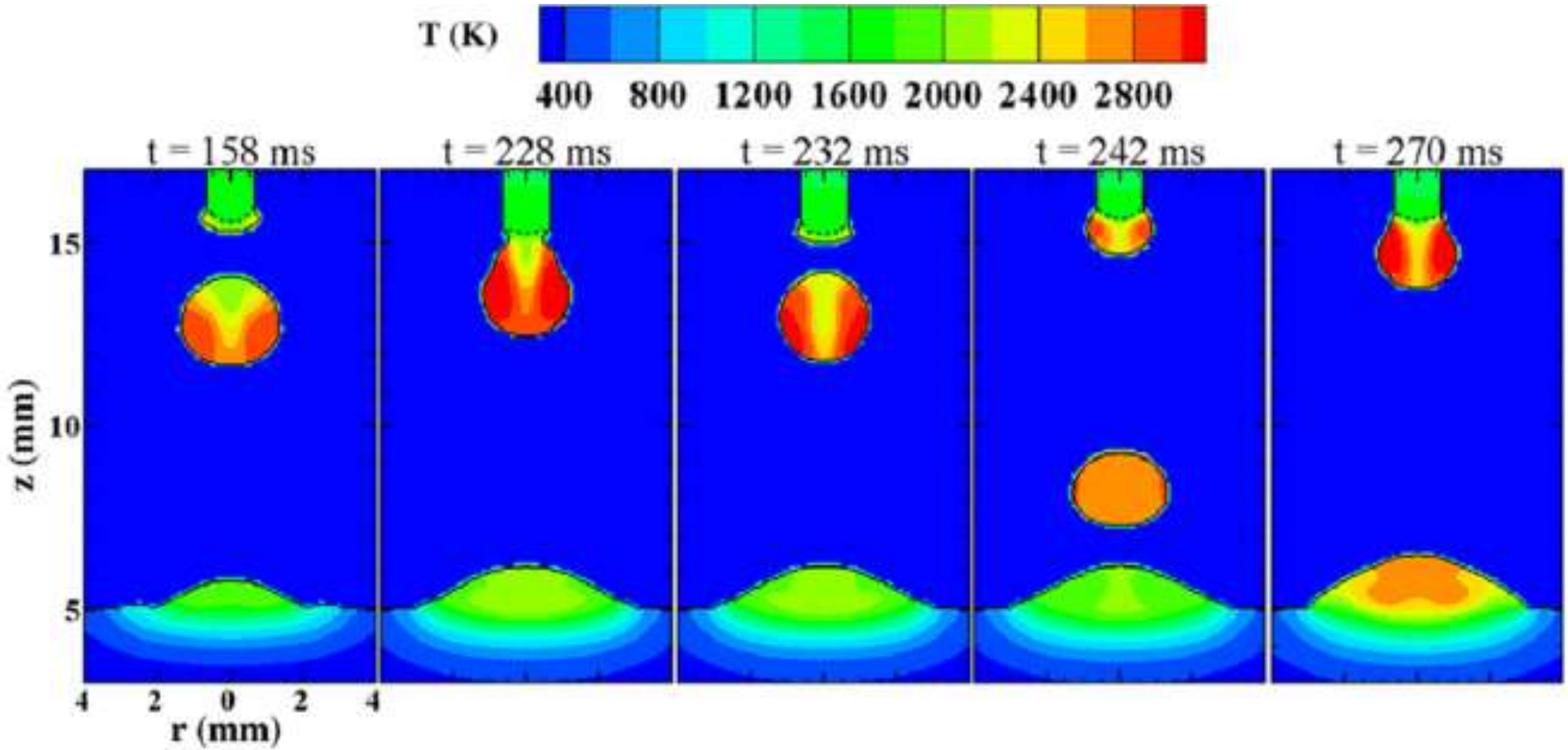


(a)

The sequences of temperature and velocity distributions in the metal and in the arc for V w = 4 cm/s, I = 200 A and d = 1.6 mm:
(a) temperature and (b) velocity



The sequence of temperature distributions in the metal showing the evolution of the third droplet: (a) V w = 6 cm/s, I = 240 A and d = 1.6 mm; (b) V w = 7 cm/s, I = 280 A and d = 1.6 mm



The sequence of temperature distributions in the metal showing the evolution of the third droplet: V w = 9 cm/s, I = 200 A and d = 1.2 mm

https://www.researchgate.net/figure/The-sequence-of-temperature-distributions-in-the-metal-showing-the-evolution-of-the-third_fig5_287214987

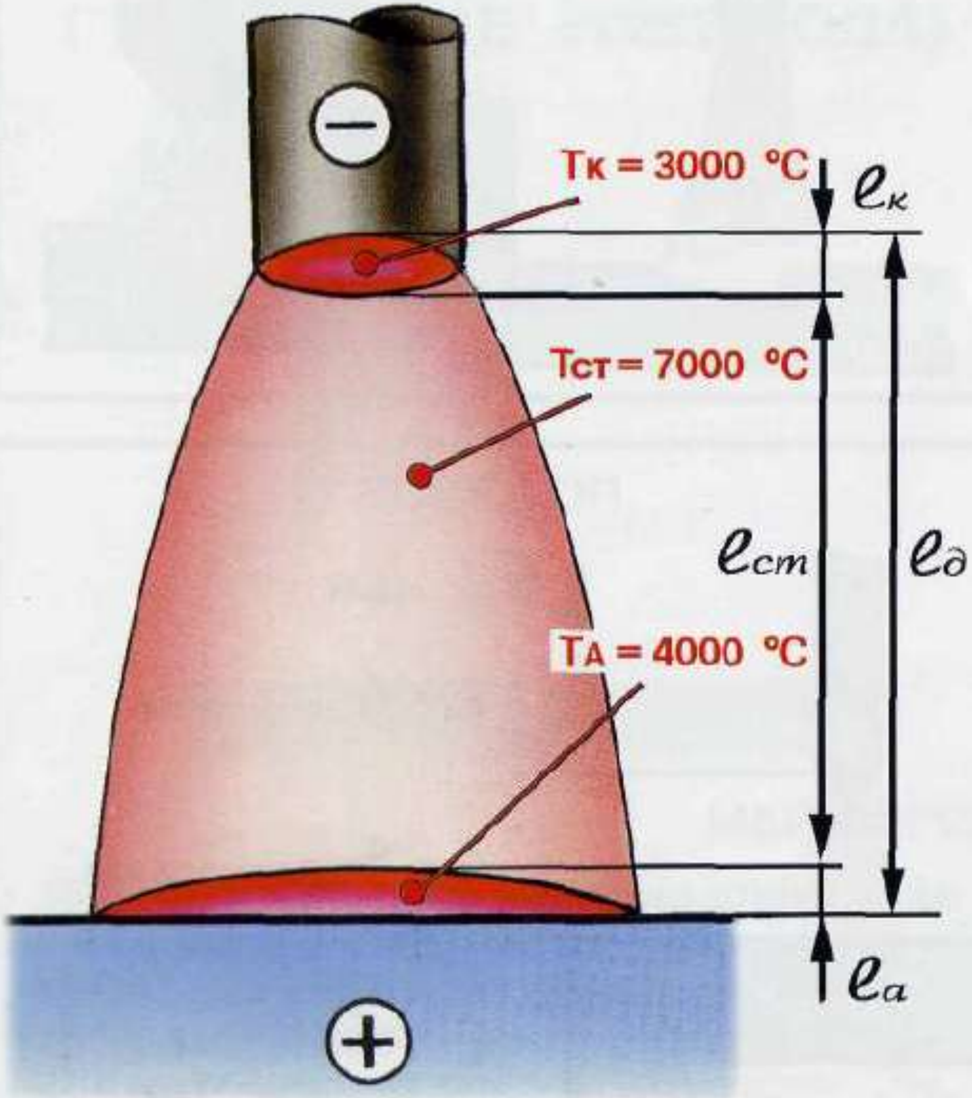
Effect of welding speed

- Increasing velocity → elongates the teardrop more and more, → narrows the fusion and heat-affected zone → overall melted volume constant
- Very high welding speeds → the tail of the teardrop weld pool detaches → isolate regions of molten metal → lead to shrinkage-induced cracks along the centerline of the weld

https://www.slideshare.net/nishant1064/welding-lectures-9-10

https://www.slideshare.net/SurenSirohi/11-welding

СТРОЕНИЕ И ХАРАКТЕРИСТИКИ



$\ell_к$ - *катодная область*

$\ell_а$ - *анодная область*

$\ell_{ст}$ - *столб дуги*

$\ell_д$ - *длина дуги*

$\ell_д = \ell_а + \ell_к + \ell_{ст}$

$\ell_а \approx \ell_к = 10^{-5} \div 10^{-3}$ см

ТЕПЛОВАЯ МОЩНОСТЬ ДУГИ

$$Q = 0{,}24\, k\, I_{св}\, U_д ,$$

где Q - тепловая мощность, кал/с;

0,24 - коэффициент перевода электрических величин в тепловые, кал/Вт · с;

k - коэффициент снижения мощности дуги при сварке на переменном токе (0,7-0,97);

$I_{св}$ - сварочный ток, А;

$U_д$ - напряжение на дуге, В

Значения эффективных КПД обычно определяют экспериментальным путем. Они представляют собой отношения тепловой мощности отдельных составляющих теплового баланса к тепловому эквиваленту электрической энергии дуги. Эффективный КПД процесса нагрева изделия сварочной дугой зависит главным образом от условий ее горения и при различных способах сварки имеет следующие значения:

Под флюсом .... 0,80...0,95
Плавящимся электродом
с высококачественным покрытием .... 0,70...0,85
В углекислом газе .... 0,58...0,72
В углекислом газе с порошковой
проволокой .... 0,70...0,85
Неплавящимся электродом в аргоне .... 0,50...0,60
Плавящимся электродом в аргоне .... 0,70...0,80
Вибрирующим электродом
в струе жидкости .... 0,60...0,70

Для большинства открытых дуг длиной 3...6 мм эффективный КПД нагрева изделия составляет 50...65 %. При полном погружении дуги, когда потери излучения возможны только через зазоры между поверхностью ванны и стержневым электродом, КПД оценивается в 75...85 %.

HEAT BALANCE

The various material, joint, and welding conditions determining the welding heat pattern in the joint.

HEAT PATTERN

The shape of the heat distribution in a material resulting from the application of heat.

HEATING PATTERN

A description of the manner in which some heat source is applied for joining, cutting, thermal spraying, preheating, postheating, or thermal forming to produce a heat pattern.

