Gas Flame and Arc Processes

Chapter 31

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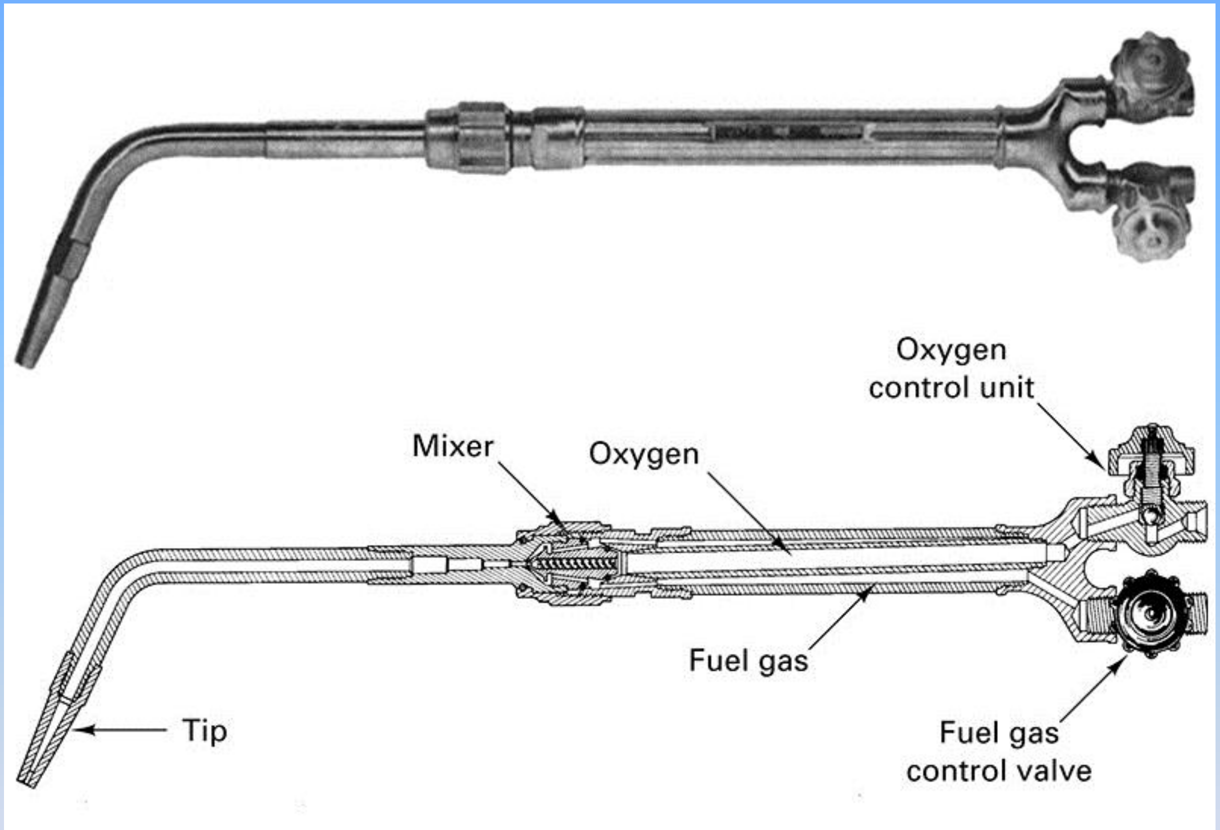
31.1 Oxyfuel-Gas Welding

Oxyacetylene Welding Torch

FIGURE 31-1 Typical oxyacetylene welding torch and cross-sectional schematic. *(Courtesy of Victor Equipment Company, Denton, TX)*



Oxyacetylene Flame Temperatures

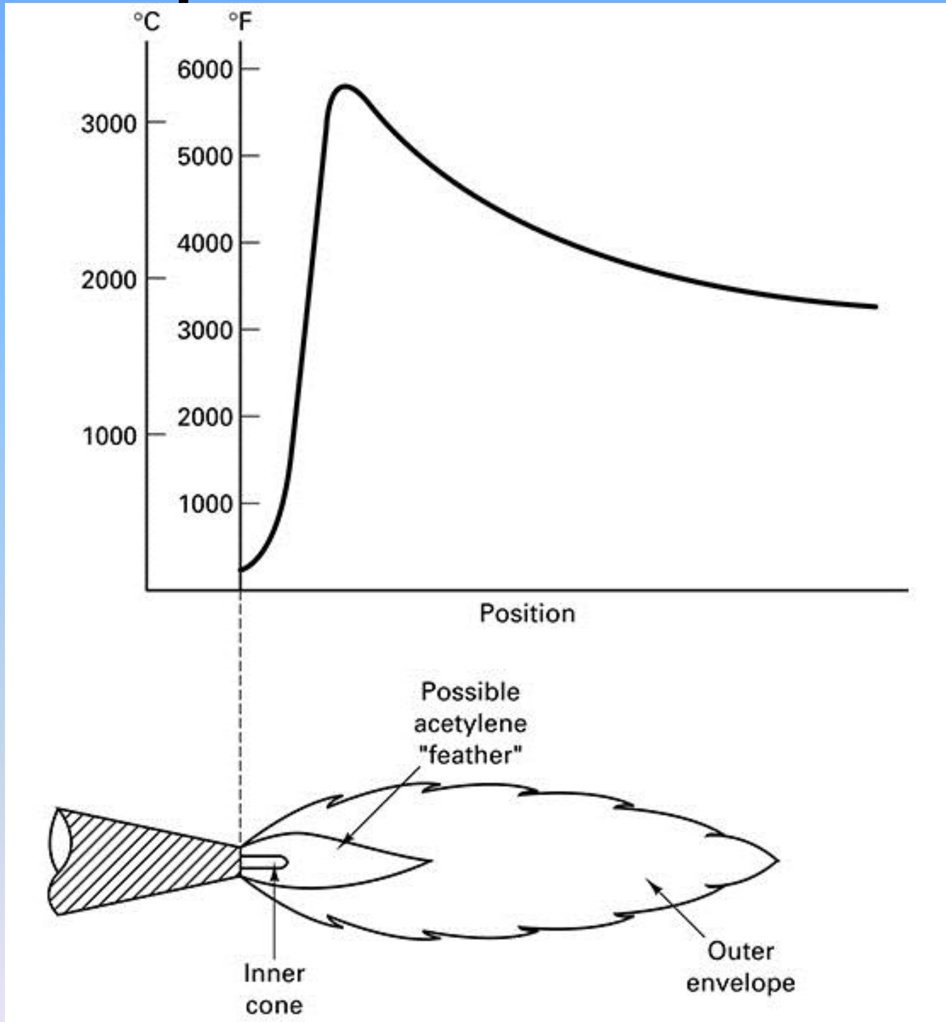
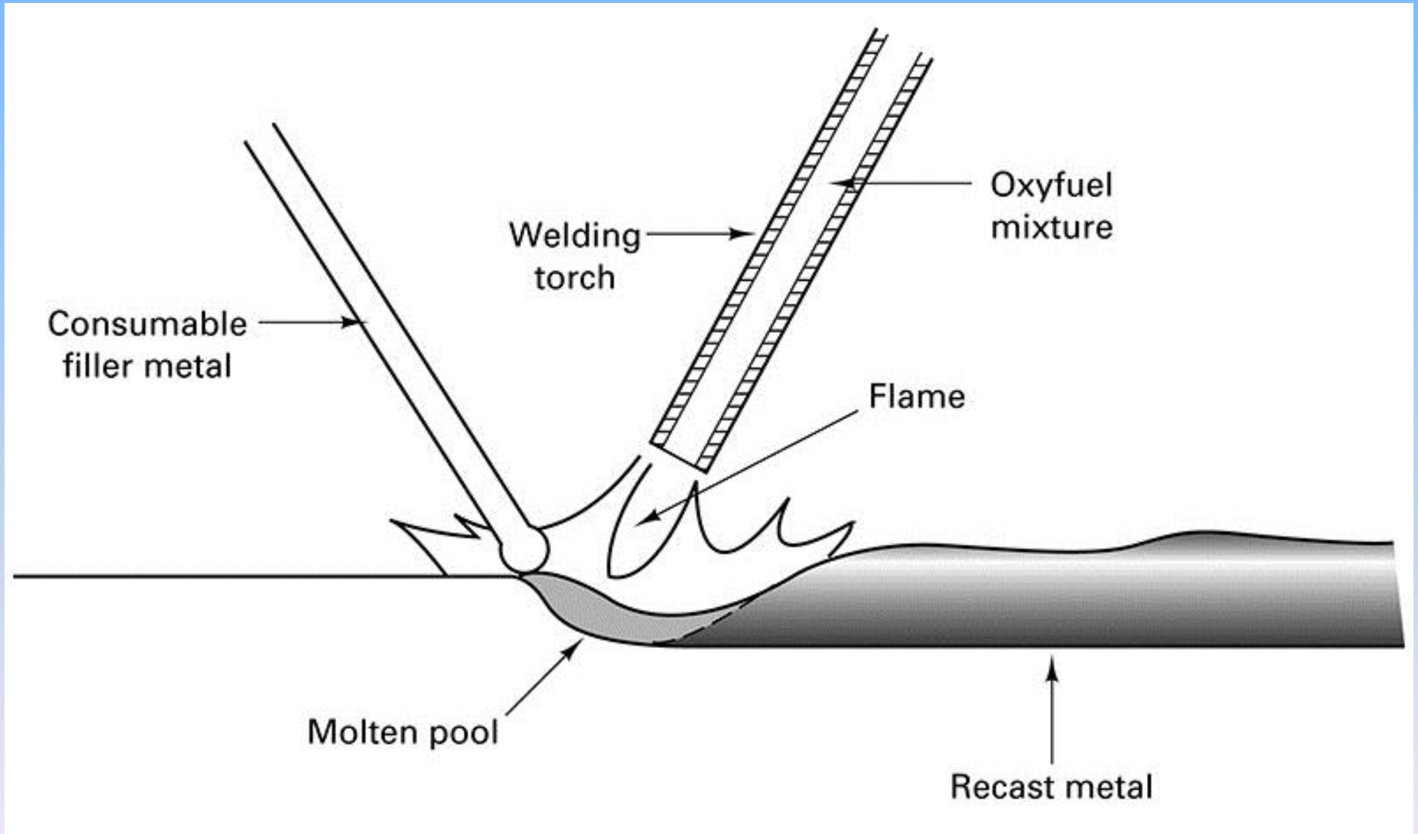


FIGURE 31-2 Typical oxyacetylene flame and the associated temperature distribution.

Oxyfuel-gas Welding

FIGURE 31-3 Oxyfuel-gas welding with a consumable welding rod.



