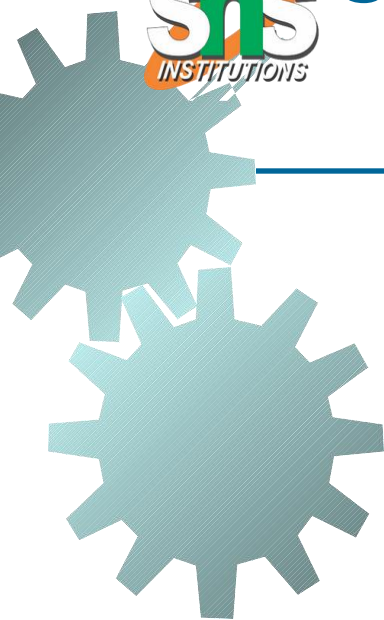




Arc welding - gas welding

- 
- Three overlapping gears of varying sizes and shades of teal and blue are positioned on the left side of the slide.
1. Arc Welding
 2. Resistance Welding
 3. Oxyfuel Gas Welding
 4. Other Fusion Welding Processes
 5. Solid State Welding
 6. Weld Quality
 7. Weldability



Two Categories of Welding Processes

- Fusion welding - coalescence is accomplished by melting the two parts to be joined, in some cases adding filler metal to the joint
 - Examples: arc welding, resistance spot welding, oxyfuel gas welding
- Solid state welding - heat and/or pressure are used to achieve coalescence, but no melting of base metals occurs and no filler metal is added
 - Examples: forge welding, diffusion welding, friction welding



Arc Welding (AW)

A fusion welding process in which coalescence of the metals is achieved by the heat from an electric arc between an electrode and the work

- Electric energy from the arc produces temperatures ~ 10,000 F (5500 C), hot enough to melt any metal
- Most AW processes add filler metal to increase volume and strength of weld joint



What is an Electric Arc?

An electric arc is a discharge of electric current across a gap in a circuit

- It is sustained by an ionized column of gas (*plasma*) through which the current flows
- To initiate the arc in AW, electrode is brought into contact with work and then quickly separated from it by a short distance

Arc Welding

A pool of molten metal is formed near electrode tip, and as electrode is moved along joint, molten weld pool solidifies in its wake

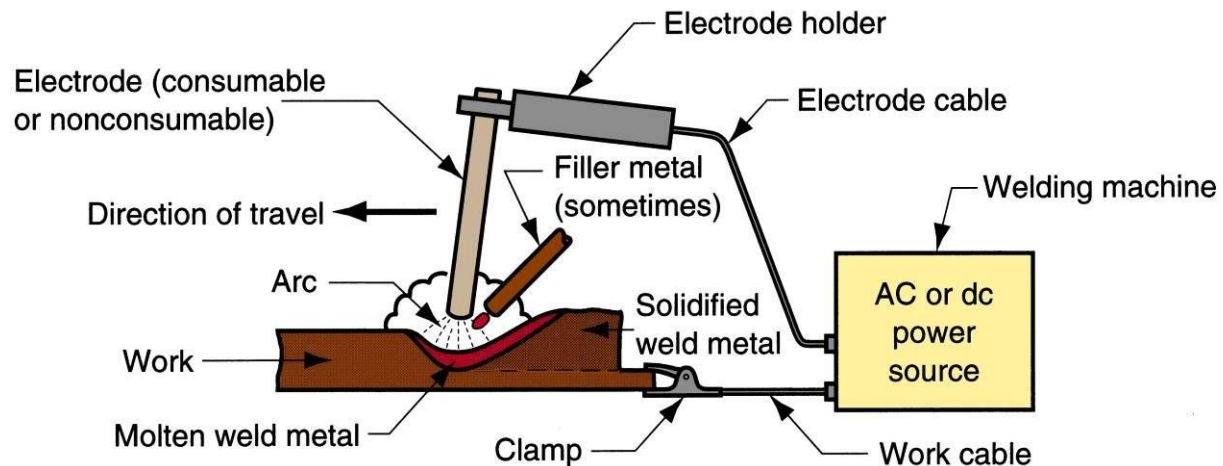


Figure 31.1 Basic configuration of an arc welding process.