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so on…

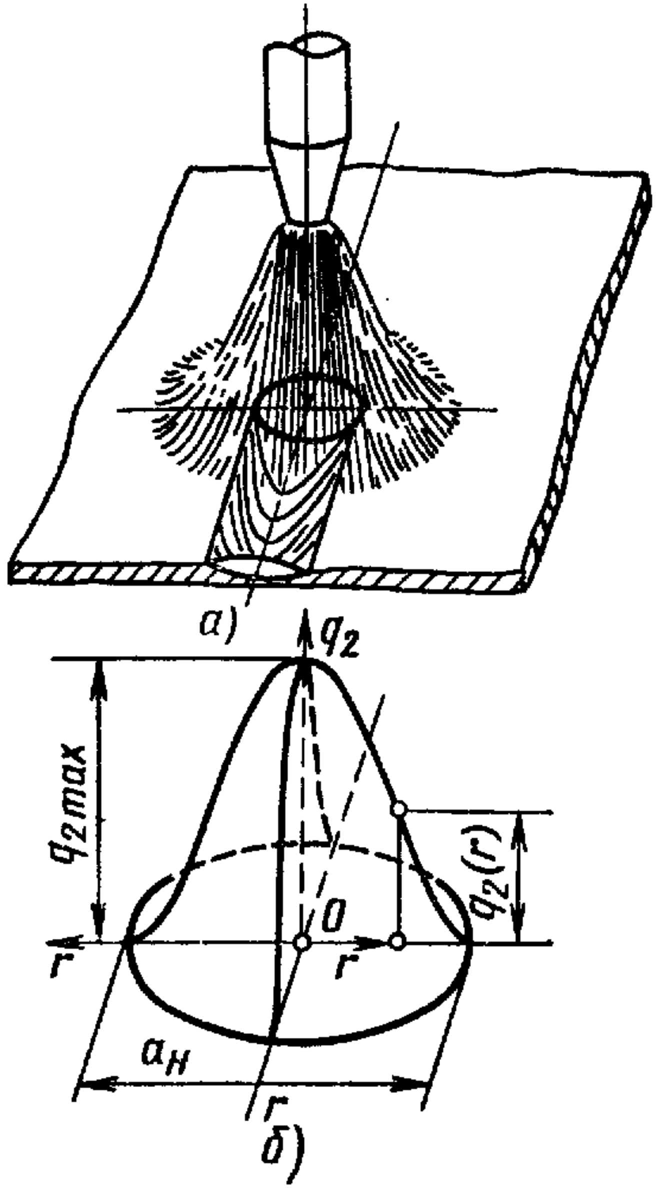
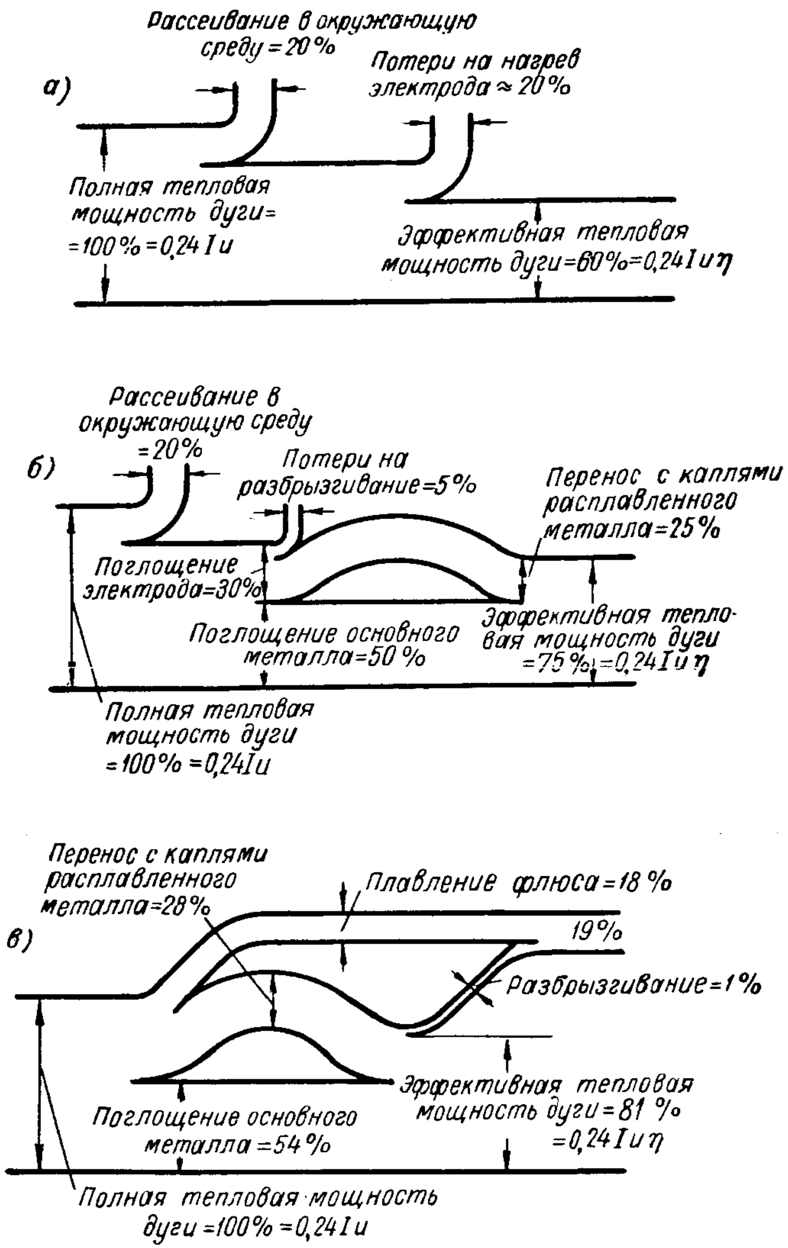
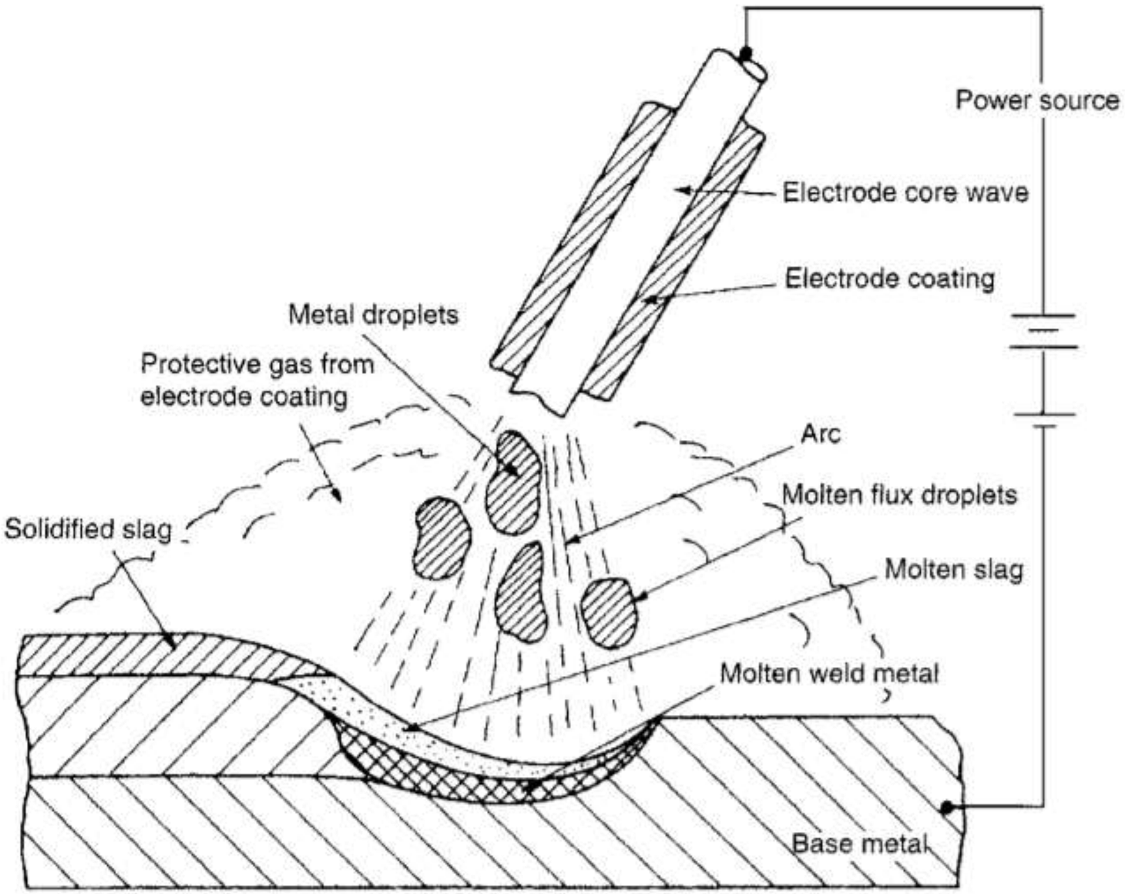


Рис. 1. Схема сварочной дуги как источника теплоты:

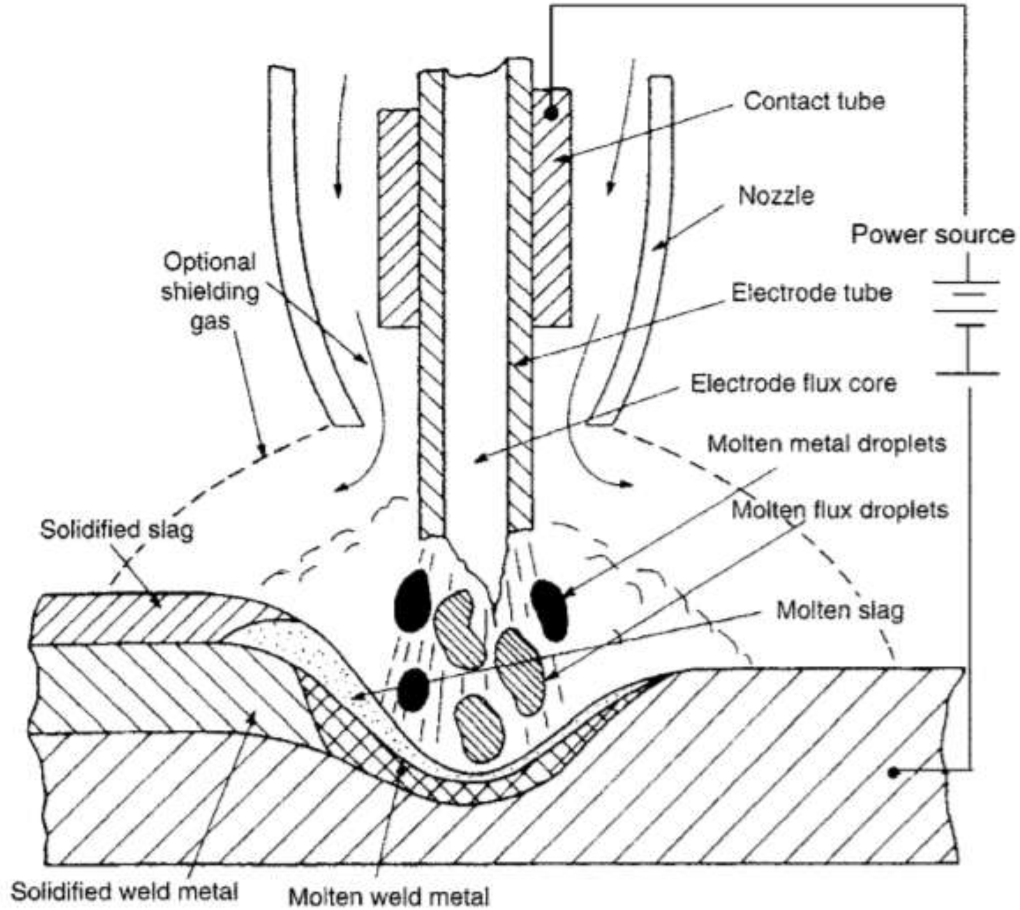
а — столб и пламя дуги; б — схема распределения теплового потока дуги (нормально-круговой источник)



Фиг. 19. Примерный тепловой баланс сварочной дуги: *а* — угольная дуга; *б* — открытая металлическая дуга; *в* — металлическая дуга под флюсом


Power source
Electrode core wave
Electrode coating
Metal droplets
Protective gas from electrode coating
Arc
Molten flux droplets
Solidified slag
Molten slag
Molten weld metal
Base metal

(a)


Contact tube
Nozzle
Power source
Optional shielding gas
Electrode tube
Electrode flux core
Molten metal droplets
Molten flux droplets
Solidified slag
Molten slag
Solidified weld metal
Molten weld metal

(b)