Oxyfuel-Gas Welding Process

TABLE 31-1 Process Summary: Oxyfuel-Gas Welding (OFW)

Heat source	Fuel gas—oxygen combustion
Protection	Gases produced by combustion
Electrode	None
Material joined	Best for steel and other ferrous metals
Rate of heat input	Low
Weld profile (Depth/Width)	$^1/_3$
Max. penetration	3 mm
Assets	Cheap, simple equipment, portable, versatile
Limitations	Large HAZ, slow

Oxyfuel Application

TABLE 31-2 Engineering Materials and Their Compatibility with Oxyfuel Welding

Material	Oxyfuel Welding Recommendation
Cast iron	Recommended with cast iron filler rods; braze welding recommended if there are no corrosion objections
Carbon and low-alloy steels	Recommended for low-carbon and low-alloy steels, using rods of the same material; more difficult for higher carbon
Stainless steel	Common for thinner material; more difficult for thicker
Aluminum and magnesium	Common for aluminum thinner than 1 in.; difficult for magnesium alloys
Copper and copper alloys	Common for most alloys; more difficult for some types of bronzes
Nickel and nickel alloys	Common for nickel, Monels, and Inconels
Titanium	Not recommended
Lead and zinc	Recommended
Thermoplastics, thermosets, and elastomers	Hot-gas welding used for thermoplastics, not used with thermosets and elastomers
Ceramics and glass	Seldom used with ceramics, but common with glass
Dissimilar metals	Difficult; best if melting points are within 50°F; concern for galvanic corrosion
Metals to nonmetals	Not recommended
Dissimilar nonmetals	Difficult

31.2 Oxygen Torch Cutting

Flame Cutting

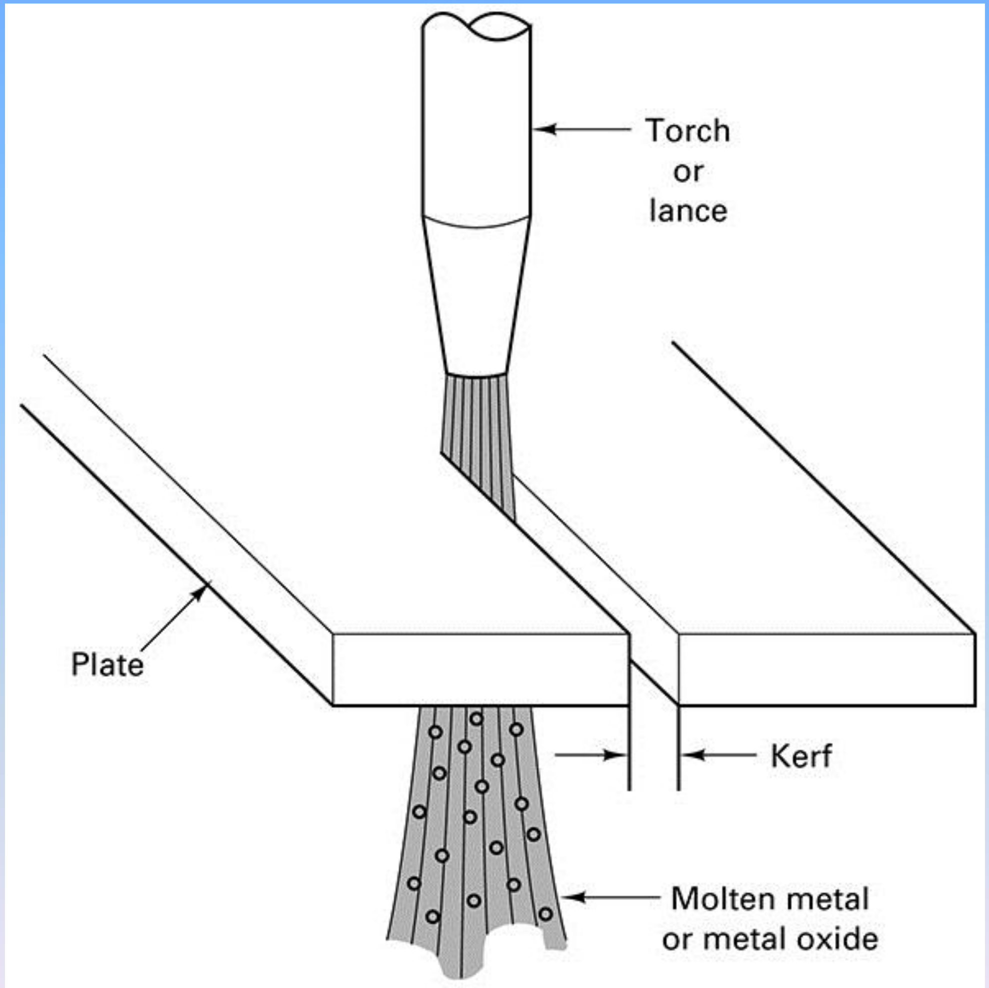
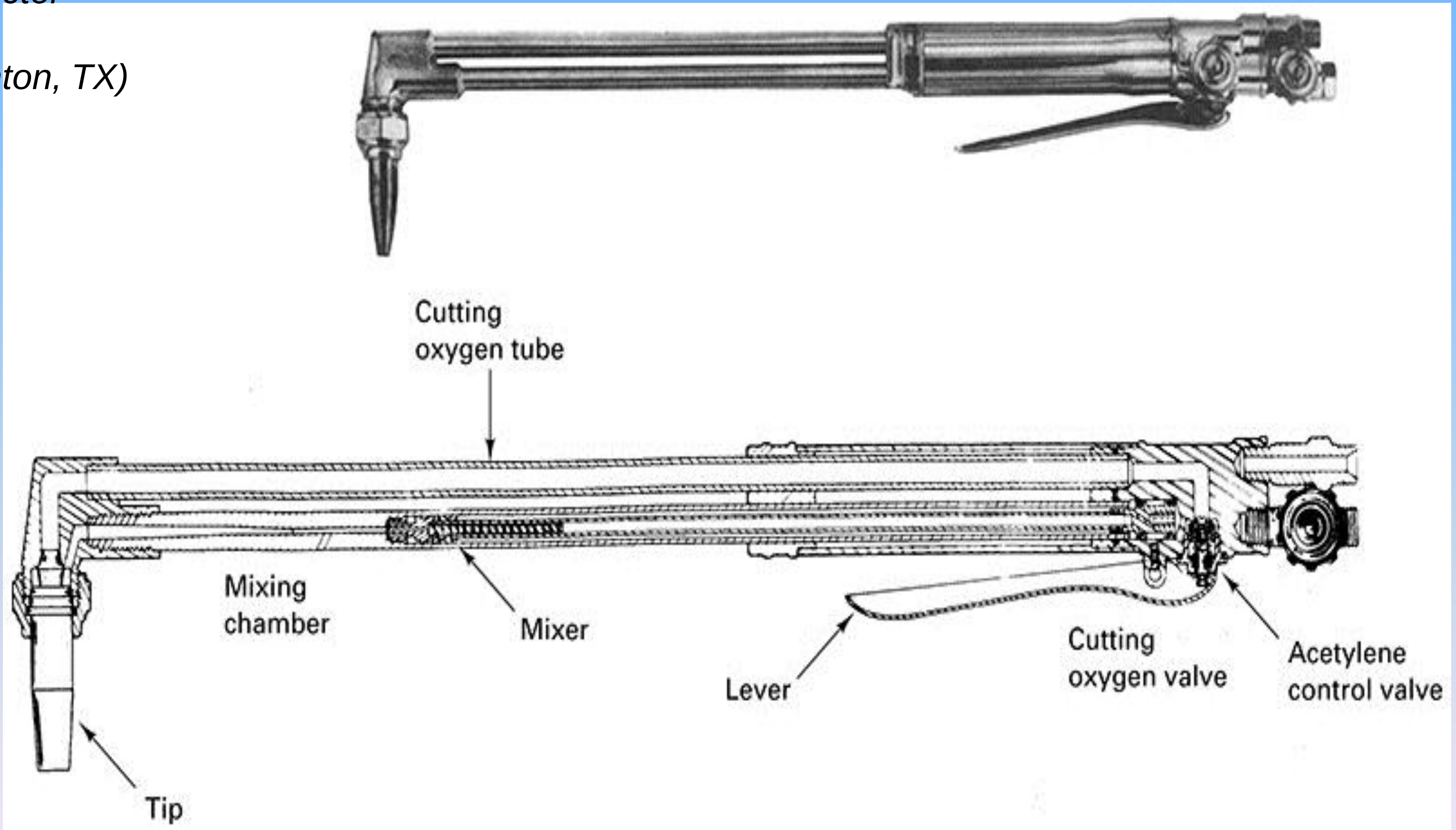


FIGURE 31-4 Flame cutting of a metal plate.

Oxyacetylene Cutting Torch

FIGURE 31-5
Oxyacetylene cutting torch and cross-sectional schematic. *(Courtesy of Victor Equipment Company, Denton, TX)*



Underwater Cutting Torch

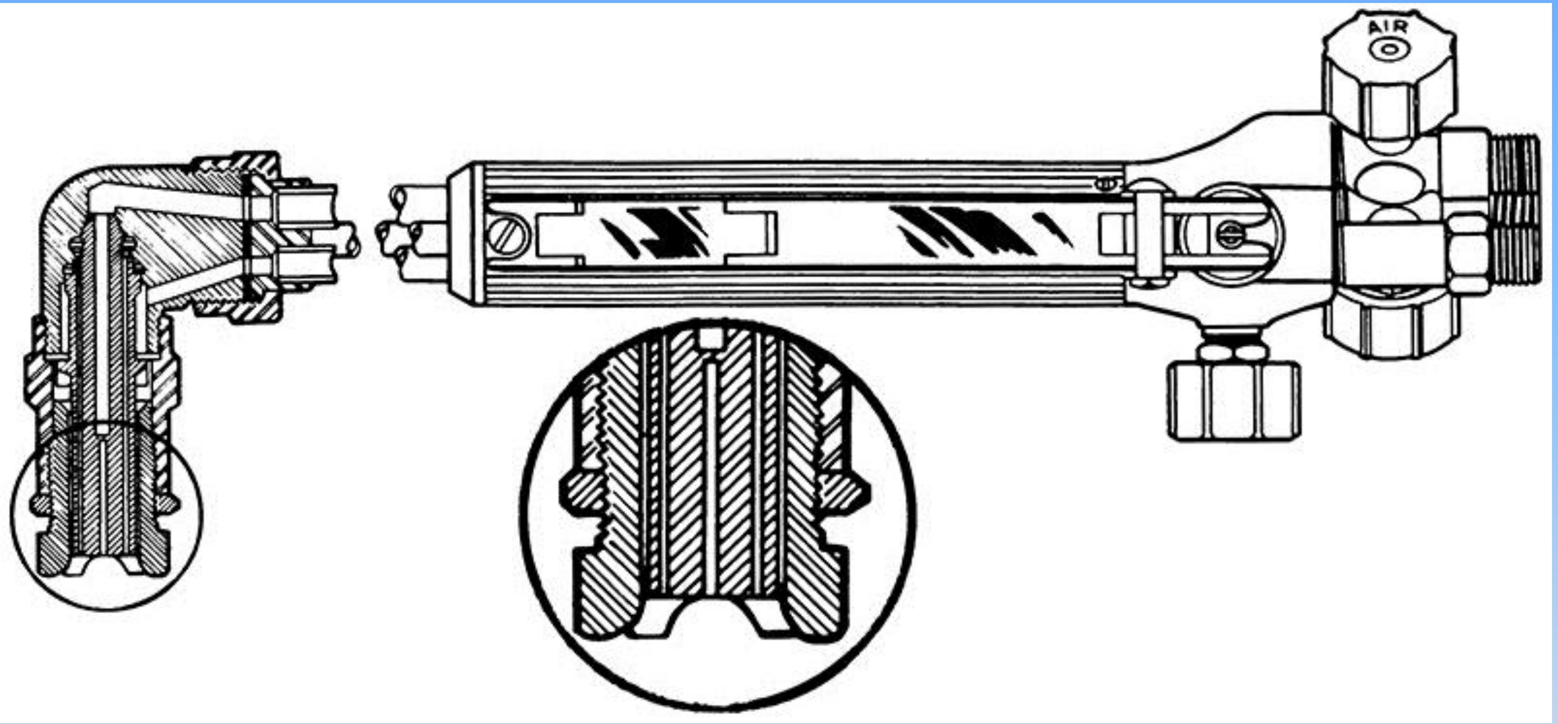


FIGURE 31-6 Underwater cutting torch. Note the extra set of gas openings in the nozzle to permit the flow of compressed air and the extra control valve. *(Courtesy of Bastian-Blessing Company, Chicago, IL)*