Two Basic Types of AW Electrodes

- Consumable – consumed during welding process
 - Source of filler metal in arc welding
- Nonconsumable – not consumed during welding process
 - Filler metal must be added separately



Consumable Electrodes

- Forms of consumable electrodes
 - Welding rods (a.k.a. sticks) are 9 to 18 inches and 3/8 inch or less in diameter and must be changed frequently
 - Weld wire can be continuously fed from spools with long lengths of wire, avoiding frequent interruptions
- In both rod and wire forms, electrode is consumed by arc and added to weld joint as filler metal



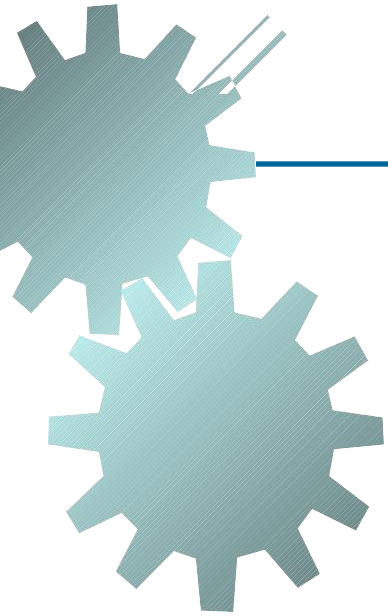
Nonconsumable Electrodes

- Made of tungsten which resists melting
- Gradually depleted during welding (vaporization is principal mechanism)
- Any filler metal must be supplied by a separate wire fed into weld pool



Arc Shielding

- At high temperatures in AW, metals are chemically reactive to oxygen, nitrogen, and hydrogen in air
 - Mechanical properties of joint can be seriously degraded by these reactions
 - To protect operation, arc must be shielded from surrounding air in AW processes
- Arc shielding is accomplished by:
 - Shielding gases, e.g., argon, helium, CO₂
 - Flux



Flux

A substance that prevents formation of oxides and other contaminants in welding, or dissolves them and facilitates removal

- Provides protective atmosphere for welding
- Stabilizes arc
- Reduces spatter



Various Flux Application Methods

- Pouring granular flux onto welding operation
- Stick electrode coated with flux material that melts during welding to cover operation
- Tubular electrodes in which flux is contained in the core and released as electrode is consumed



Power Source in Arc Welding

- Direct current (DC) vs. Alternating current (AC)
 - AC machines less expensive to purchase and operate, but generally restricted to ferrous metals
 - DC equipment can be used on all metals and is generally noted for better arc control



Consumable Electrode AW Processes

- Shielded Metal Arc Welding
- Gas Metal Arc Welding
- Flux-Cored Arc Welding
- Electrode Gas Welding
- Submerged Arc Welding



Shielded Metal Arc Welding (SMAW)

Uses a consumable electrode consisting of a filler metal rod coated with chemicals that provide flux and shielding

- Sometimes called "stick welding"
- Power supply, connecting cables, and electrode holder available for a few thousand dollars