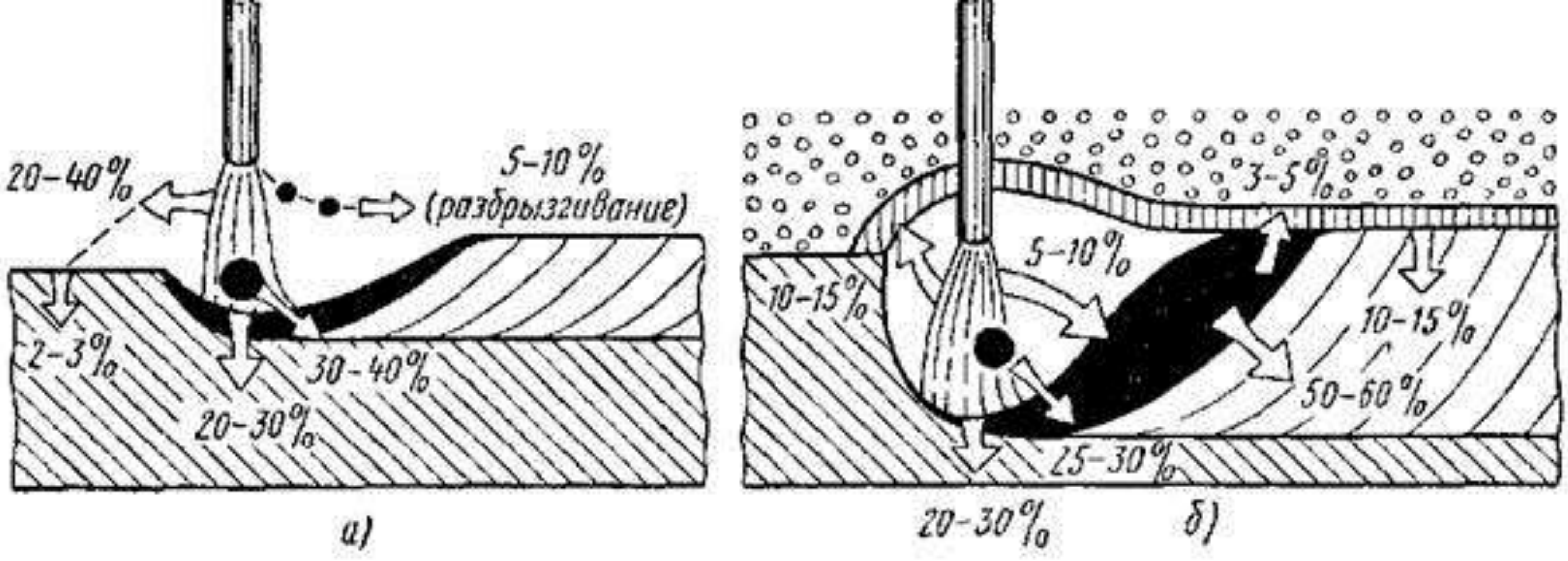
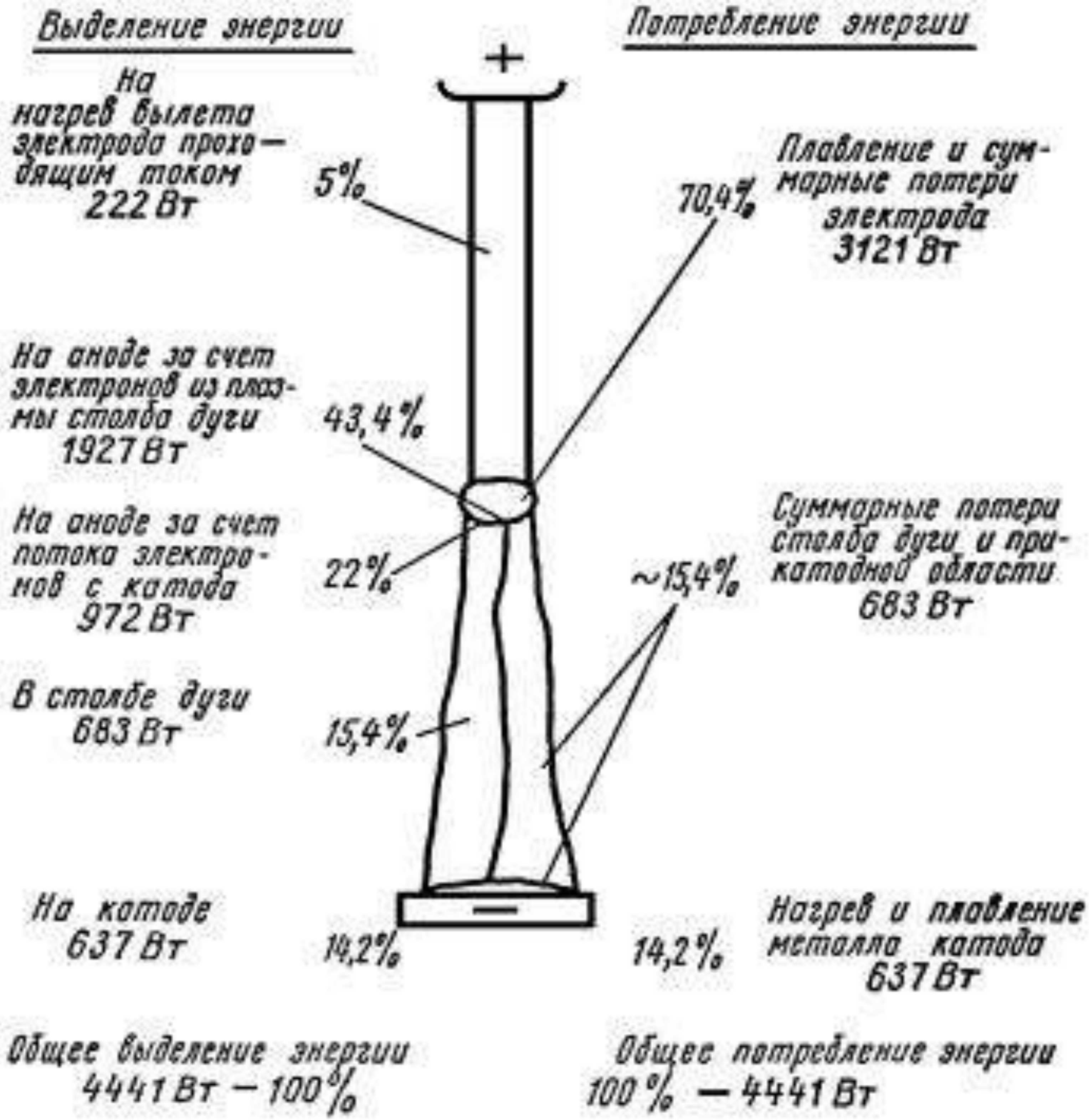
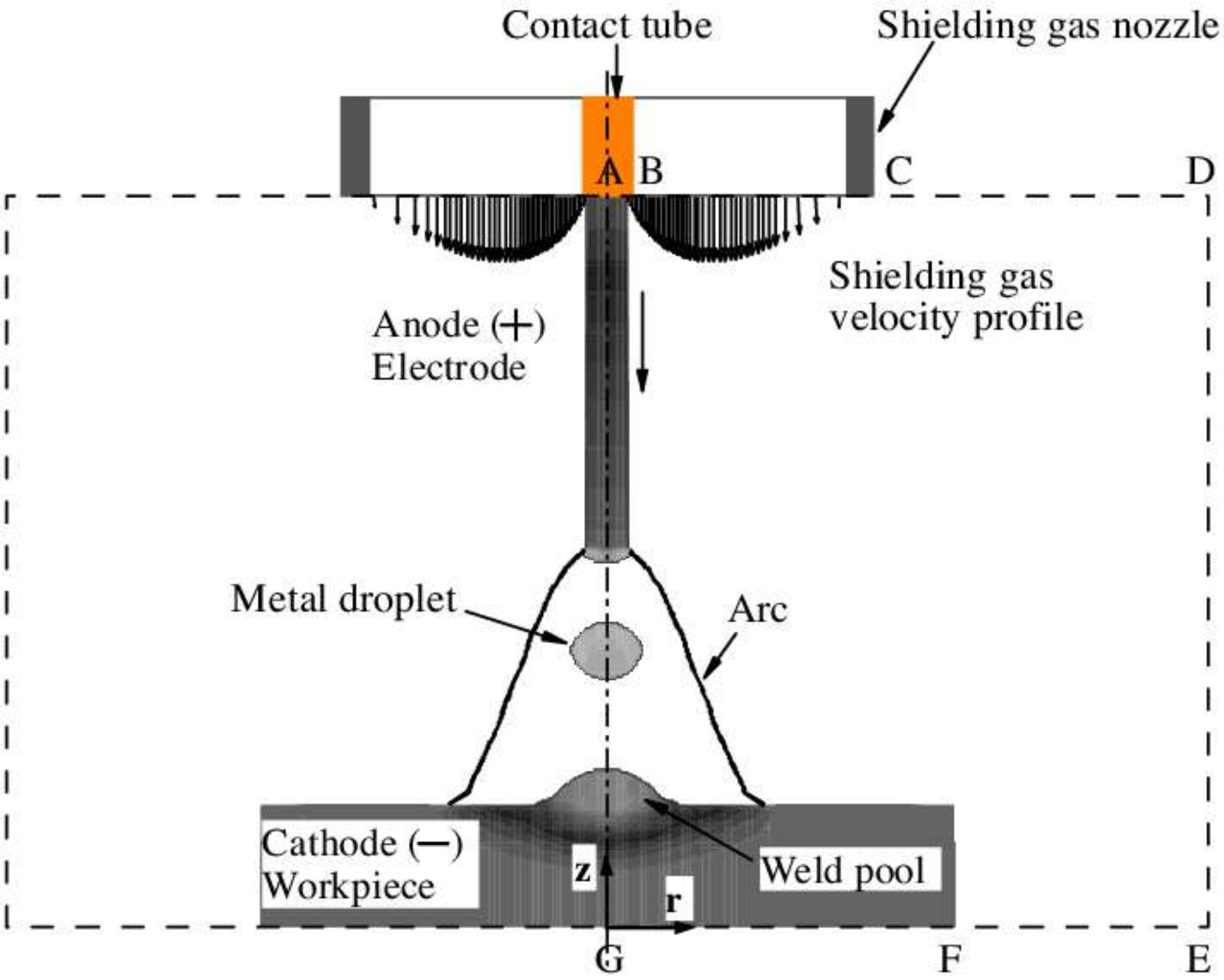


Рис. 2-14. Схема ввода теплоты в изделие сварочной дугой:

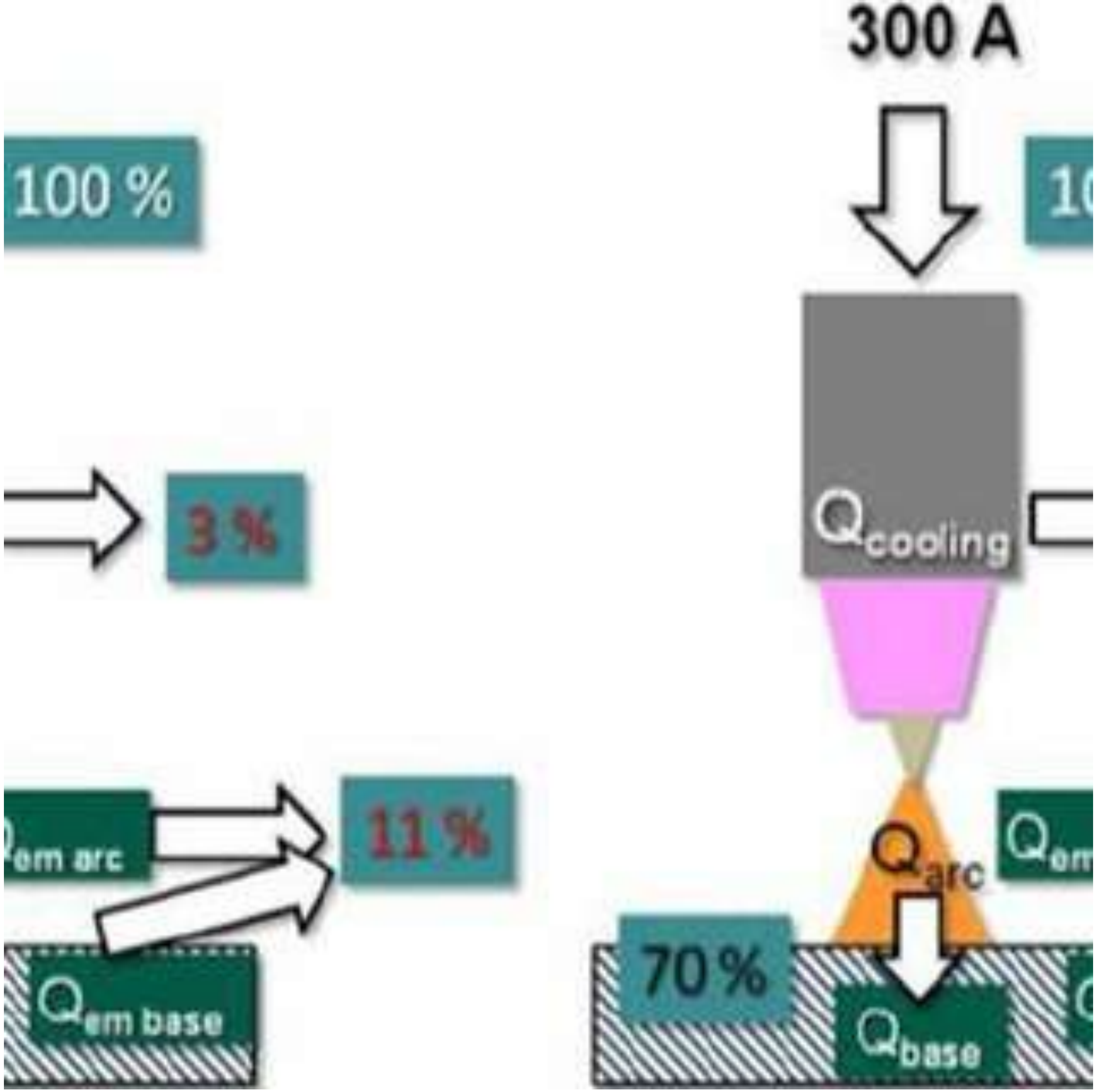
а — открытая дуга небольшой мощности; *б* — дуга большой мощности под слоем флюса



Выделение энергии
Потребление энергии
+
На нагрев вылета электрода проходящим током 222 Вт
5%
Плавление и суммарные потери электрода 3121 Вт
70,4%
На аноде за счет электронов из плазмы столба дуги 1927 Вт
43,4%
На аноде за счет потока электронов с катода 972 Вт
22%
Суммарные потери столба дуги и прикатодной области 683 Вт
~15,4%
В столбе дуги 683 Вт
15,4%
На катоде 637 Вт
14,2%
—
Нагрев и плавление металла катода 637 Вт
14,2%
Общее выделение энергии 4441 Вт — 100%
Общее потребление энергии 100% — 4441 Вт



Contact tube
Shielding gas nozzle
A
B
C
D
Shielding gas
velocity profile
Anode (+)
Electrode
Metal droplet
Arc
Cathode (−)
Workpiece
z
r
Weld pool
G
F
E



https://www.researchgate.net/figure/sualization-of-energy-balance-of-GTAW-with-variable-welding-current-parameters-as-shown_fig3_257809753

МЕТАЛЛУРГИЧЕСКИЕ РЕАКЦИИ ПРИ СВАРКЕ

При сварке без защиты расплавляемый металл интенсивно поглощает азот и кислород из воздуха, вследствие чего сварные швы характеризуются низкими механическими свойствами (табл. 1).