31.3 Flame Straightening

Flame Straightening

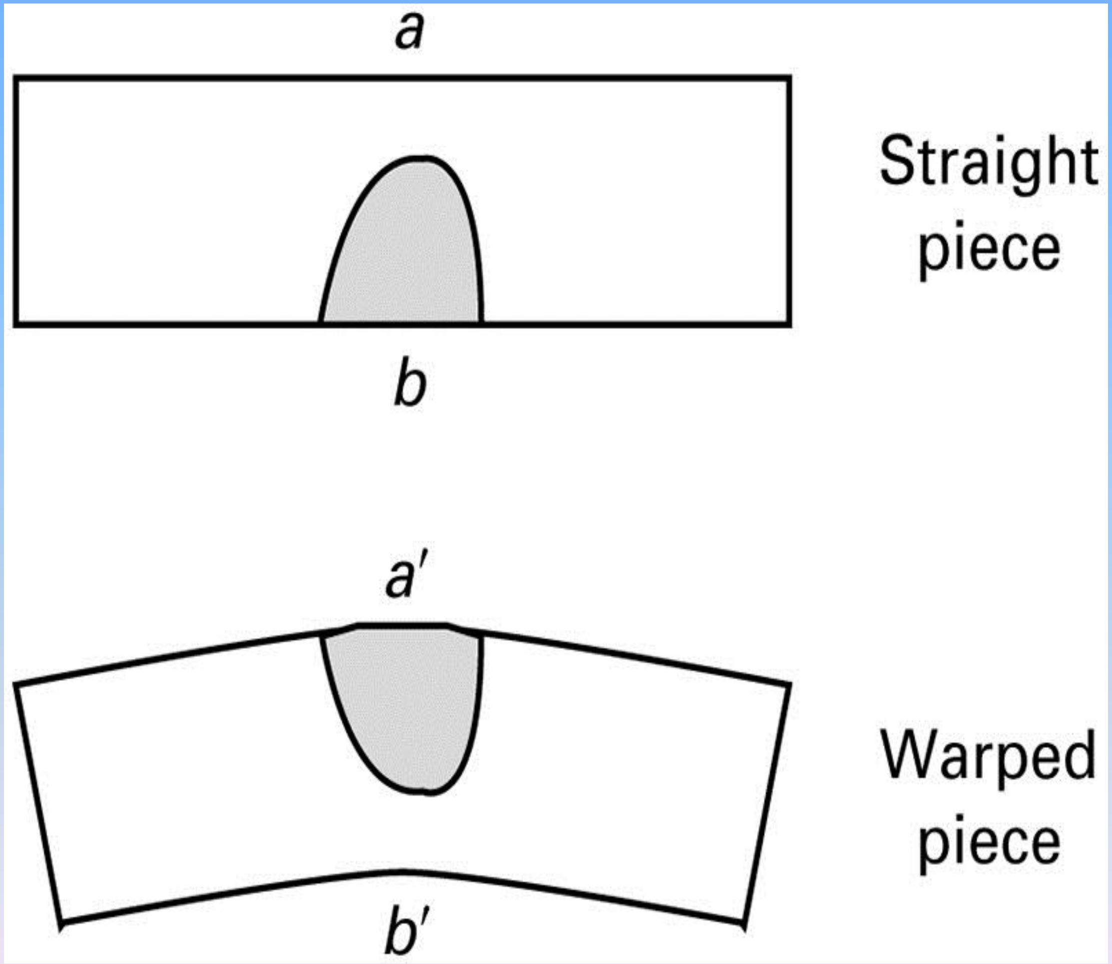


FIGURE 31-7 Schematic illustrating the theory of flame straightening.

31.4 Arc Welding

Arc Welding Schematic

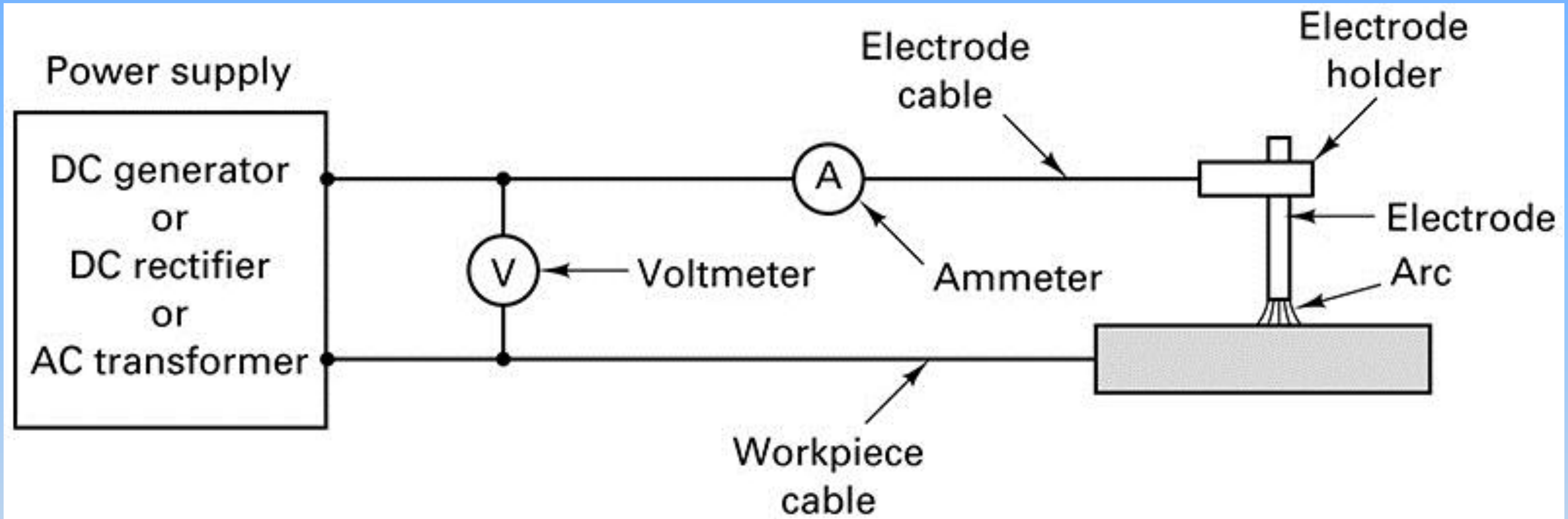


FIGURE 31-8 The basic electrical circuit for arc welding.

Metal Transfer Modes

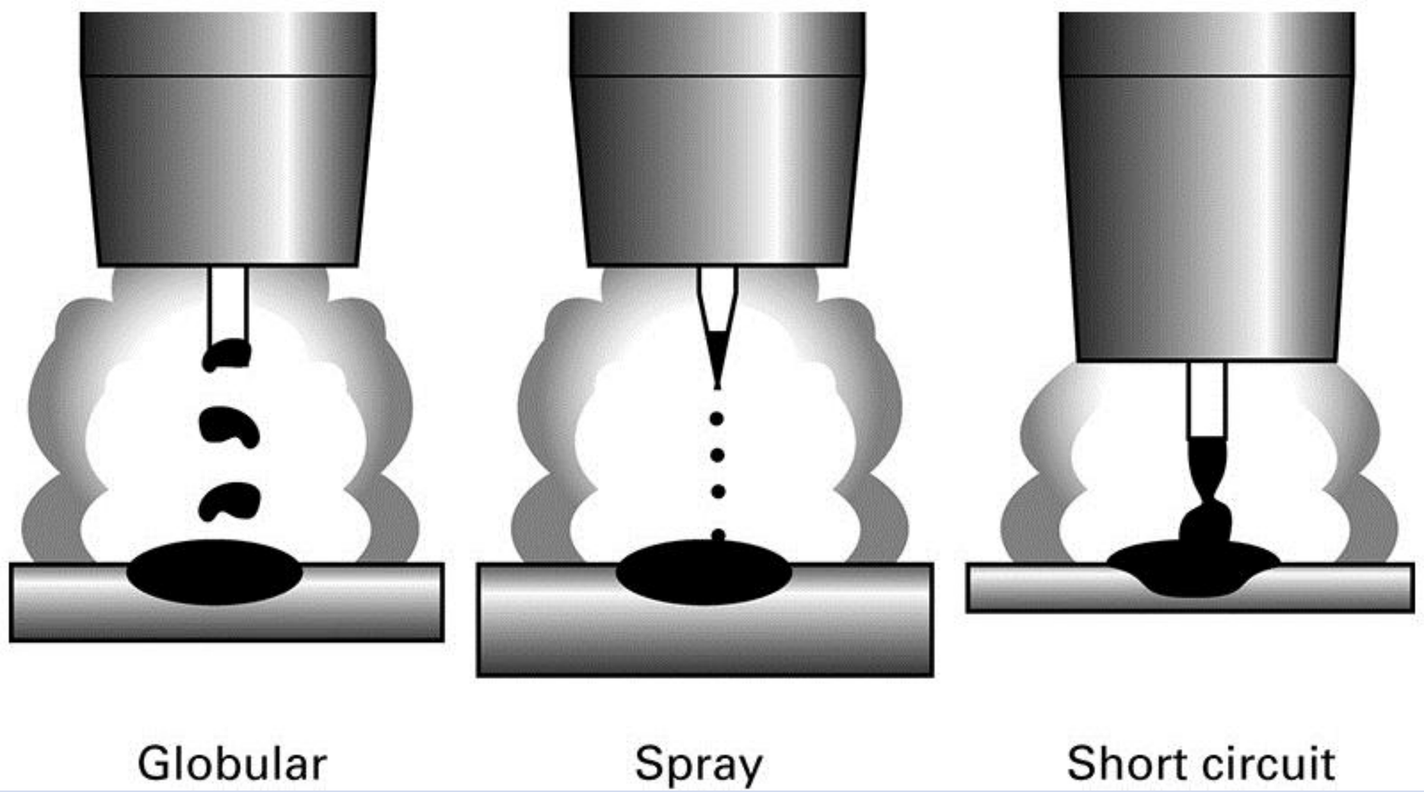


FIGURE 31-9 Three modes of metal transfer during arc welding. *(Courtesy of Republic Steel Corporation, Youngstown, OH)*