Shielded Metal Arc Welding

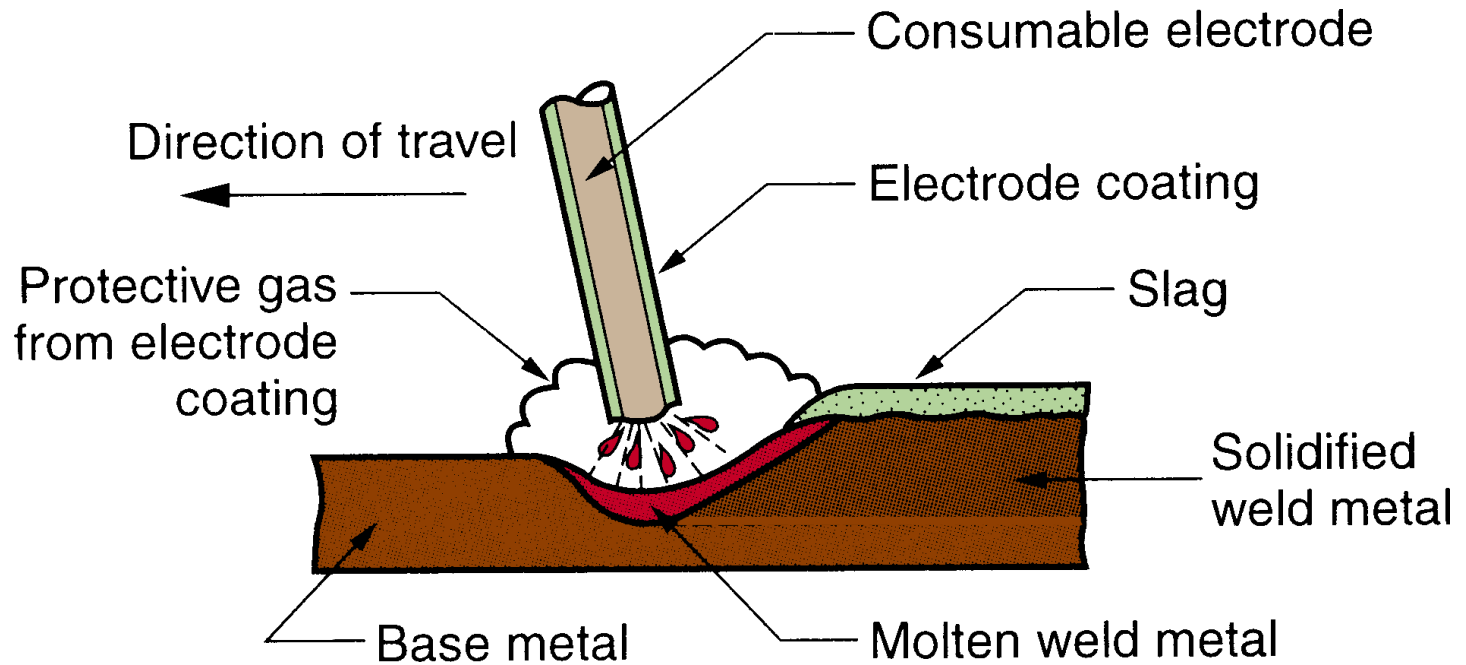


Figure Shielded metal arc welding (SMAW).