1. Характеристика металла сварного шва

Наименование показателей	Основной металл (сталь Ст3)	Металл шва при сварке проволокой Св-08А
Содержание кислорода, %	До 0,02	0,1—0,2
Содержание азота, %	0,04—0,08	0,1—0 2
Предел прочности, кгс/мм²	40—45	34—40
Относительное удлинение, %	25—30	5—10
Угол загиба, градусы	180	20—40
Ударная вязкость, кгс · м/см²	> 15	0,5—2,5

Gas Tungsten-arc Welding (GTAW)

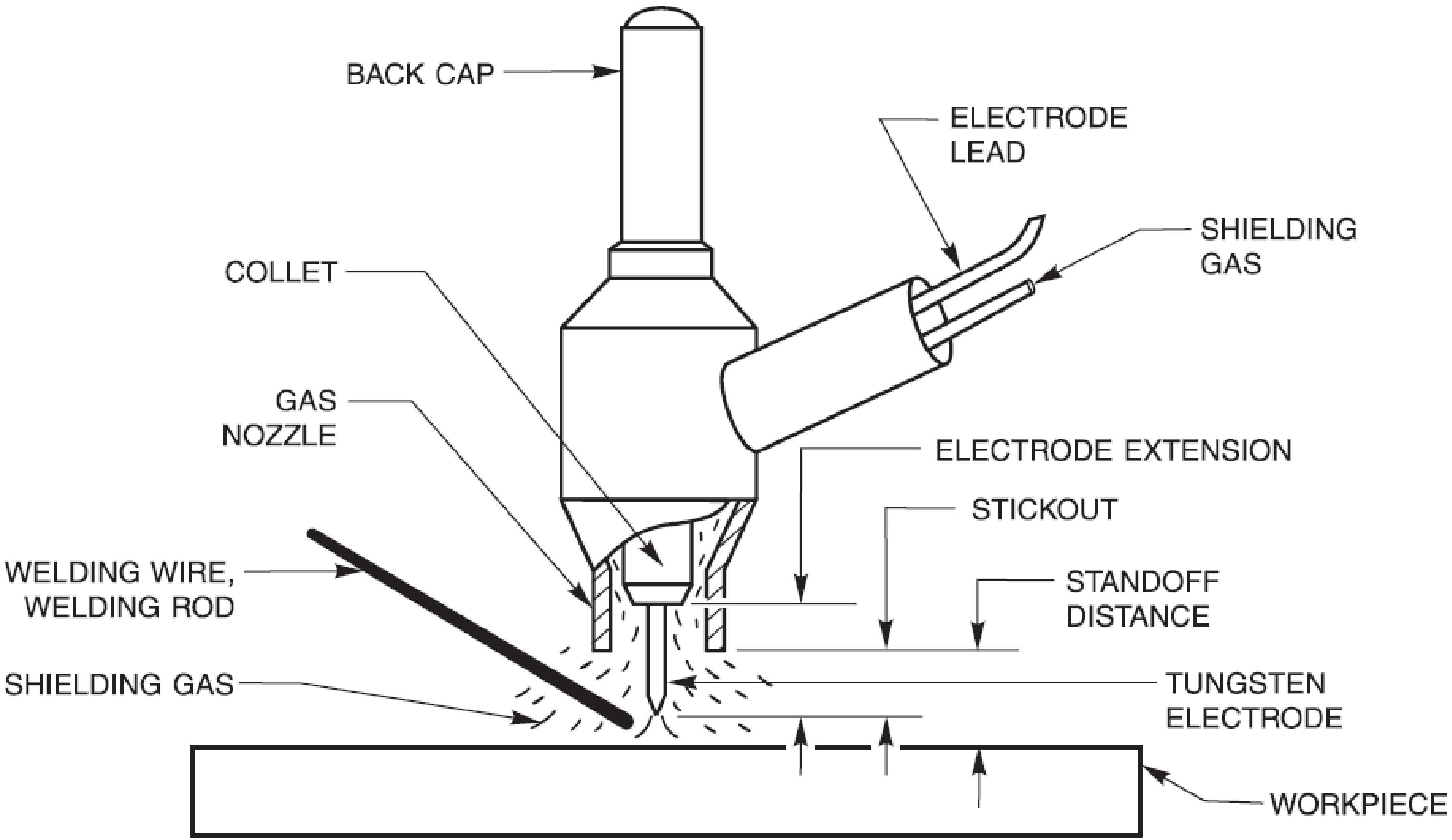


Figure B.36—Gas Tungsten Arc Welding Torch Nomenclature

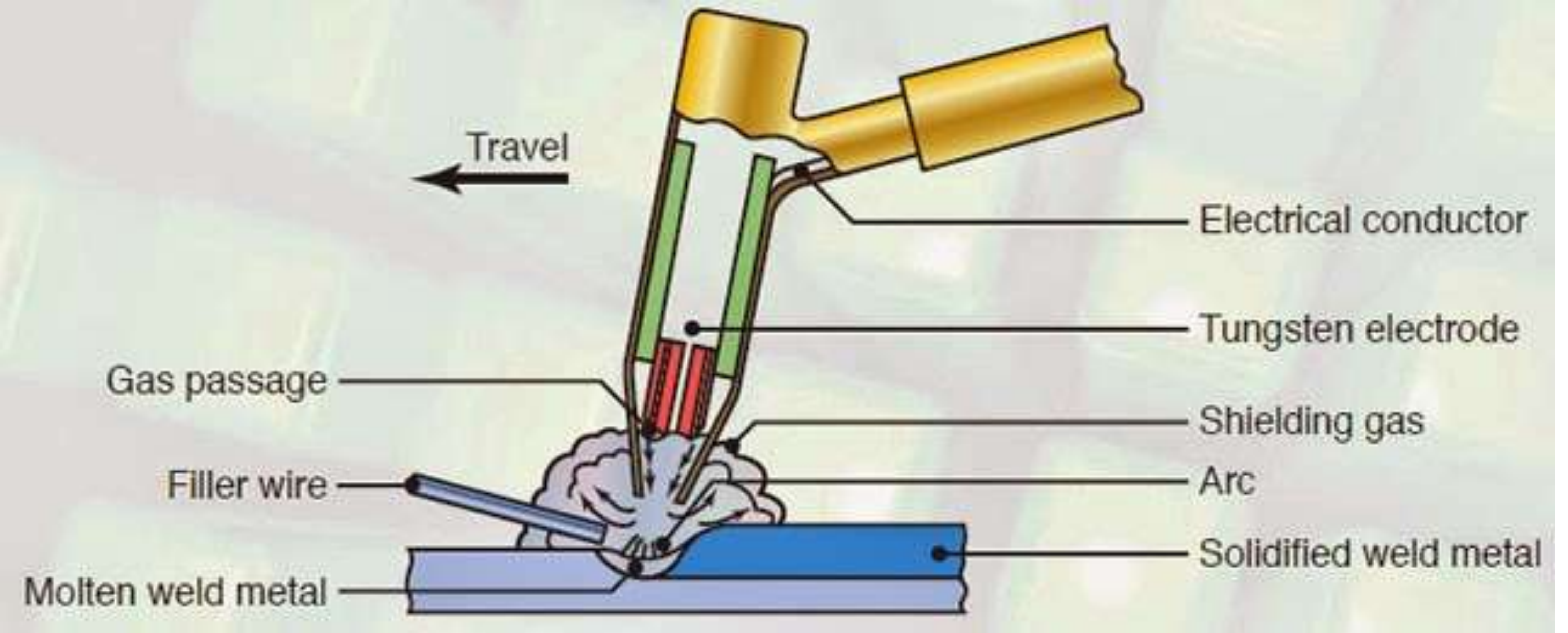
Gas Tungsten-arc Welding (GTAW)

formerly known as TIG (Tungsten Inert Gas) welding, the filler metal is supplied from a filler wire as shown in the figure below. The tungsten electrode is not used (*is not consumed*) during this welding operation, a constant and stable arc gap is maintained at a constant current level.

The filler metals are similar to the metals to be welded and flux is not used.

The shielding gas used in this welding process is usually argon or helium (or a mixture of these both gases).

Welding with gas tungsten-arc welding may be done without using filler metals. for example, in the welding of close-fit joints.



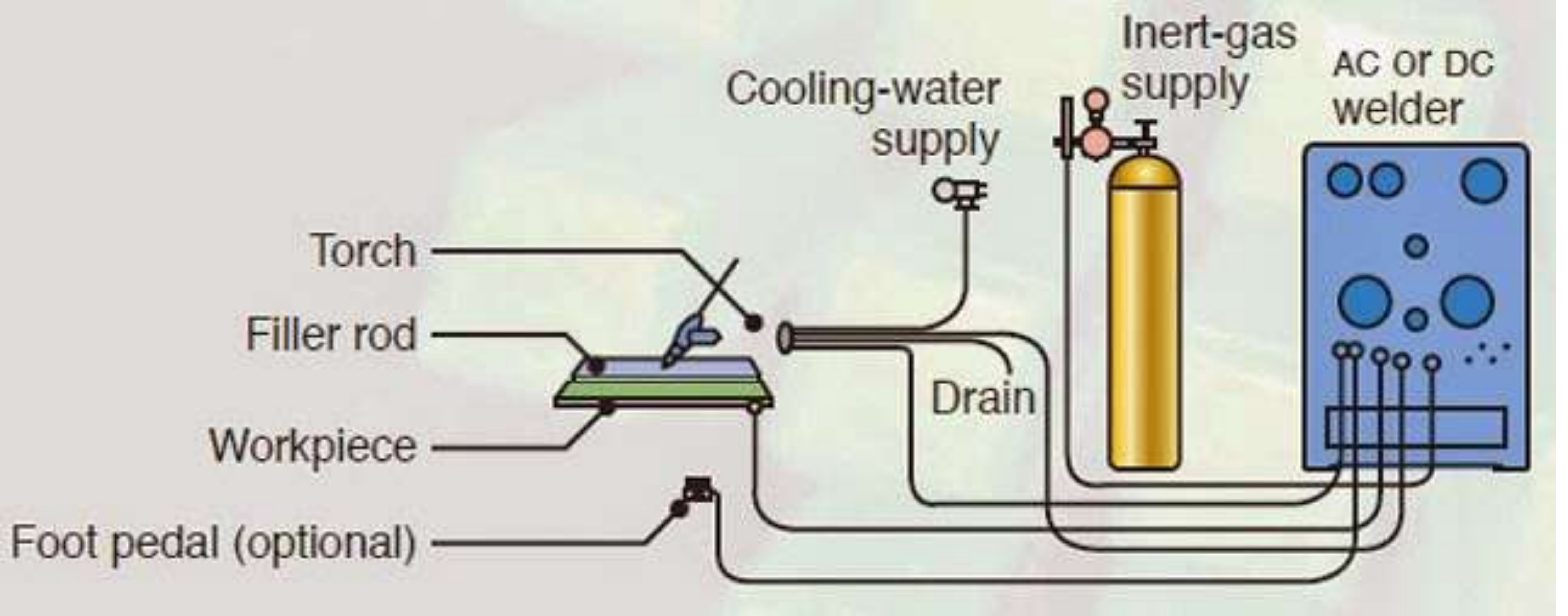
Schematic diagram of Gas Tungsten-arc welding process

Depending on the type of metals to be welded, the power supply is either DC at 200A or AC at 500A (see below image). In general, *AC is preferred for welding metals aluminium and magnesium*, because the cleaning action of AC removes oxides and improves weld quality.

Thorium or zirconium can be used in the tungsten electrodes to improve their electron emission characteristics.

The power supply ranges from 8 to 20 kW.

Contamination of the tungsten electrode by the molten metal ***can be a major problem***, particularly in critical applications, because it can cause discontinuities in the weld. Contact of the electrode with the molten-metal pool should be avoided.



Equipments used for gas tungsten-arc welding operations

The gas tungsten-arc welding process is used for a wide variety of applications and metals, particularly aluminium, magnesium, titanium and the refractory metals. It is highly suitable for thin metals. The cost of the inert gas makes this process more expensive than Shielded Metal-arc

Welding but provides welds of very high quality and surface finish. The equipment used for gas tungsten-arc welding process is portable.

Applications of Gas Tungsten-arc Welding:

- Originally developed for welding Aluminium and Magnesium.
- The other metals are Stainless steel, High carbon steel, Copper, Monel(Ni + Cu+ Fe + Mg)), Inconel (Cu + Cr + Fe), Brass, Bronze, Silver, Molybdenum etc.
- This process is used for joining various combinations of dissimilar metals like brazing and braze welding.
- Pipe work required for high pressure steam lines, chemical and petroleum industries.
- Welding of air craft frame, jet engine casing, rocket motor casing.
- Accuracy welding of parts in atomic energy.
- Expansions bellows, transistors cases, instrument diagrams etc.

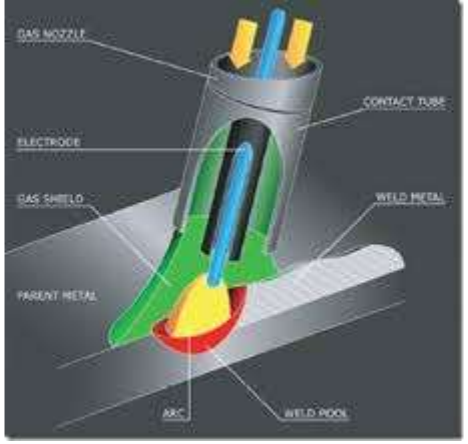
Advantages of Gas Tungsten-arc Welding:

- Gas Tungsten-arc welds are stronger and more ductile.
- No danger corrosion due to no flux is used.
- No post weld cleaning because of no slag.
- Wide variety of joints can be made because no flux is used.
- There is very little or no smoke, fumes or sparks at all. This helps in making a neat and sounder weld.
- As the shielding gas is transparent, operator can clearly observe the weld.
- Fusion welds can be made in merely all commercial metals.