31.5 Consumable-Electrode Arc Welding

Welding Electrode Designation

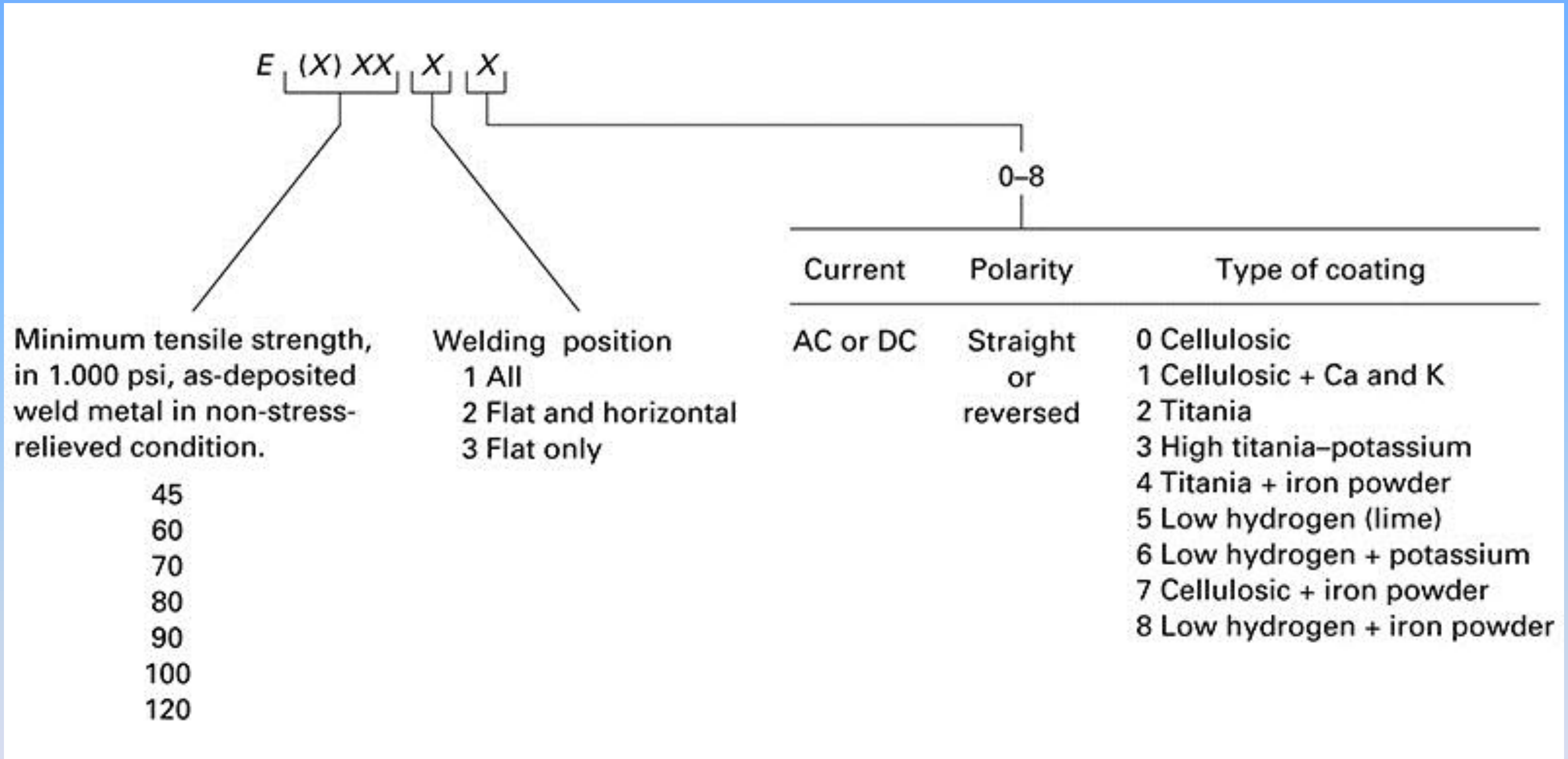
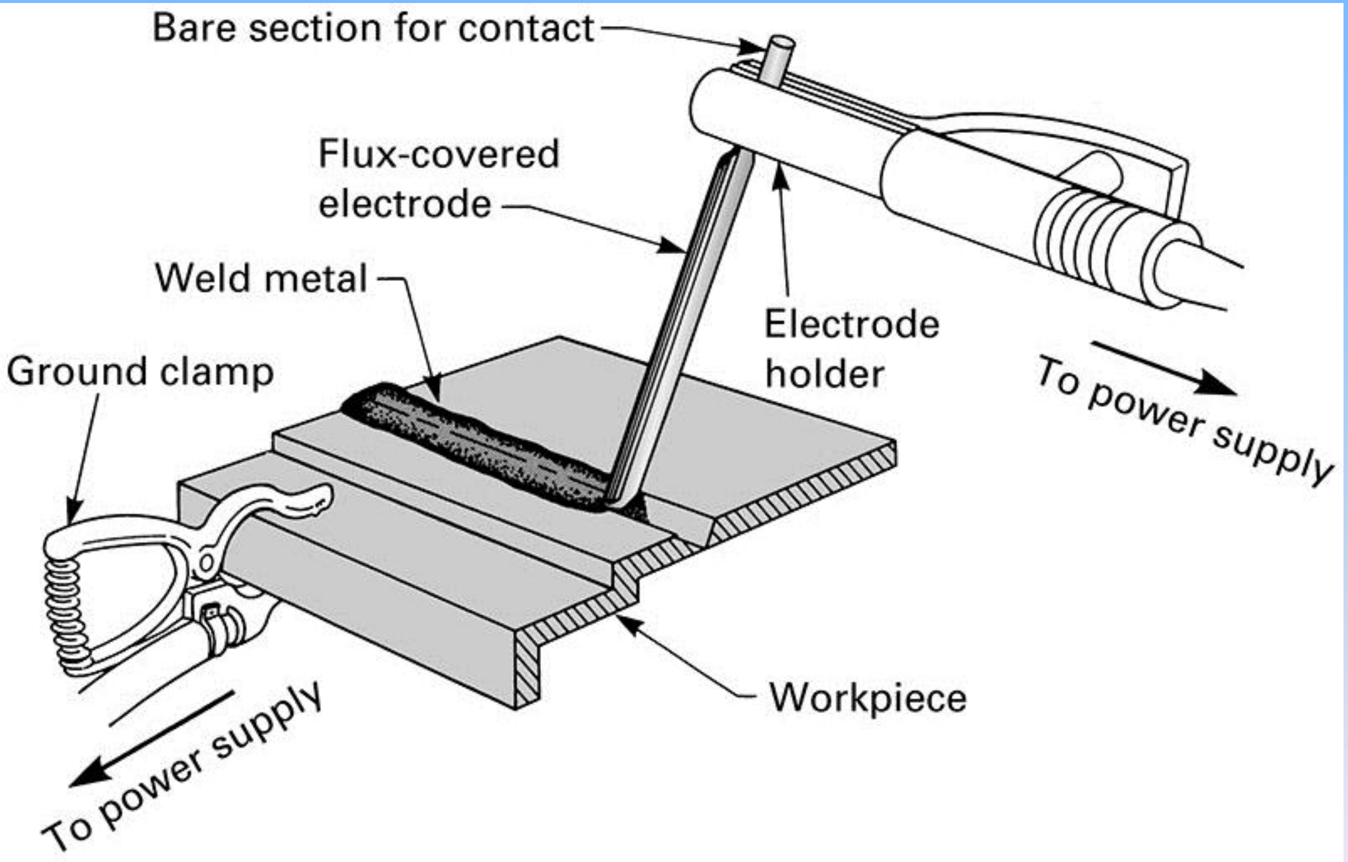


FIGURE 31-10 Designation system for arc-welding electrodes.

Shielded Metal Arc Welding

FIGURE 31-11 A shielded metal arc welding (SMAW) system.



Schematic of SMAW

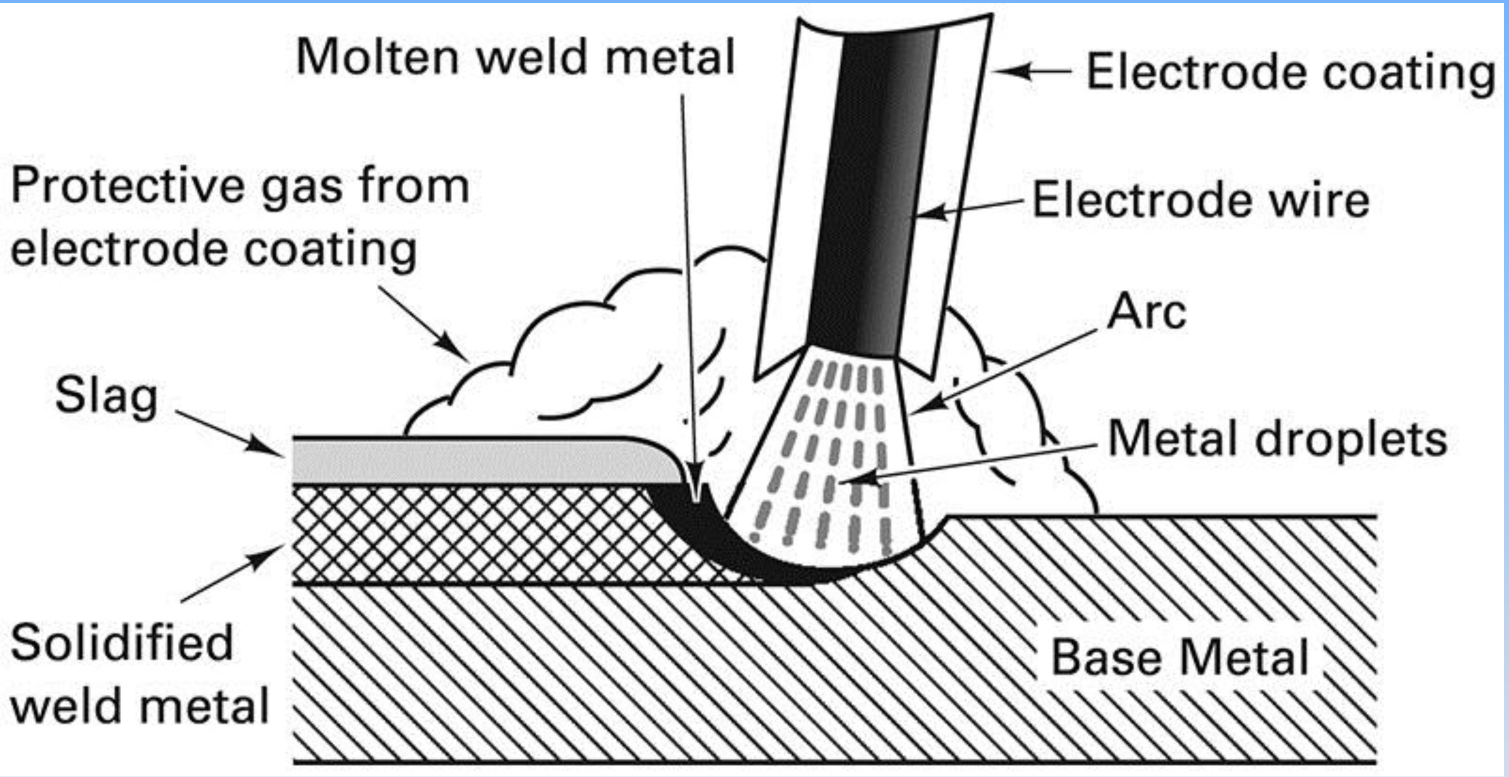


FIGURE 31-12 Schematic diagram of shielded metal arc welding (SMAW).
(Courtesy of American Iron and Steel Institute, Washington, DC.)

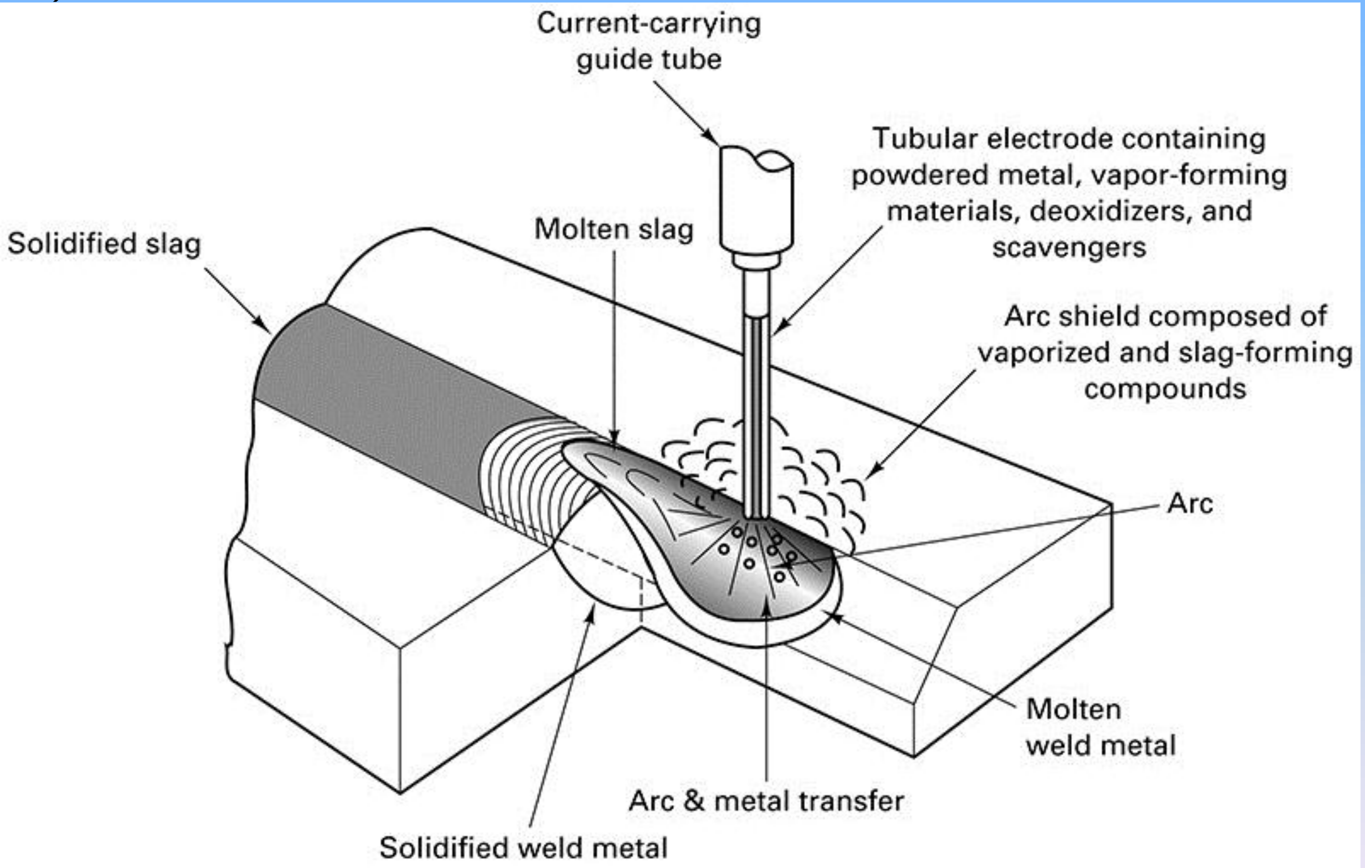
Process Summary of SMAW

TABLE 31-3 Process Summary: Shielded Metal Arc Welding (SMAW)