Shielded Metal Arc Welding

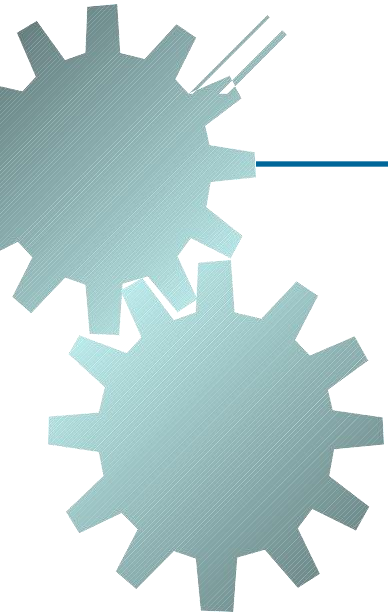
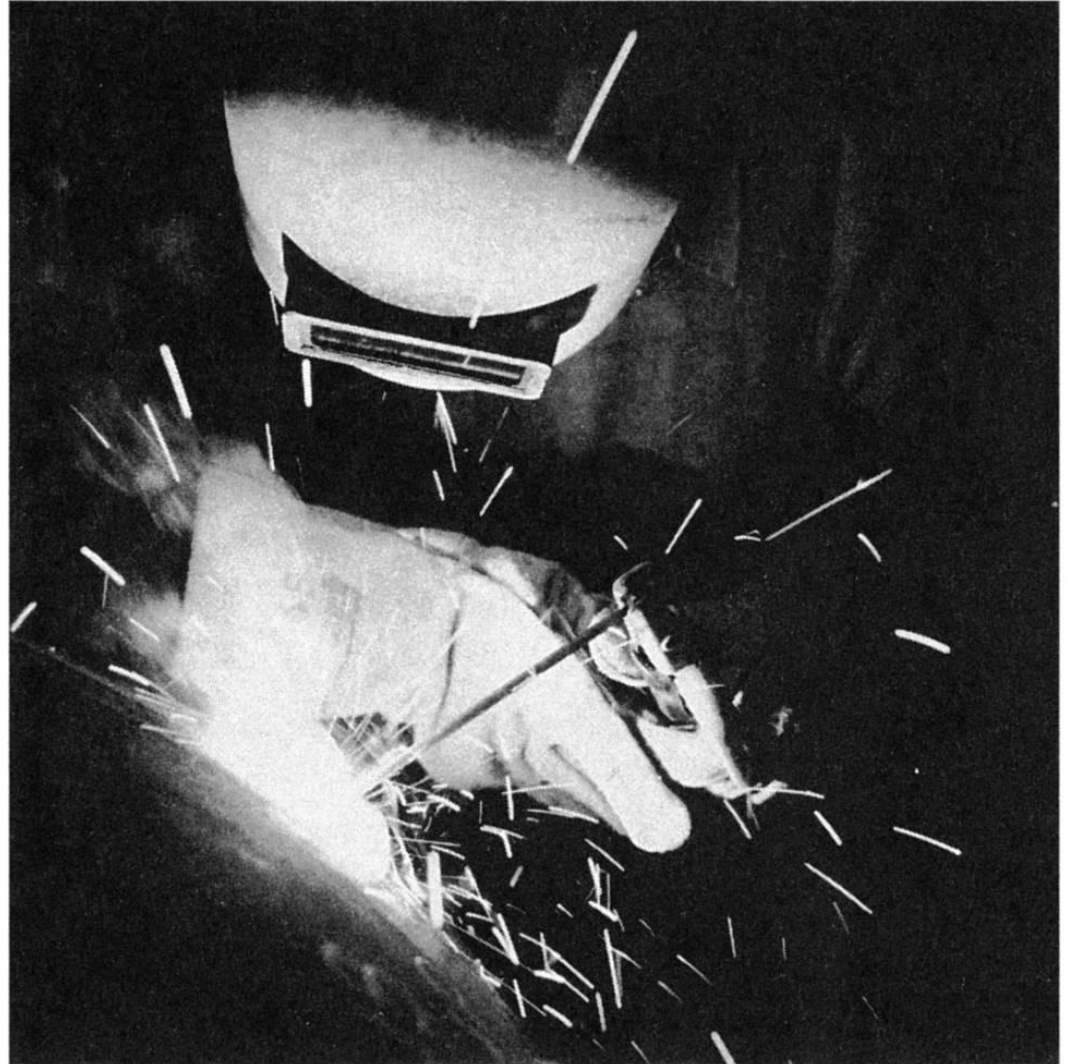


Figure Shielded metal arc welding (stick welding) performed by a (human) welder (photo courtesy of Hobart Brothers Co.).





SMAW Applications

- Used for steels, stainless steels, cast irons, and certain nonferrous alloys
- Not used or rarely used for aluminum and its alloys, copper alloys, and titanium



Gas Metal Arc Welding (GMAW)

Uses a consumable bare metal wire as electrode and shielding accomplished by flooding arc with a gas

- Wire is fed continuously and automatically from a spool through the welding gun
- Shielding gases include inert gases such as argon and helium for aluminum welding, and active gases such as CO₂ for steel welding
- Bare electrode wire plus shielding gases eliminate slag on weld bead - no need for manual grinding and cleaning of slag