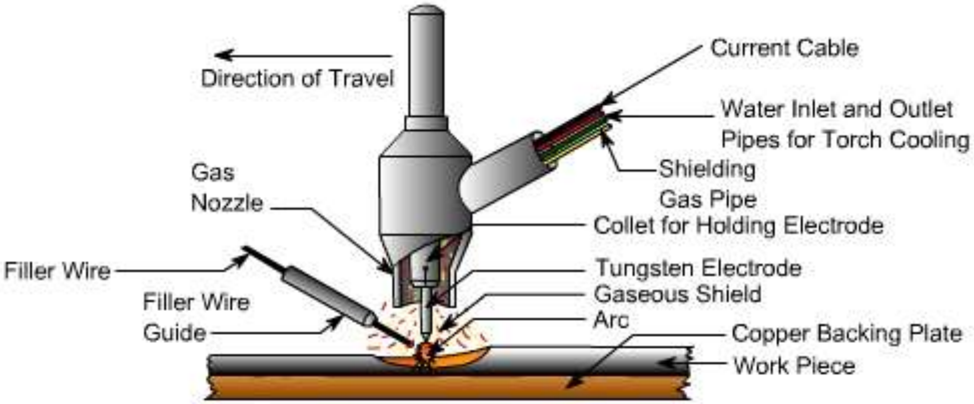
Limitations of Gas Tungsten-arc Welding:

- Because of usage of inert gas, coolant and coolant pump etc the cost of Tungsten Inert Gas welding is very high.
- Maximum thickness of plate which can be joined by this welding process directly is up to 5mm.
- For welding of above 5 mm thickness plate additional filler rod must be used.
- Even though tungsten electrode is not melting but at high temperature the atoms of tungsten may get diffused from the tip of electrodes and entering into the weld pool which will increase the brittleness of weld bead.

To overcome this limitations, the next welding process developed is Gas Metal-arc Welding.



gas tungsten arc welding (GTAW). An arc welding process using an arc between a tungsten electrode (nonconsumable) and the weld pool. The process is used with shielding gas and without the application of pressure. See also **hot wire welding** and **pulsed gas tungsten arc welding**. See Figure B.36.



https://me-mechanicalengineering.com/classification-of-welding-and-allied-processes/

gas shielded arc welding. A group of processes including **electrogas welding**, **flux cored arc welding**, **gas metal arc welding**, **gas tungsten arc welding**, and **plasma arc welding**.

shielded carbon arc welding (CAW-S). A carbon arc welding process variation using shielding from the combustion of solid material fed into the arc, or from a blanket of flux on the workpieces, or both. This is an obsolete or seldom used process.

shielded metal arc cutting (SMAC). An arc cutting process employing a covered electrode.

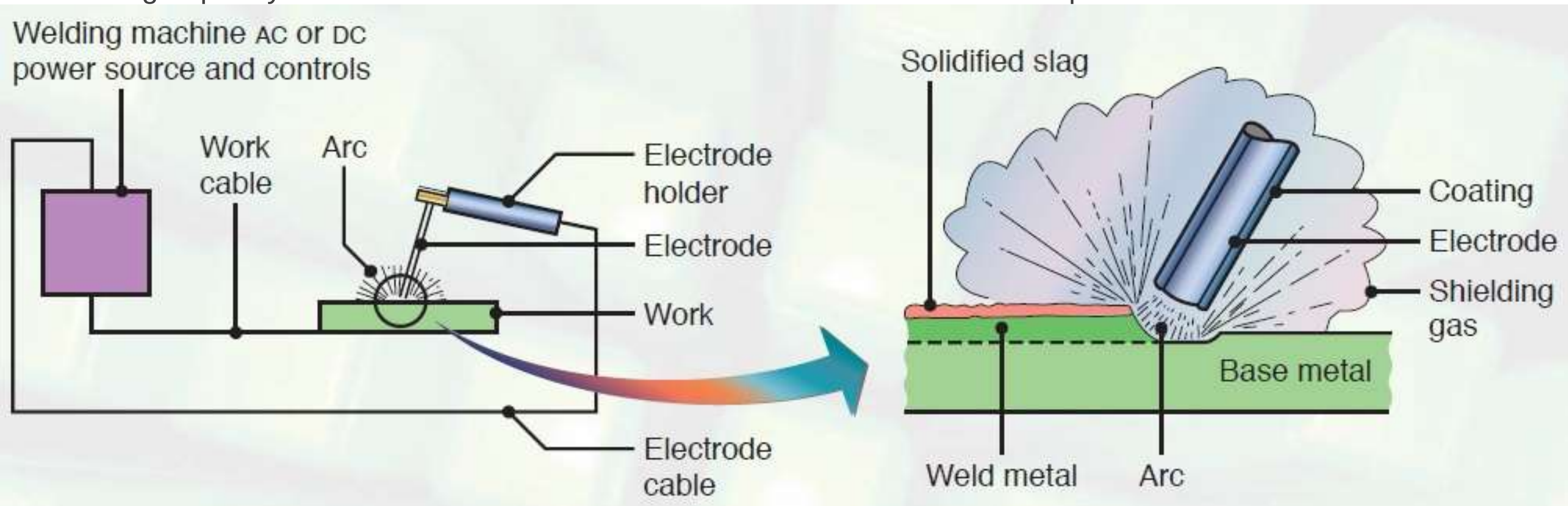
shielded metal arc welding (SMAW). An arc welding process with an arc between a covered electrode and the weld pool. The process is used with shielding from the decomposition of the electrode covering, without the application of pressure, and with filler metal from the electrode. See also **firecracker welding**.

shielding gas. A gas used to produce a protective atmosphere. See also **backing gas** and **inert gas**.

protective atmosphere. A gas or vacuum envelope present during joining, thermal cutting, or thermal spraying used to prevent or reduce the formation of oxides and other detrimental surface substances and facilitate their removal. See also **backing gas**, **inert gas**, **reducing atmosphere**, and **shielding gas**.

gas shielded flux cored arc welding (FCAW-G). A flux cored arc welding process variation in which shielding gas is supplied through the gas nozzle in addition to that obtained from the flux within the electrode.

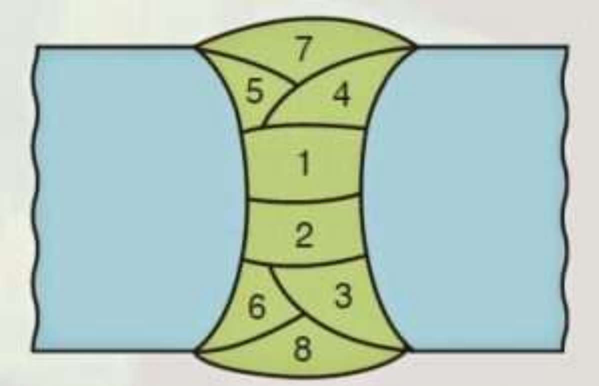
Shielded Metal-arc Welding (SMAW) is the simplest and used for many joining processes. More than 50% of industrial and maintenance welding currently is performed by this welding process. In this welding operation, an electric arc is generated by touching the tip of a coated electrode against the workpiece and withdrawing it quickly to a distance sufficient to maintain the arc as shown in the picture below.



Schematic illustration of the shielded metal-arc welding process

The electrodes are in the shapes of thin, long rods that are held manually. The heat generated melts a portion of the electrode tip, its coating and the base metal in the immediate arc area. The molten metal consists of a mixture of the base metal, the electrode metal, and substances from the coating on the electrode, this mixture forms the weld when it solidifies. The electrode coating de-oxidizes the weld area and provides a shielding gas to protect it from oxygen in the surroundings. A bare section at the end of the electrode is clamped to one terminal of the power source, while the other terminal is connected to the workpiece being welded. The current may be either DC or AC usually in the range of 50 to 300 A.

For sheet-metal welding, DC is suitable because of the steady arc it produces. Power requirement is generally less than 10 kW.



weld shield metal arc beads

The *shield Metal-arc welding process has the advantages* of being relatively simple and requiring a smaller variety of electrodes. The equipment consists of a power supply, cables, and an electrode holder. The shield metal-arc welding process commonly is used in general construction, shipbuilding, pipelines and other maintenance work. It is mainly used for work in remote areas where a portable fuel-powered generator can be used as the power supply. shield metal-arc welding is best suited for the workpiece of thickness 3 to 19 mm, although this range can be extended easily by skilled operators using multiple-pass techniques as shown in the picture. The multiple-pass approach requires that the slag is removed after each weld bead. Unless removed fully, the solidified slag can cause severe corrosion of the weld area and lead to failure of the weld but it also prevents the fusion of welded layers. Before applying another weld, the slag should be removed completely by using wire brushing or weld chipping.

https://me-mechanicalengineering.com/shielded-metal-arc-welding/

flux cored arc welding (FCAW). An arc welding process using an arc between a continuous filler metal electrode and the weld pool. The process is used with shielding gas from a flux contained within the tubular electrode, with or without additional shielding from an externally supplied gas, and without the application of pressure. See also **flux cored electrode**, **gas shielded flux cored arc welding**, and **self-shielded flux cored arc welding**.

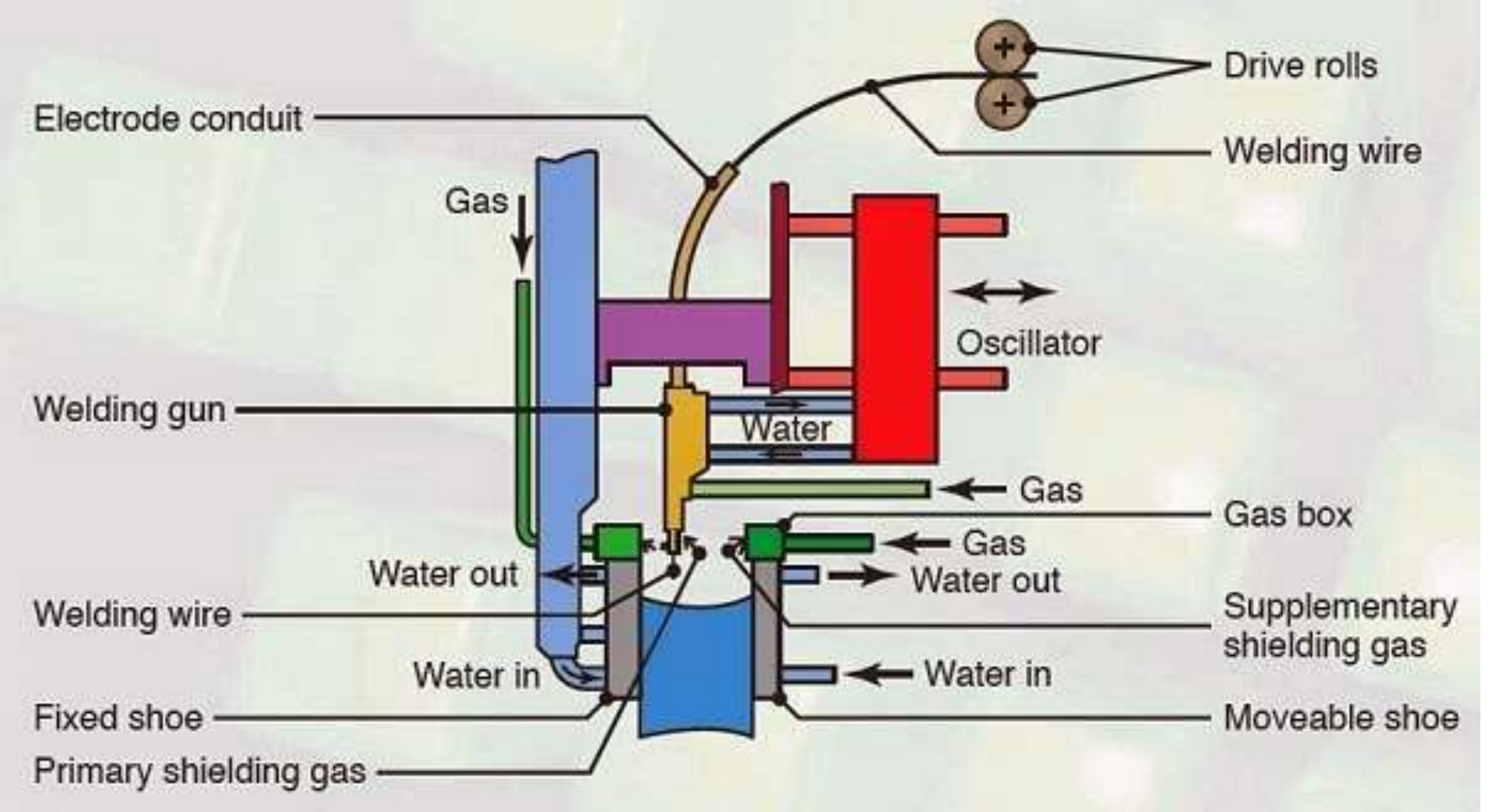
flux. A material applied to the workpiece(s) before or during joining or surfacing to cause interactions that remove oxides and other contaminants, improve wetting, and affect the final surface profile. Welding flux may also affect the weld metal chemical composition. See also **brazing flux**, **soldering flux**, **and welding flux**.

self-shielded flux cored arc welding (FCAW-S). A flux cored arc welding process variation in which shielding gas is obtained exclusively from the flux within the electrode.

welding filler metal. The metal or alloy to be added in making a weld joint that alloys with the base metal to form weld metal in a fusion welded joint.

welding flux. A flux used for welding. See also **brazing flux** and **soldering flux.**

welding flux, *submerged arc welding.* A granular material comprised of metallic and nonmetallic constituents applied during welding to provide atmospheric shielding and cleaning of the molten weld metal and influence the profile of the solidified weld metal. This material may also provide filler metal and affect the weld metal composition. See **active flux**, **agglomerated flux**, **alloy flux**, **bonded flux**, **fused flux**, **mechanically mixed flux**, **neutral flux**, **reconditioned flux**, **recycled flux**, and **virgin flux**.