Heat source	Electric arc
Protection	Slag from flux and gas from vaporized coating material
Electrode	Discontinuous, consumable
Material joined	Best for steel
Rate of heat input	Medium
Weld profile (D/W)	1
Current	<300 amps
Max. penetration	3–6 mm
Assets	Cheap, simple equipment
Limitations	Discontinuous, shallow welds; requires slag removal

Flux-Cored Arc Welding

FIGURE 31-13 The flux-cored arc welding (FCAW) process. *(Courtesy of The American Welding Society, New York.)*

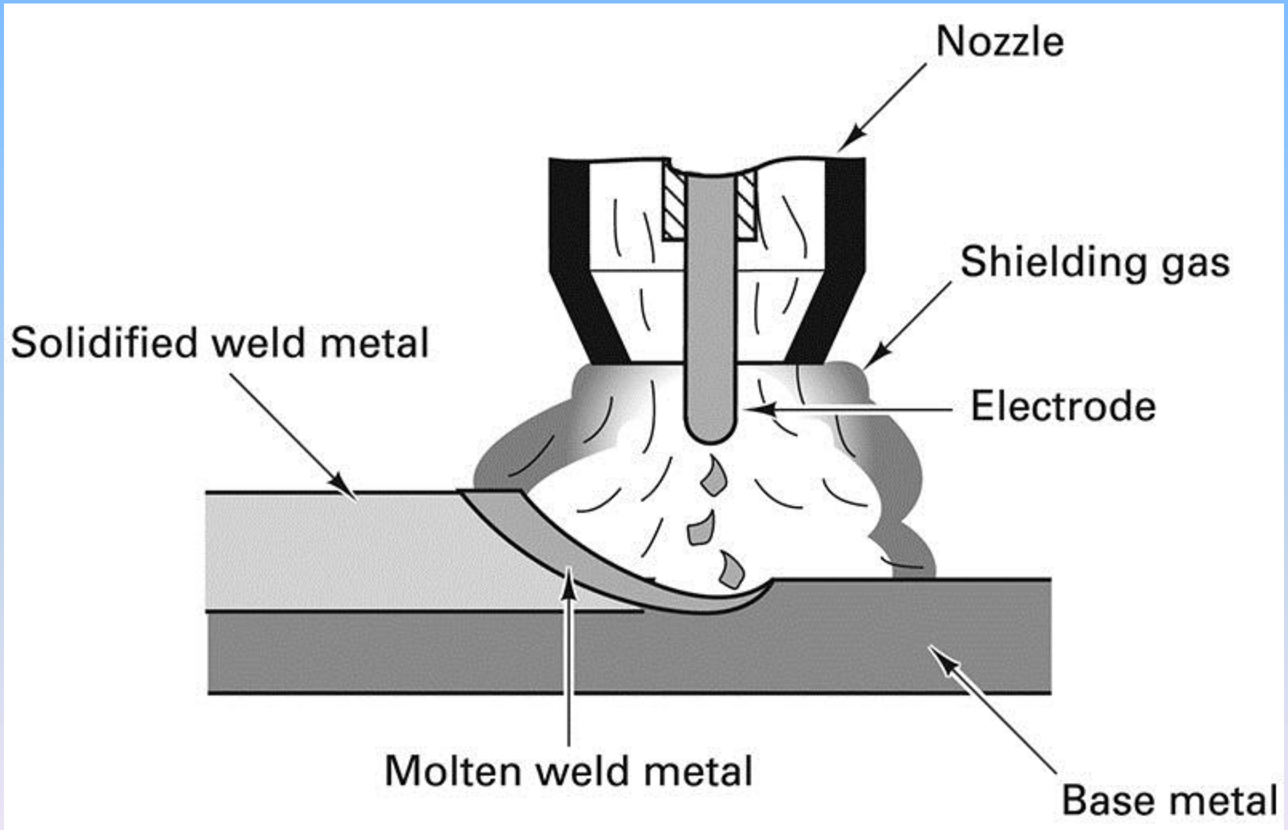


Process Summary of FCAW

TABLE 31-4	Process Summary: Flux-Cored Arc Welding (FCAW)
Heat source	Electric arc
Protection	Slag and gas from flux (optional secondary gas shield)
Electrode	Continuous, consumable
Material joined	Best for steel
Rate of heat input	Medium
Weld profile (D/W)	1
Current	<500 amps
Max. penetration	6–10 mm
Assets	Continuous electrode
Limitations	Requires slag removal

Schematic of Gas Metal Arc Welding

FIGURE 31-14 Schematic diagram of gas metal arc welding (GMAW). *(Courtesy of American Iron and Steel Institute, Washington, DC.)*



Process Summary of GMAW

TABLE 31-5 Process Summary: Gas Metal Arc Welding (GMAW)

Heat source	Electric arc
Protection	Externally supplied shielding gas
Electrode	Continuous, consumable
Material joined	All common metals
Rate of heat input	Medium
Weld profile (D/W)	1
Current	<500 amps
Max. penetration	6–10 mm
Assets	No slag to remove
Limitations	More costly equipment than SMAW or FCAW

Schematic of Submerged Arc Welding

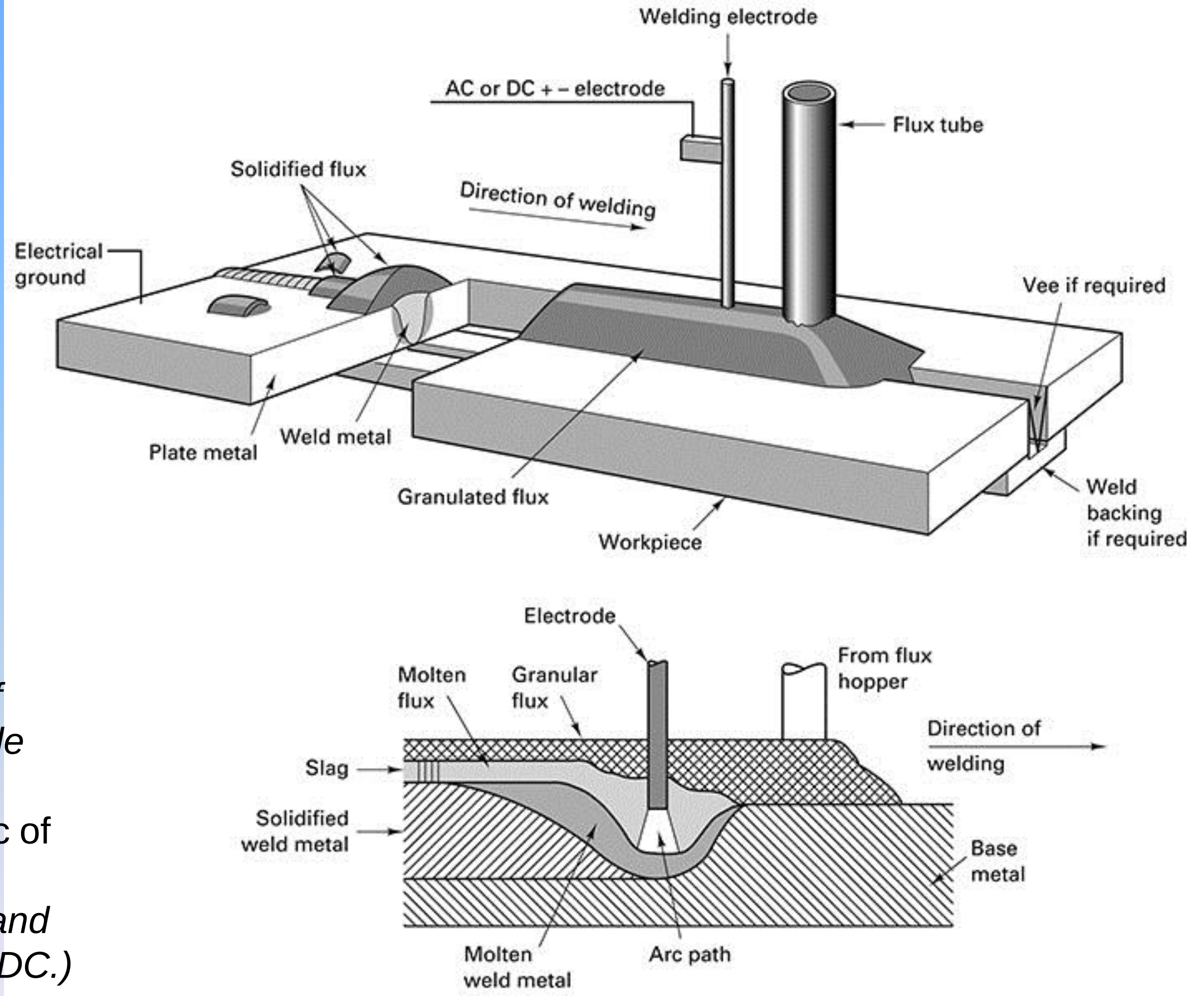


FIGURE 31-15 (Top) Basic features of submerged arc welding (SAW). *(Courtesy of Linde Division, Union Carbide Corporation, Houston, TX)* (Bottom) Cutaway schematic of submerged arc welding. *(Courtesy of American Iron and Steel Institute, Washington, DC.)*

Process Summary of SAW

TABLE 31-6 Process Summary: Submerged Arc Welding (SAW)

Heat source	Electric arc
Protection	Granular flux provides slag and an isolation blanket
Electrode	Continuous, consumable
Material joined	Best for steel
Rate of heat input	Medium
Weld profile (D/W)	1
Current	<1000 amps
Max. penetration	25 mm
Assets	High-quality welds, high deposition rates
Limitations	Requires slag removal, difficult for overhead and out-of-position welding, joints often require backing plates