Gas Metal Arc Welding

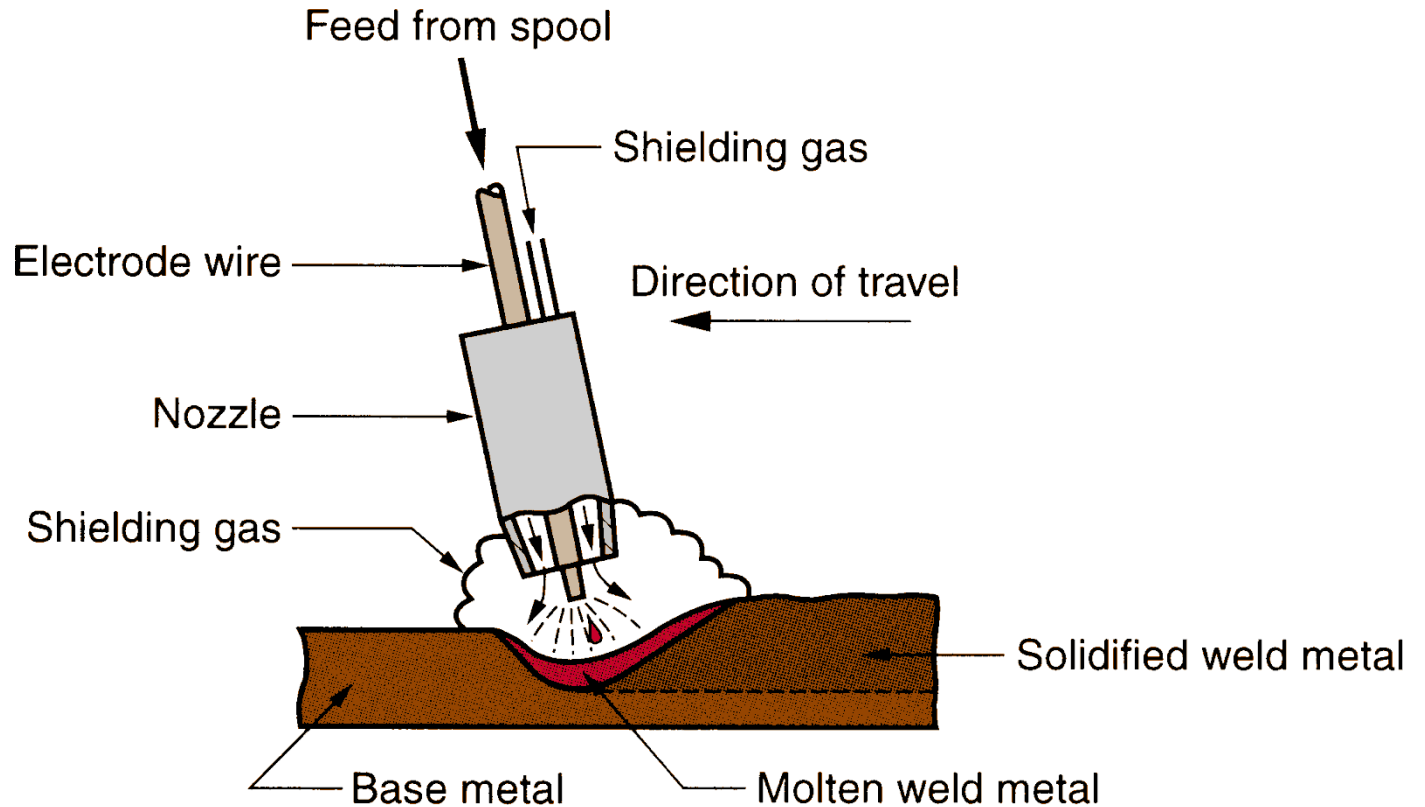


Figure Gas metal arc welding (GMAW).