Electrogas welding (EGW) process is a vertical positioned welding process, is used for welding the edges of sections vertically and in one pass with the pieces placed edge to edge.

Electrogas welding (EGW) is an vertical positioned arc welding process, is used for welding the edges of sections vertically and in one pass with the pieces placed edge to edge (butt joint). It is classified as a machine-welding process, because for its operation requires special equipment. The weld metal is deposited into a weld cavity between the two pieces to be joined. The space is covered by two water-cooled copper dams(shoes) to prevent the molten slag from running off; mechanical drives move the shoes upward.

One or more electrodes are fed through a conduit and a continuous arc is maintained by flux-cored electrodes at up to 750 A or solid electrodes at 400 A. Power requirements is 20 kW. Shielding is done by means of an inert gas, such as argon or helium depending on the type of material being welded. The gas may be provided either from an external source, from a flux-cored electrode or from both the sources. The equipment of electrogas welding is reliable and training an operator is easy. Weld thickness is between 12 mm to 75 mm on steels, titanium and aluminum alloys.

Electrogas welding process is used in the construction of bridges, pressure vessels, thick-walled and large-diameter pipes, storage tanks, submarines and ships.

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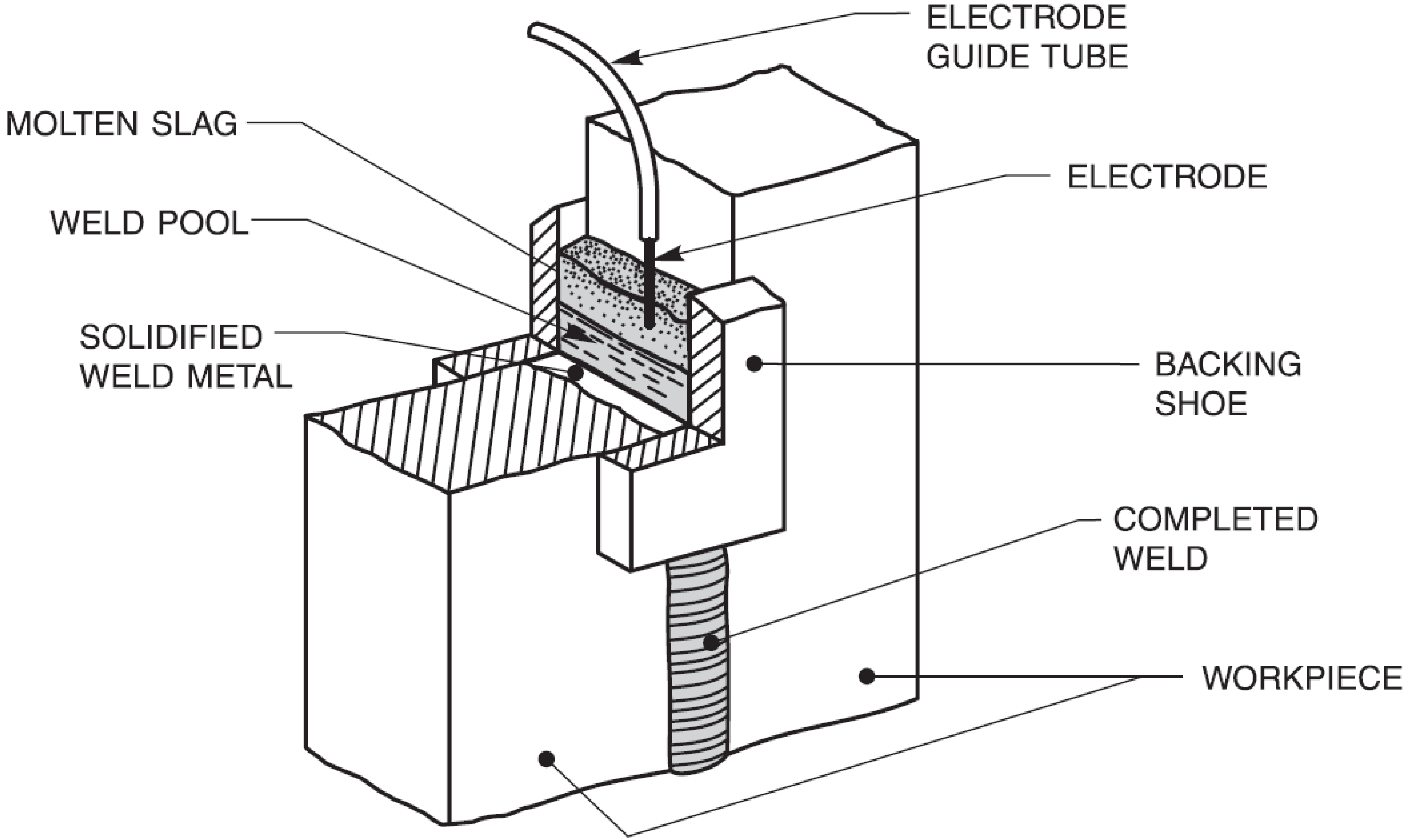
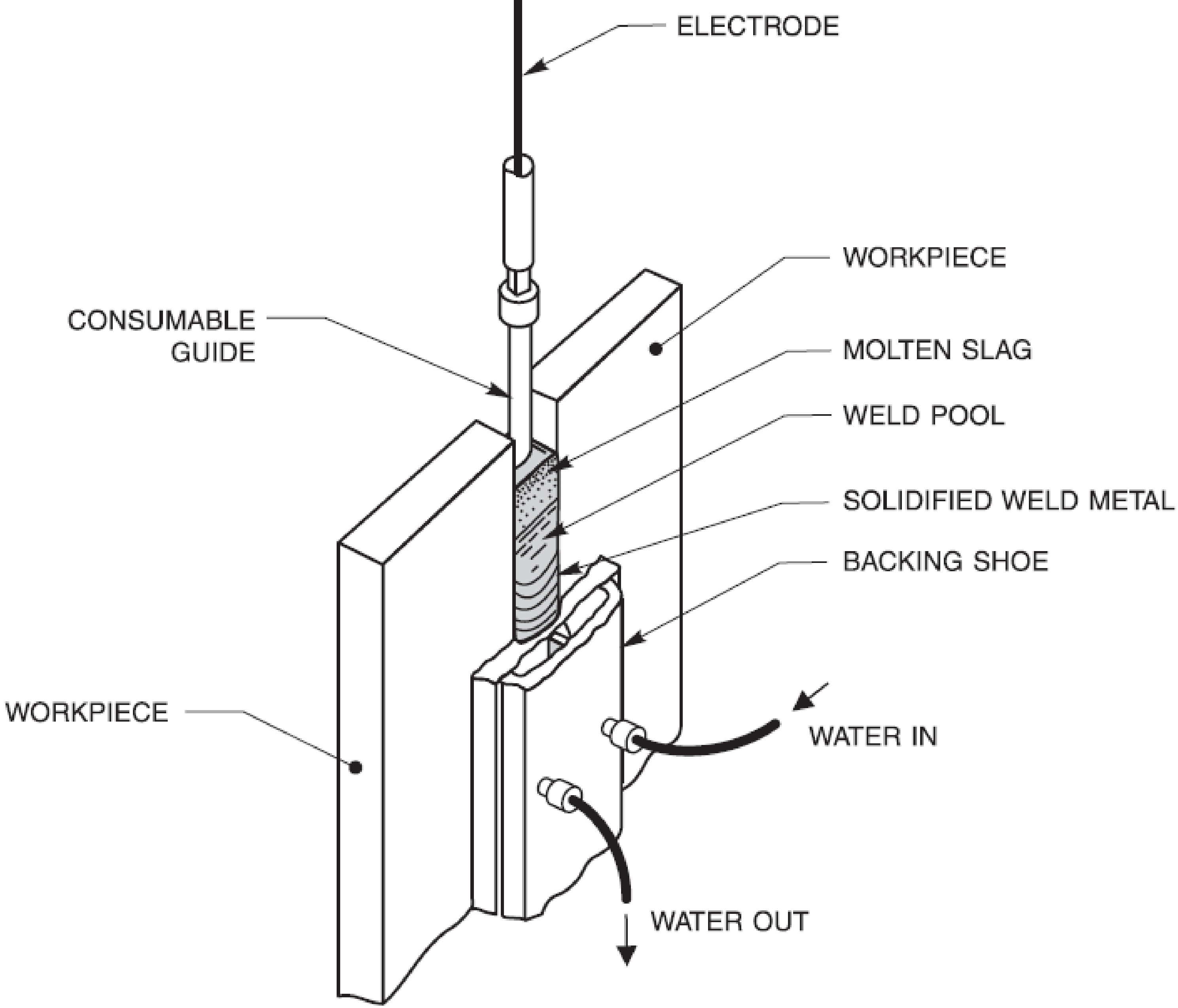
https://me-mechanicalengineering.com/electrogas-welding-egw/



(A) ELECTROSLAG WELDING NOMENCLATURE



(B) CONSUMABLE GUIDE ELECTROSLAG WELDING NOMENCLATURE

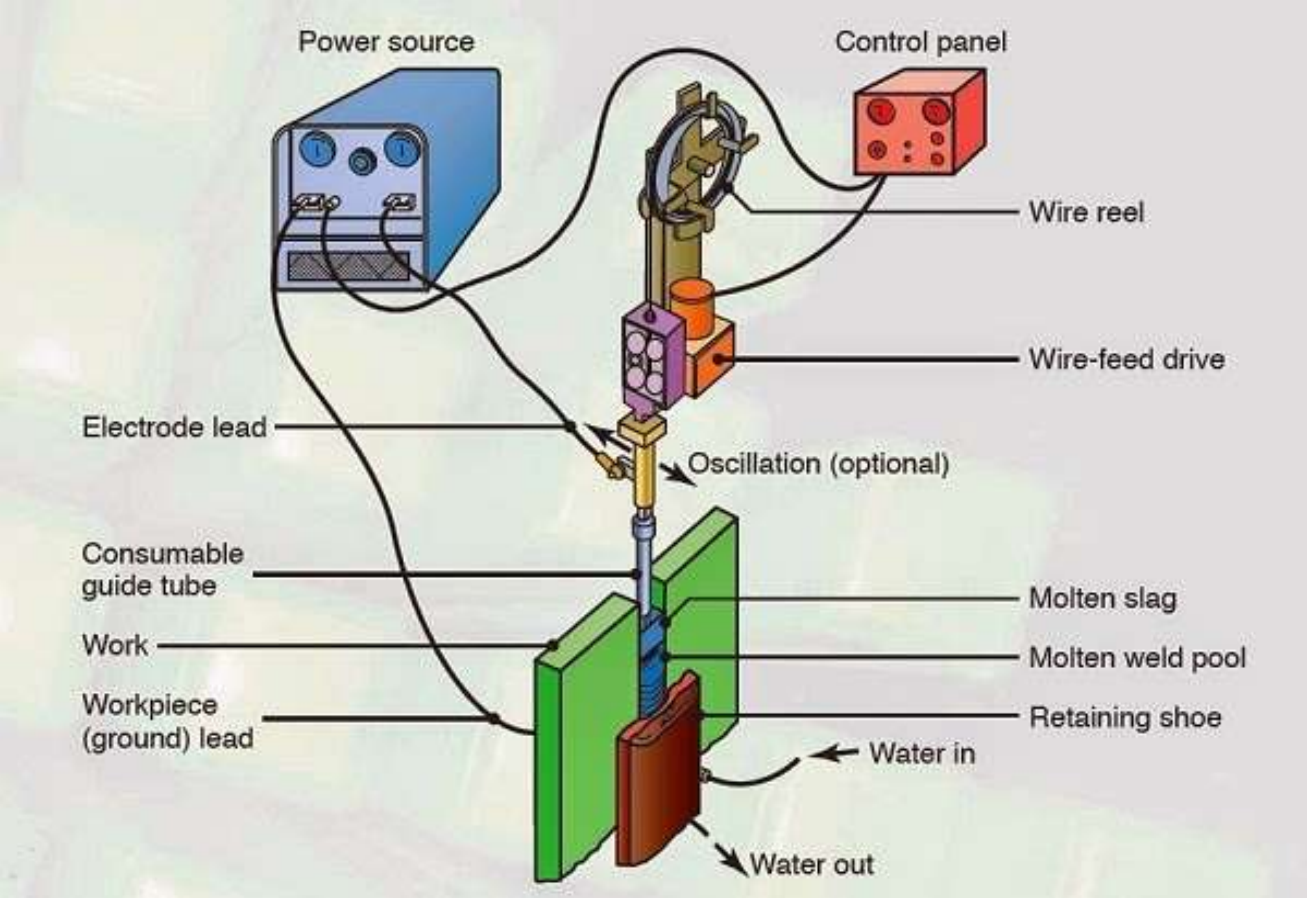
Figure B.37—Electroslag Welding Process Nomenclature

Electroslag Welding (ESW)

electroslag welding (ESW). A welding process producing coalescence of metals with molten slag, melting the filler metal and the surfaces of the workpieces. The weld pool is shielded by this slag, which moves along the full cross section of the joint as welding progresses. The process is initiated by an arc that heats the slag. The arc is then extinguished by the conductive slag, which is kept molten by its resistance to electric current passing between the electrode and the workpieces. See also **electroslag welding electrode** and **consumable guide electroslag welding**.
See Figure B.37.

electroslag welding electrode. A filler metal component of the welding circuit through which current is conducted from the electrode guiding member to the molten slag.