Stud Welding Gun

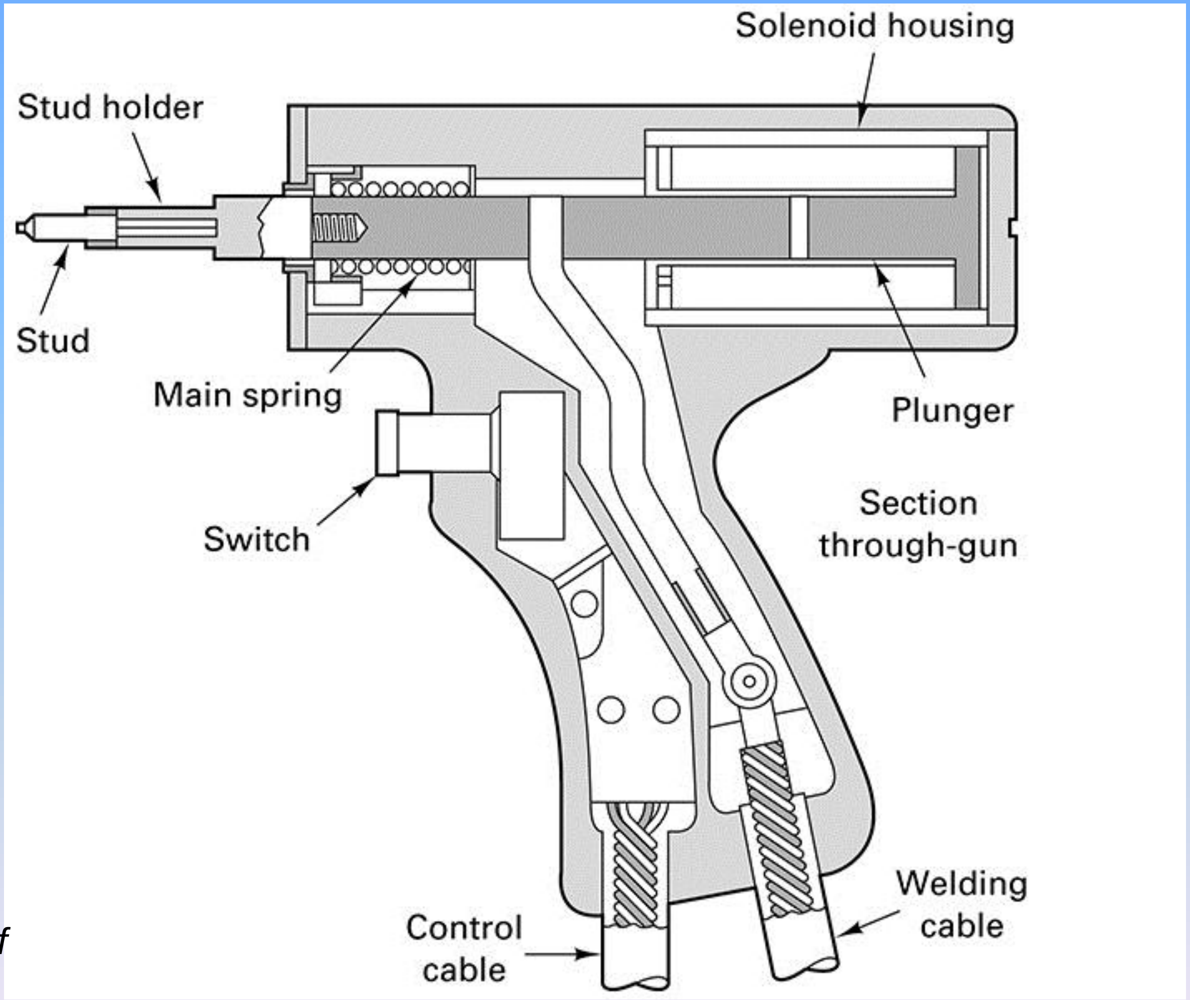


FIGURE 31-16 Diagram of a stud welding gun. *(Courtesy of American Machinist.)*

Stud Welding Examples

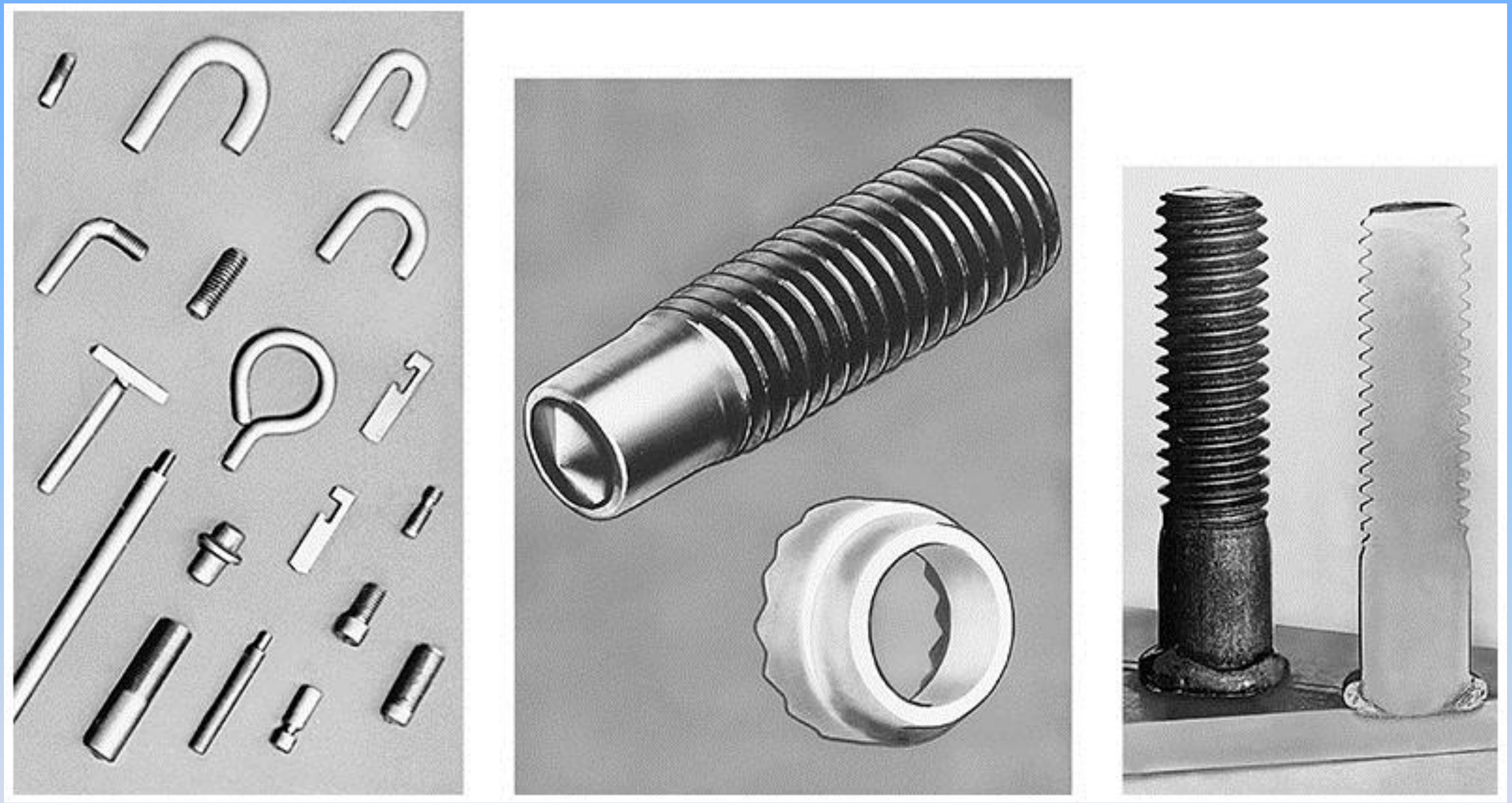
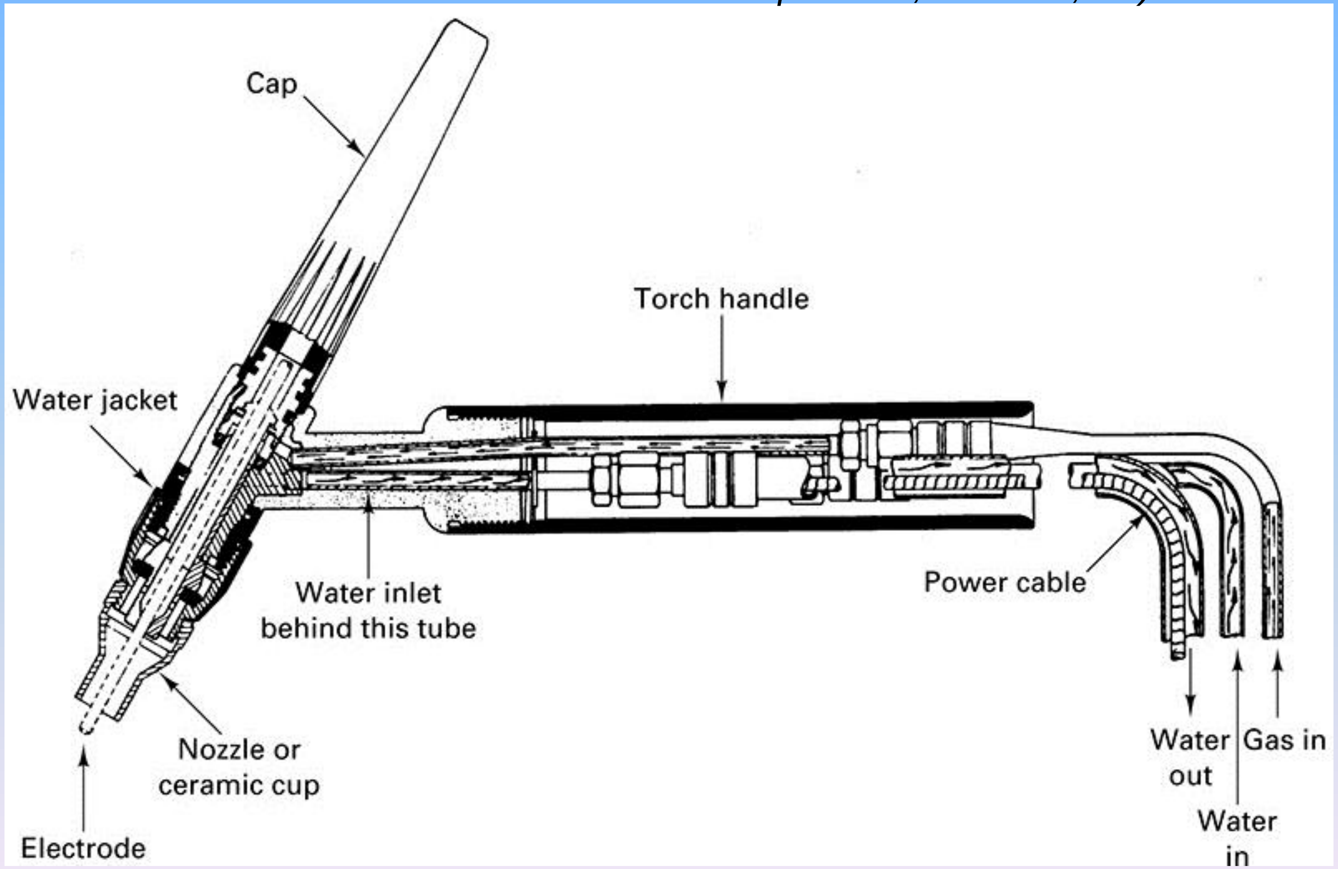


FIGURE 31-17 (Left) Types of studs used for stud welding. (Center) Stud and ceramic ferrule. (Right) Stud after welding and a section through a welded stud. *(Courtesy of Nelson Stud Welding Co, Elyria, OH)*

31.6 Nonconsumable-Electrode Arc Welding

Gas Tungsten Arc Welding Torch

FIGURE 31-18 Welding torch used in nonconsumable electrode, gas tungsten arc welding (GTAW), showing feed lines for power, cooling water, and inert-gas flow. *(Courtesy of Linde Division, Union Carbide Corporation, Houston, TX)*