Electroslag welding (ESW) applications are similar to electrogas welding. The main difference is that the arc is started between the electrode tip and the bottom of the part to be welded. Flux is added, which then melts by the heat of the arc. After the molten slag reaches the tip of the electrode, the arc is extinguished. Heat is produced continuously by the electrical resistance of the molten slag. Because the arc is extinguished, Electroslag welding is not strictly an arc-welding process. Single or multiple solid as well as flux-cored electrodes may be used.



Power source
Control panel
Wire reel
Wire-feed drive
Electrode lead
Oscillation (optional)
Consumable
guide tube
Molten slag
Work
Molten weld pool
Workpiece
(ground) lead
Retaining shoe
Water in
Water out

Equipment used for Electroslag Welding operations

Electroslag welding is capable of welding plates with thicknesses ranging from 50 mm to more than 900 mm and welding is done in one pass. The current required is about 600 A at 40 to 50 Volts although higher currents are used for thick plates. The travel speed of the weld is in the range from 12 to 36 mm/min. Weld quality is high. This process is used for large structural-steel sections, such as heavy machinery, bridges, ships and nuclear-reactor vessels.

The quality of weld in Electroslag welding depends on

- The ratio of width of the weld pool and its maximum depth known as Form Factor.
- Weld current and voltage.
- Slag depth.
- Number of electrodes and their spacing etc.

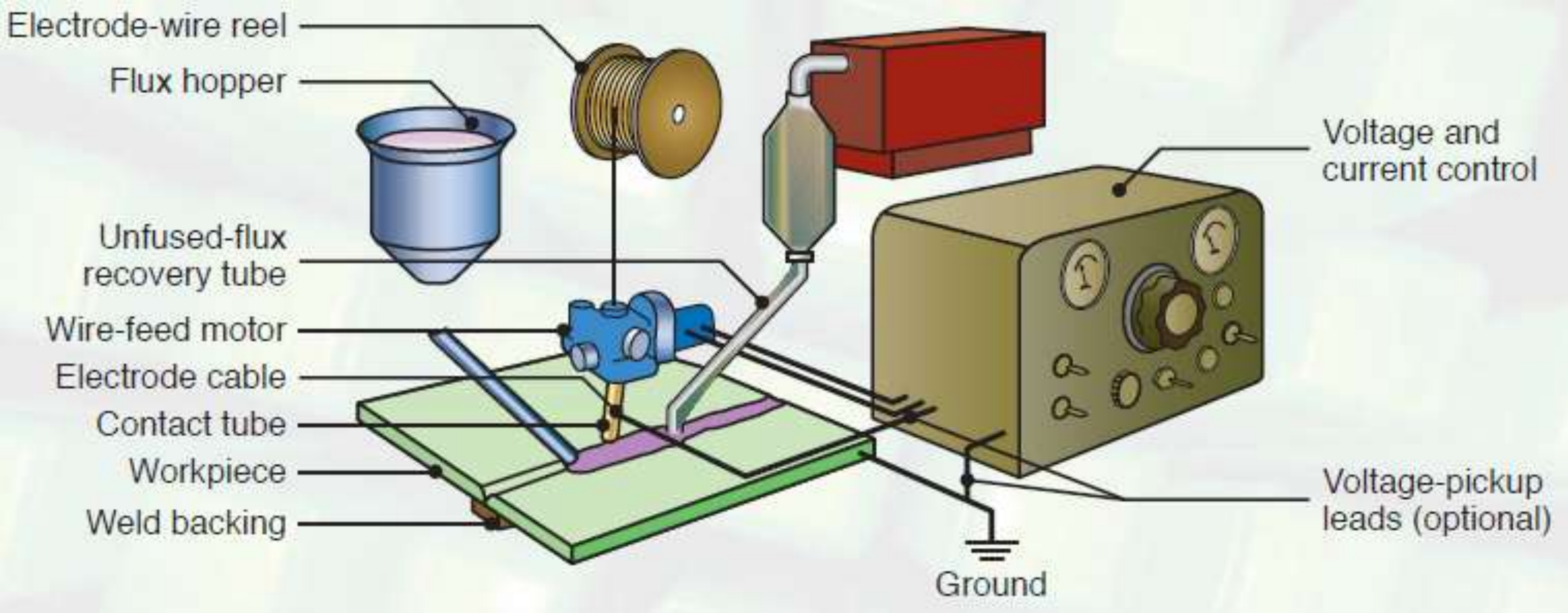
https://me-mechanicalengineering.com/electroslag-welding-esw/

Submerged-arc Welding (SAW)

submerged arc welding (SAW). An arc welding process using an arc or arcs between a bare metal electrode or electrodes and the weld pool. The arc and molten metal are shielded by a blanket of granular flux on the workpieces. The process is used without pressure and with filler metal from the electrode and sometimes from a supplemental source (welding rod, flux, or metal granules). See also **hot wire welding** and **series submerged arc welding**.

In **Submerged-arc Welding (SAW)**, the weld arc is shielded by a granular flux consisting of lime, silica, manganese oxide, calcium fluoride and other compounds. The flux is fed into the weld zone from a hopper by gravity flow through a nozzle. The thick layer of flux completely covers the molten metal. Covered flux prevents spatter and sparks and suppresses the intense ultraviolet radiation and fumes characteristic of the shielded metal-arc welding (SMAW) process. The flux acts as a thermal insulator by promoting deep penetration of heat into the workpiece.

The consumable electrode is a coil of bare round wire 1.5 to 10 mm in diameter, consumable electrode is fed automatically through a tube. Electric currents typically range from 300 to 2000A. The power supplies usually are connected to standard single-phase or three-phase power lines with a primary rating up to 440V.



Schematic illustration of the submerged-arc welding equipment.

The flux is gravity fed, the Submerged-arc welding process is limited largely to welds in a flat or horizontal position having a backup piece. Circular welds can be made on pipes and cylinders-provided that they are rotated during welding. As image shows, the unfused flux is recovered, treated and reused. Submerged-arc welding is automated and is used to weld a variety of carbon and alloy steel and stainless-steel sheets or plates at speeds as high as 5 m/min. The quality of the Weld is very high with good toughness, ductility and uniformity of properties. The Submerged-arc welding process provides very high welding productivity, depositing 4 to 10 times the amount of weld metal per hour as the shielded metal-arc welding process.

Applications:

The weld made by Submerged-arc welding have high strength and ductility with low Hydrogen and Nitrogen content. It is suitable for welding low alloy steel, high tensile steel, LC and MC steels, high resisting steel, corrosion resistant steel, high strength steel and many of non-ferrous alloys.

Advantages:

- Smooth welds of high strength and ductility with low H_2 and N_2 content.
- Because of high current, high metal deposition, high welding speeds and good penetration are achieved.
- Due to high speeds less distortion will occur.
- Elimination of fumes and spatter.
- Absence of visible arc and ease of penetration.

Limitations:

- During welding process arc is not visible, judging the welding progress is difficult and so tools like jigs, fixtures and guides are required.
- Pre-placing of flux may not always possible.
- This welding process is limited to flat position.
- Flux is subjected to contamination that may cause weld porosity.
- Chlorine, Aluminium, Magnesium, Lead, Zinc can not be welded.

https://me-mechanicalengineering.com/submerged-arc-welding/

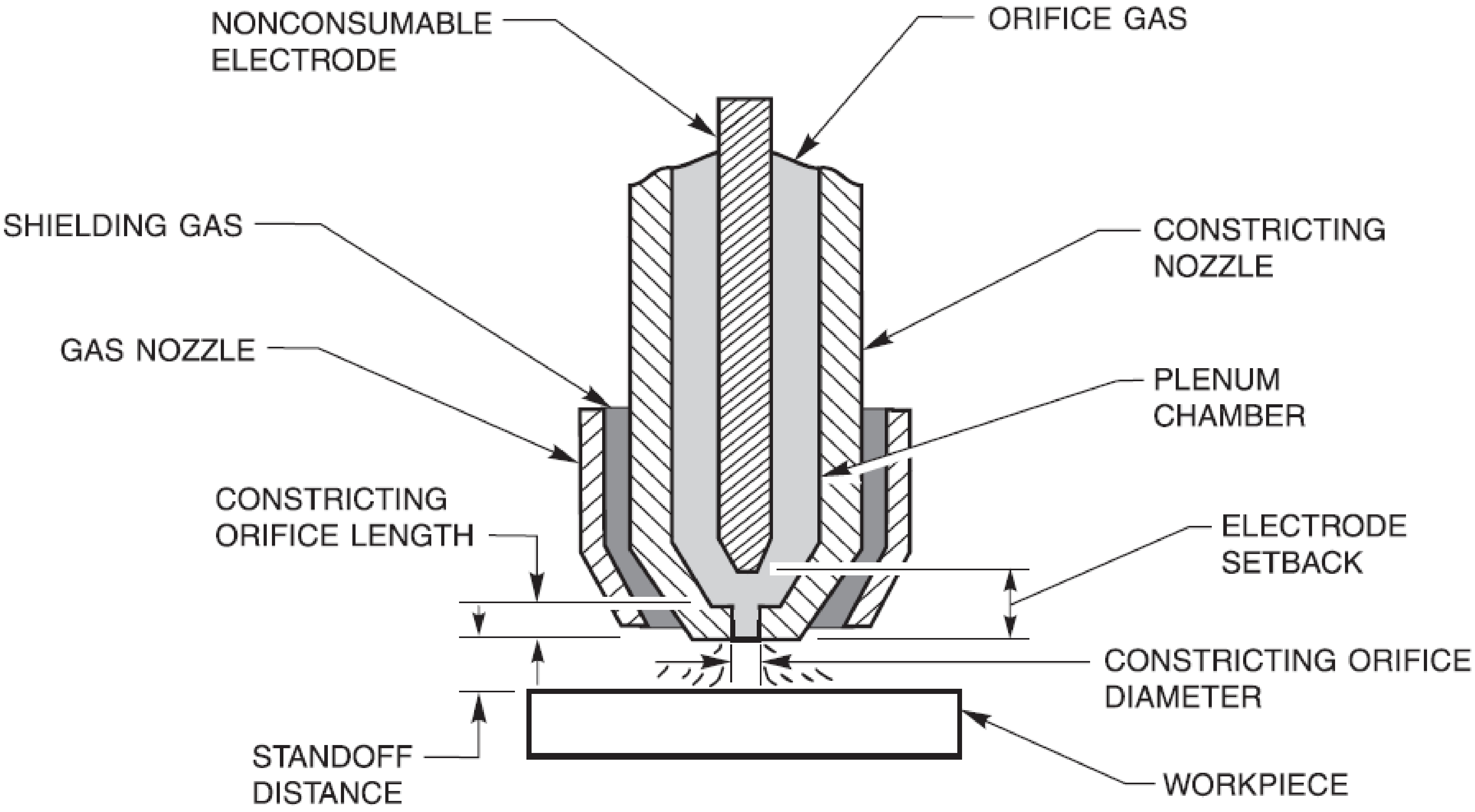


Figure B.35—Plasma Arc Torch Nomenclature

Plasma-arc Welding (PAW)

plasma arc welding (PAW). An arc welding process employing a constricted arc between a nonconsumable electrode and the weld pool (transferred arc) or between the electrode and the constricting nozzle (nontransferred arc). Shielding is obtained from the ionized gas issuing from the torch, which may be supplemented by an auxiliary source of shielding gas.
The process is used without the application of pressure.
See also **hot wire welding**.