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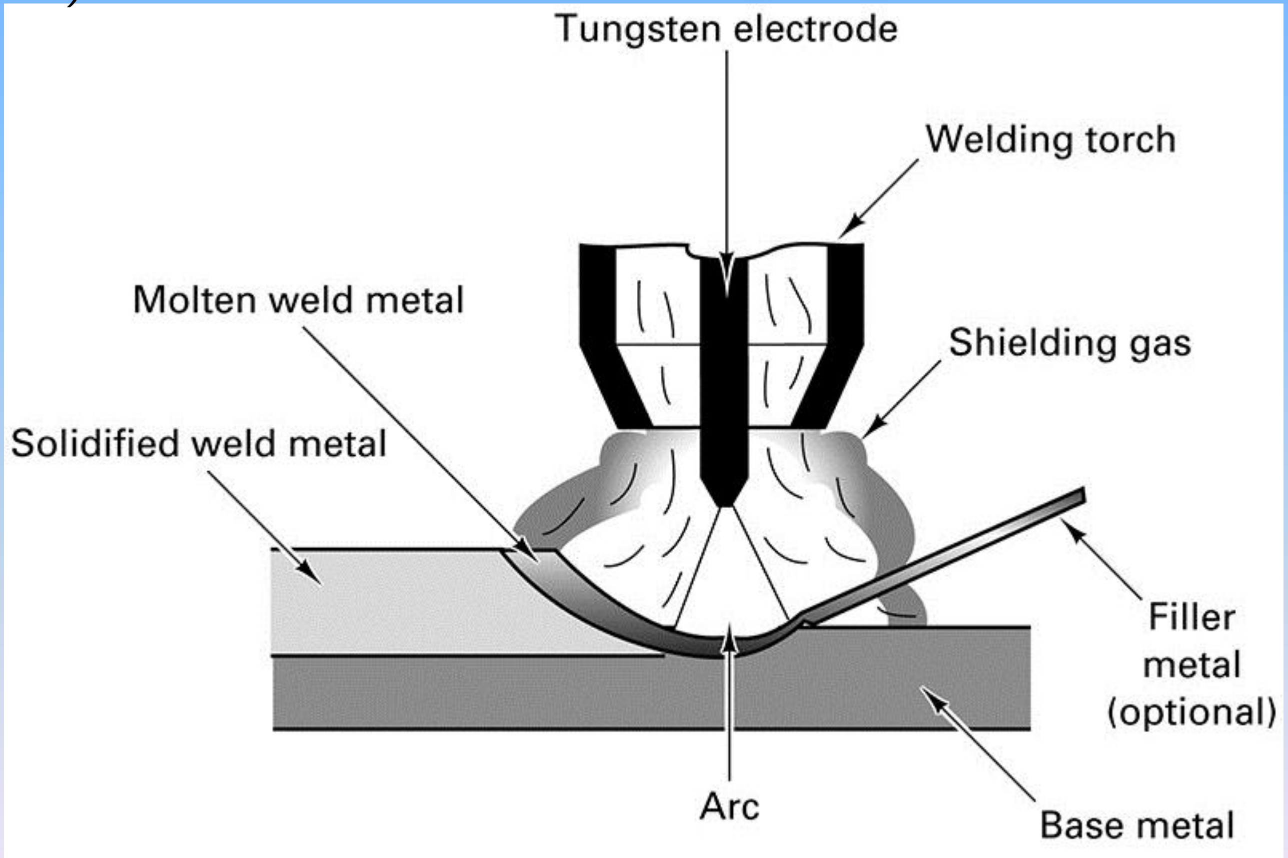
Schematic of GTAW

FIGURE 31-19 Diagram of gas tungsten arc welding (GTAW). *(Courtesy of American Iron and Steel Institute, Washington, DC.)*



Metal Deposition Rate Comparison

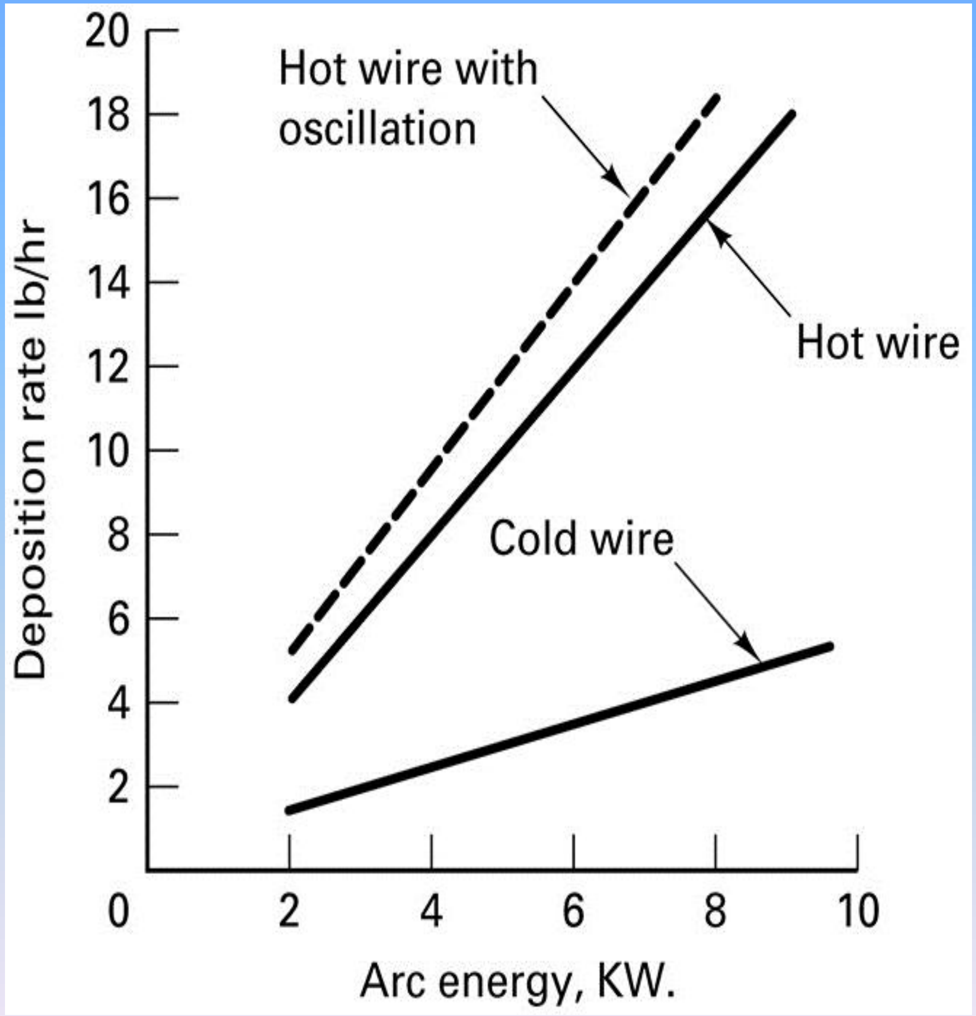


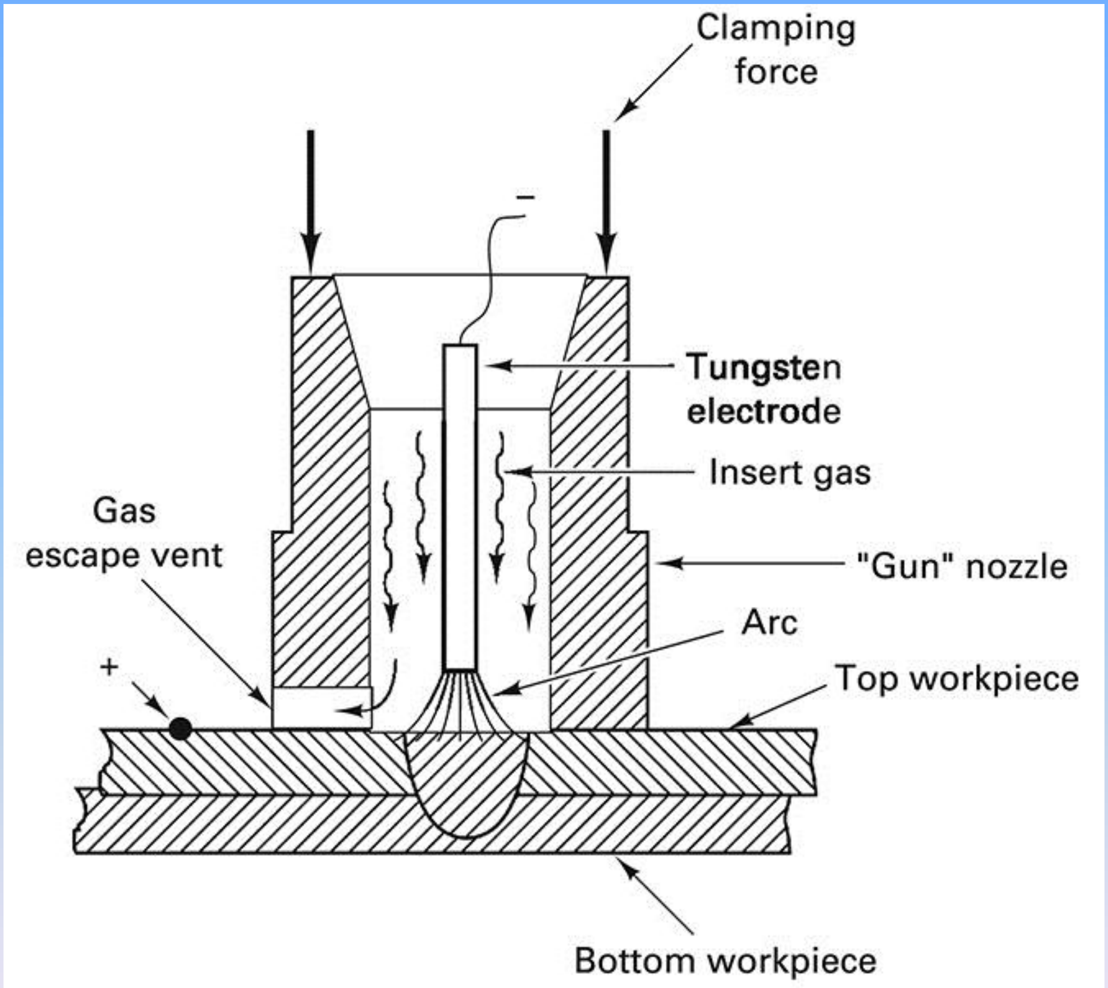
FIGURE 31-20 Comparison of the metal deposition rates in GTAW with cold, hot, and oscillating-hot filler wire. (*Courtesy of* Welding Journal.)

Process Summary of GTAW

TABLE 31-7	Process Summary: Gas Tungsten Arc Welding (GTAW)
Heat source	Electric arc
Protection	Externally supplied shielding gas
Electrode	Nonconsumable
Material joined	All common metals
Rate of heat input	Medium
Weld profile (D/W)	1
Current	<500 amps
Max. penetration	3 mm
Assets	High-quality welds, no slag to be removed
Limitations	Slower than consumable electrode GMAW

Schematic of Inert-Gas-Shielded Tungsten Arc Welding

FIGURE 31-21 Process schematic of spot welding by the inert-gas-shielded tungsten arc process.



Example of GTAW

FIGURE 31-22 Making a spot weld by the inert-gas-shielded tungsten arc process. *(Courtesy of Air Reduction Company Inc., New York, NY)*

Types of Plasma Arc Torches

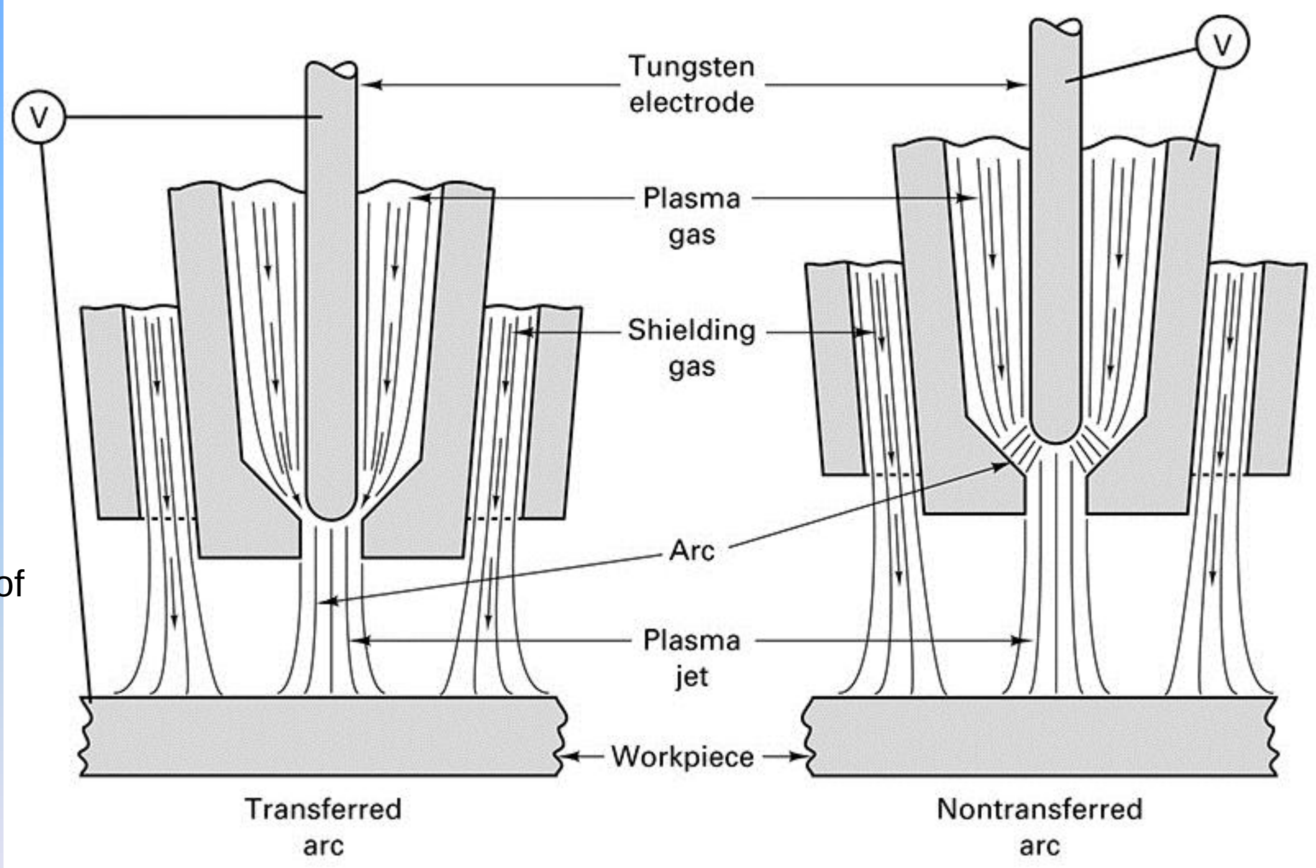


FIGURE 31-23 Two types of plasma arc torches. (Left) Transferred arc; (right) nontransferred arc.