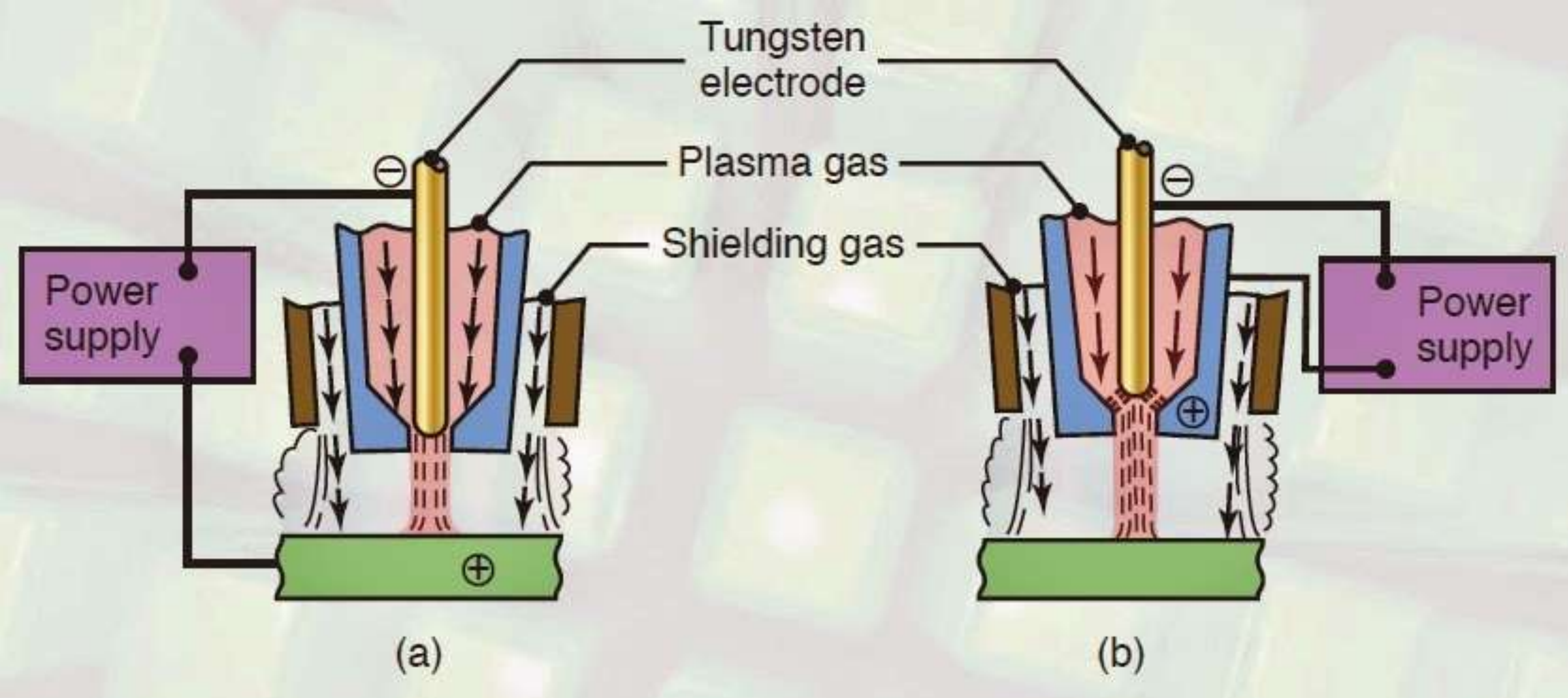
plasma arc cutting (PAC). An arc cutting process employing a constricted arc and removing molten metal with a high-velocity jet of ionized gas issuing from the constricting orifice.

arc plasma. A gas heated by an arc to at least a partially ionized condition, enabling it to conduct an electric current.

In **Plasma-arc Welding** (PAW) is an arc welding process, a concentrated plasma arc is produced and directed towards the weld area. The arc is stable and reaches temperatures as high as 33,000°C. A plasma is an ionized very hot gas composed of nearly same numbers of electrons and ions. The plasma starts between the tungsten electrode and the orifice by a low current pilot arc. What makes plasma-arc welding unlike other processes is that the plasma arc is concentrated because it is forced through a relatively small orifice. Operating currents usually are less than 100 A. When a filler metal is used it is fed into the arc as is done in Gas Tungsten-arc Welding. Arc and weld-zone shielding are supplied by means of an outer shielding ring and the use of inert gases like argon, helium or mixtures.

There are two methods of plasma-arc welding:

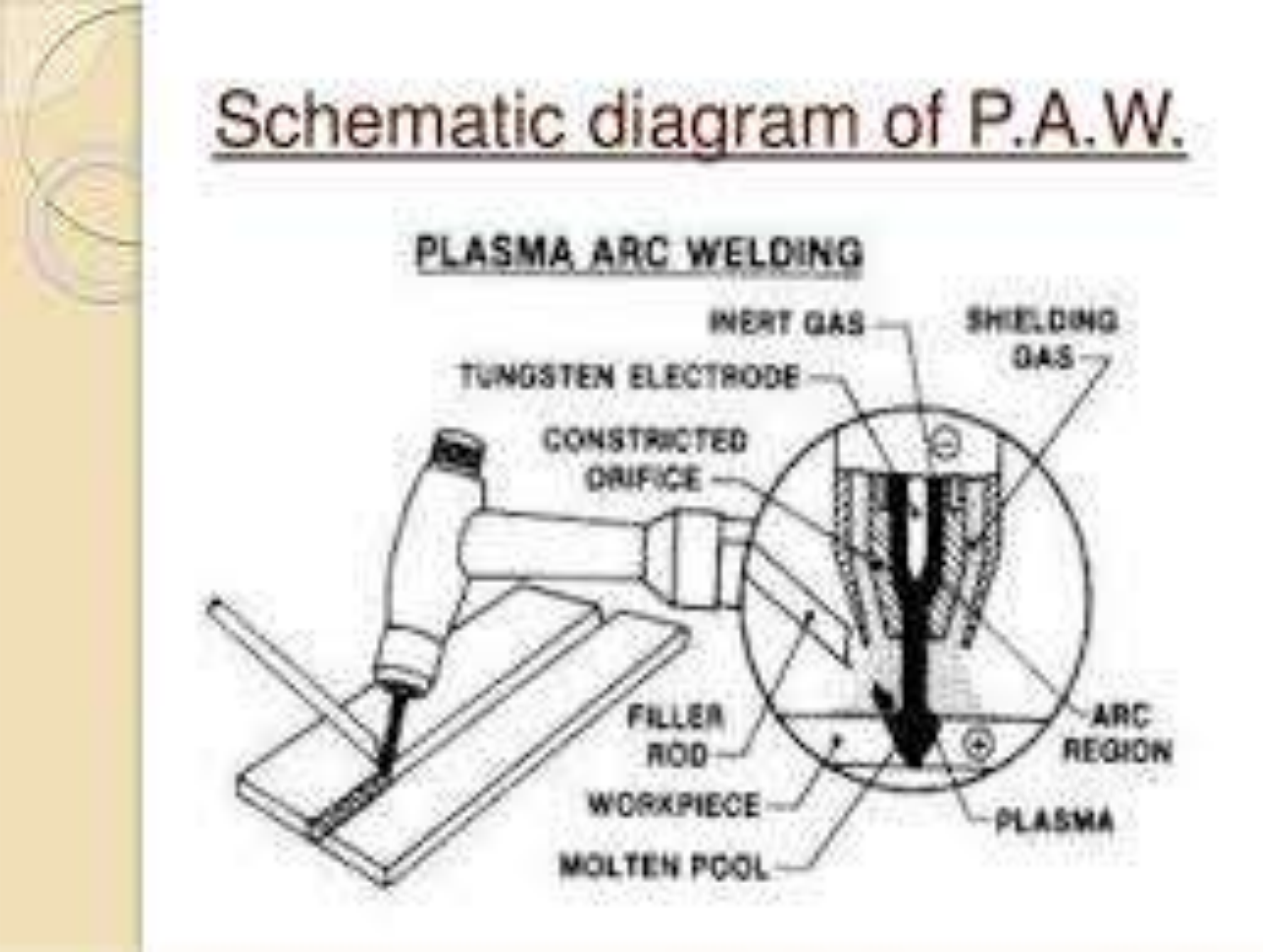
1. In the transferred-arc method of plasma-arc welding(in pic left side), the workpiece being welded is part of the electrical circuit. The arc transfers from the electrode to the workpiece hence the term transferred.
2. In the non-transferred arc method of plasma-arc welding(in pic right side), the arc occurs between the electrode and the nozzle and the heat is carried to the workpiece by the plasma gas. This thermal transfer mechanism is similar to that for an oxy-fuel flame.



Two methods of plasma-arc welding processes (a) transferred and (b) non-transferred

Compared to other arc welding processes, Plasma-arc Welding process has better arc stability, less thermal distortion, and higher energy concentration, thus permitting deeper and narrower welds. PAW has higher welding speed ranges from 120 mm/min to 1000 mm/min. A variety of metals can be welded with part thicknesses less than 6 mm.

The high heat concentration can penetrate completely through the joint with thicknesses as much as 20 mm for some titanium and aluminum alloys. In the keyhole technique, the force of the plasma arc displaces the molten metal and produces a hole at the leading edge of the weld pool. Plasma arc welding often is used rather than Gas Tungsten-arc welding for butt and lap joints because of its higher energy concentration, better arc stability and higher speed of welding. Proper training and skill are required for the operator who works on this equipment.



Guidelines for Welding Process Selection

ME Mechanical Team

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There are a number of welding processes available; however, their application is dictated by the mechanical properties, type of welded joints, their quality required in the service condition, cost and availability of the machine and operators skill.

Below discussion gives a comparative study of the different joining processes, their applicability to different types of materials and helps the welders in selecting suitable welding process.

1. Shielded Metal Arc Welding

Shielded metal arc welding process is widely used in many industries. All engineering materials can be welded. however, low melting and high reactive metals will be difficult to weld. this process is easy to operate and plates of thickness ranging from 1 mm to 25 mm can be easily welded. Preheating will be required in some alloy steels. welding can be done in flat, inclined, vertical and overhead position. Edge preparations are essential in welding thick plates.

Manual arc welding is commonly used in the erection of structural works like storage tanks, bridge etc. In open breezy conditions, flux cored self-shielded welding is better suited. Heavier plates are usually grooved weld.

TIG welding process is extensively used for welding cupronickel (70:30 alloy) for water pipe and condenser tubes. while welding carbon and alloy steel pipes by MMA (Manual Metal Arc) process for steam, power plants, backing rings are rarely used for piping in oil refineries and chemical plants.

2. Submerged Arc Welding

With Submerged arc welding (SAW), carbon and alloy steels and copper alloys can be welded; generally applied for plate thickness above 10 mm. Best suited for automatic welding in boilers, pressure vessels, shipbuilding where high-quality welds for larger thickness plates are required. This process is generally used for flat and horizontal positions. Not suitable for cast iron.

3. Oxy-acetylene Gas Welding

Oxy-acetylene gas welding process can be used for carbon steel, copper, aluminum, bronze welding, Sheet metal welding. Small diameter pipe welding can be effectively carried out. Control of the flame is important, Plates of thickness up to 8 mm – 10 mm can be welded. Red brass and yellow brass are preferably welded by the oxy-acetylene process to minimize vaporization of zinc.

4. Gas metal arc welding (TIG and MIG)

All engineering material except zinc can be welded using gas metal arc welding (GMAW) process The thickness of the plates ranges from 1 mm to 6 mm. TIG welding process is applied to all non-ferrous and alloy steel welding and also for root pas in pipe welding. Welding equipment is more complex and costly. difficult to weld small corners and, out-door applications are limited. MIG welding process in semi-automatic or fully automatic form is used for non-ferrous and stainless steel pressure vessel parts. In the manufacture of boiler units, a large number of tube butt welds have to be made with the tubes positioned at any angle from horizontal to vertical, with restricted access. In such cases, automated orbital TIG welding with automatic cold wire feed is used. titanium alloy tubes with wall thickness 1.6 mm and below are normally welded by TIG process without filler wire. For heavier pipes, filler metals are used.

5. Spot, Projection and seam welding

These processes meant for sheet metals are widely applied in automobile parts, tube manufacturing parts and sheet metal industries. all engineering metals can be welded. precautions are necessary in the case of copper and aluminum alloys which are good thermal and electrical conductors. Flash or induction welding is used for tubular joints in boiler construction. At the site, such welds are made by TIG for the root pass and manual metal arc welding for subsequent passes. Seam welding is normally limited to sheets up to 5 mm thick. Baffles and other interior parts are spots welded in place. A typical application of projection welding is in the manufacture of honeycomb panels. Propeller and drive shafts are commonly made of resistance welded tubing with the end forging are welded by submerged arc or MIG/CO_2process.

6. Electro-slag Welding

Electro-slag welding (ESW) process is for thick section welding, 5 cm and above, of alloy steels, This is mainly used for pressure vessel parts, steel plant types of equipment, large shafts etc. Both Electro-slag welding and Submerged-arc welding (SAW) are best suited for thick plates; however, ESW is more specialized in its application and less flexible compared to SAW.

7. Electron and laser beam welding

Stainless steel, nickel base alloys, titanium and zirconium and other reactive metals up to 10 to 25 mm can be welded. Special applications are in electronic industries, nuclear and aerospace industries. The process is rather costly. Laser welding has the ability to make tiny spot welds. So it is applied in micro electronic circuits. The Laser beam can weld metals on silicon and germanium.

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