GTAW versus Plasma Arc Process

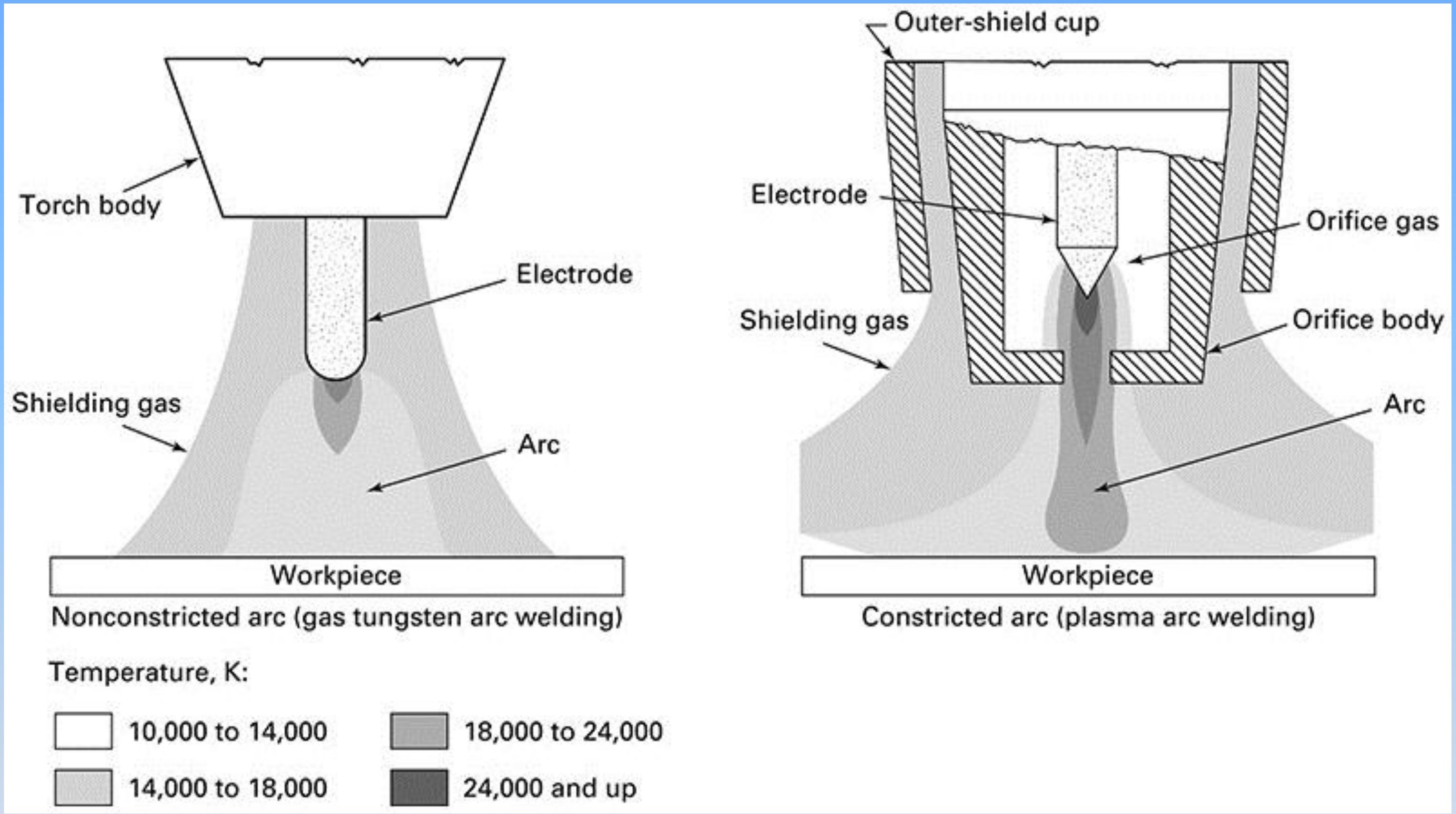


FIGURE 31-24 Comparison of the nonconstricted arc of gas tungsten arc welding and the constricted arc of the plasma arc process. Note the level and distribution of temperature. *(Courtesy ASM International, Materials Park, OH.)*

Process Summary of PAW

TABLE 31-8 Process Summary: Plasma Arc Welding (PAW)

Heat source	Plasma arc
Protection	Externally supplied shielding gas
Electrode	Nonconsumable
Material joined	All common metals
Rate of heat input	High
Weld profile (D/W)	3
Current	<500 amps
Max. penetration	12–18 mm
Assets	Can have long arc length
Limitations	High initial equipment cost, large torches may limit accessibility

31.7 Welding Equipment

Voltage Characteristics

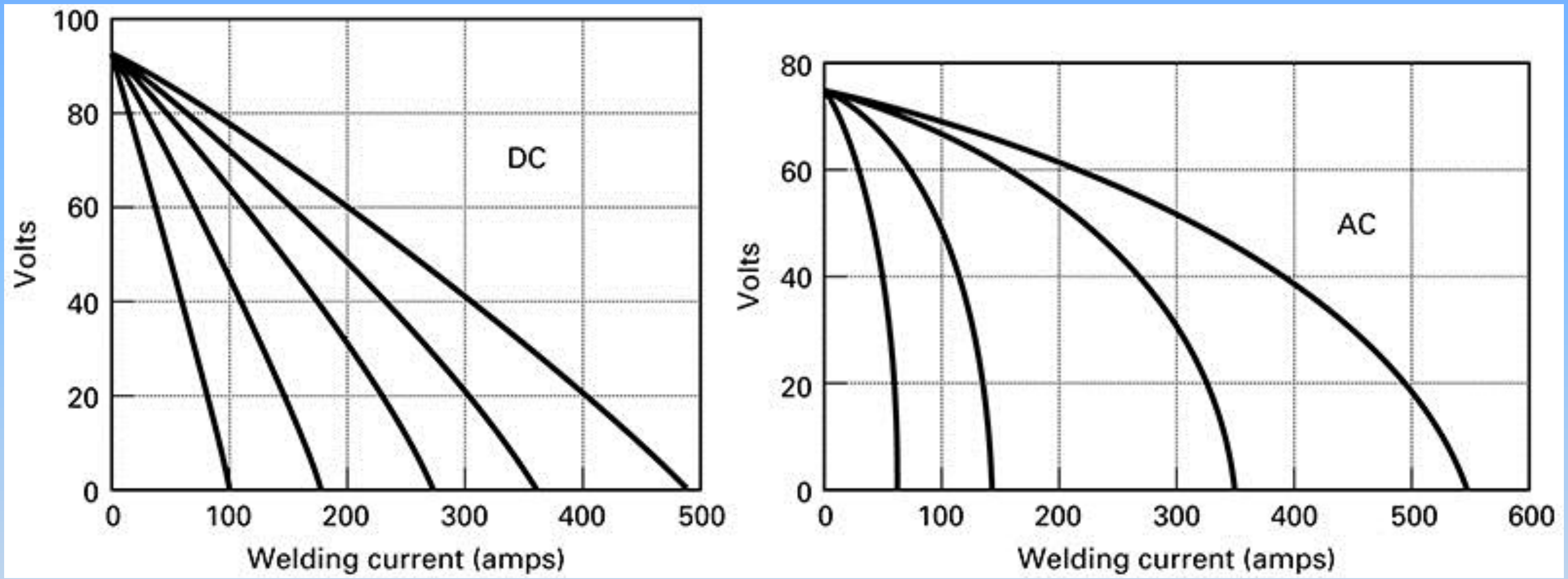


FIGURE 31-25 Drooping-voltage characteristics of typical arc-welding power supplies. (Left) Direct current; (right) alternating current.

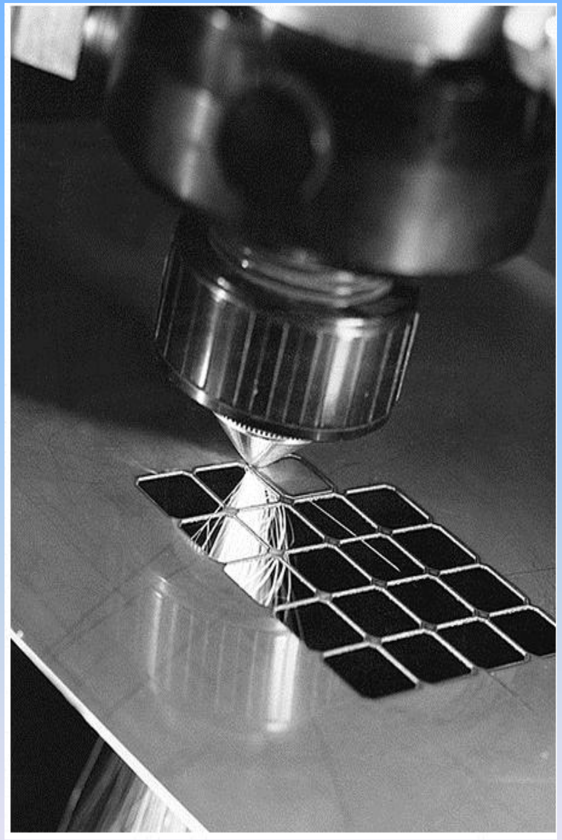
Welding Equipment

FIGURE 31-26 Rectifier-type AC and DC welding power supply. *(Courtesy of Lincoln Electric Company, Cleveland, OH)*

31.8 Arc Cutting

Example of Plasma Torch

FIGURE 31-27 Cutting sheet metal with a plasma torch. *(Courtesy of GTE Sylvania, Danvers, MA)*



31.9 Metallurgical and Heat Effects in Thermal Cutting

Cutting Process Comparison

TABLE 31-9 Cutting Process Comparison: Oxyfuel, Plasma Arc, and Laser

Feature	Oxyfuel Cutting	Plasma Arc Cutting	Laser Cutting
Preferred materials	Carbon steel and titanium	All electrically conductive metals	Metal, plastic, wood, textiles
Quality of cut	Average	Similar to oxyfuel Almost as good as laser on thin material	Good quality—best for plate material less than $^1/_2$-inch thick
Thickness range			
1. Steel	3/16 inch to unlimited	26 ga. to 3 inch	Foil to 1 inch
2. Stainless	not used	26 ga. to 5 inch	20 ga. to $^3/_4$ inch
3. Aluminum	not used	22 ga. to 6 inch	20 ga. to $^3/_4$ inch
Cutting speed or time	Long preheat is required	Fast cutting	Slower than plasma, but faster than oxyfuel