GMAW Advantages over SMAW

- Better arc time because of continuous wire electrode
 - Sticks must be periodically changed in SMAW
- Better use of electrode filler metal than SMAW
 - End of stick cannot be used in SMAW
- Higher deposition rates
- Eliminates problem of slag removal
- Can be readily automated



Flux-Cored Arc Welding (FCAW)

Adaptation of shielded metal arc welding, to overcome limitations of stick electrodes

- Electrode is a continuous consumable tubing (in coils) containing flux and other ingredients (e.g., alloying elements) in its core
- Two versions:
 - Self-shielded FCAW - core includes compounds that produce shielding gases
 - Gas-shielded FCAW - uses externally applied shielding gases

Flux-Cored Arc Welding

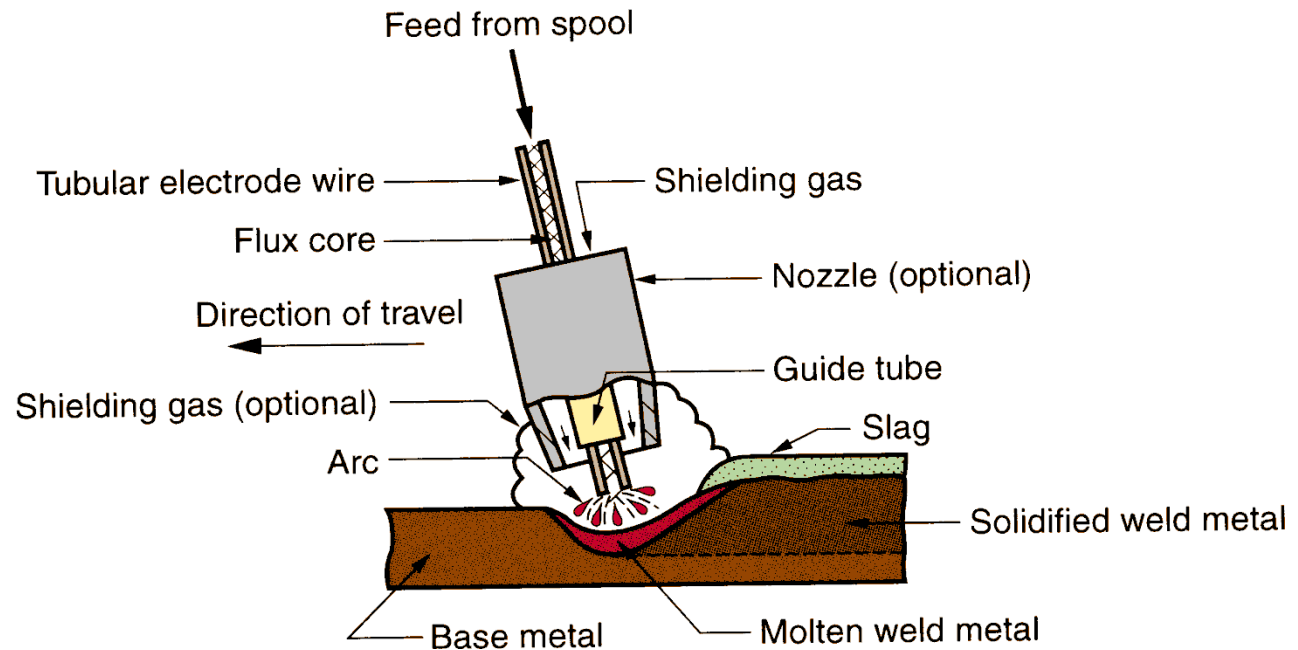


Figure Flux-cored arc welding. Presence or absence of externally supplied shielding gas distinguishes the two types: (1) self-shielded, in which core provides ingredients for shielding, and (2) gas-shielded, which uses external shielding gases.



Electrogas Welding (EGW)

Uses a continuous consumable electrode, either flux-cored wire or bare wire with externally supplied shielding gases, and molding shoes to contain molten metal

- When flux-cored electrode wire is used and no external gases are supplied, then special case of self-shielded FCAW
- When a bare electrode wire used with shielding gases from external source, then special case of GMAW

Electrogas Welding

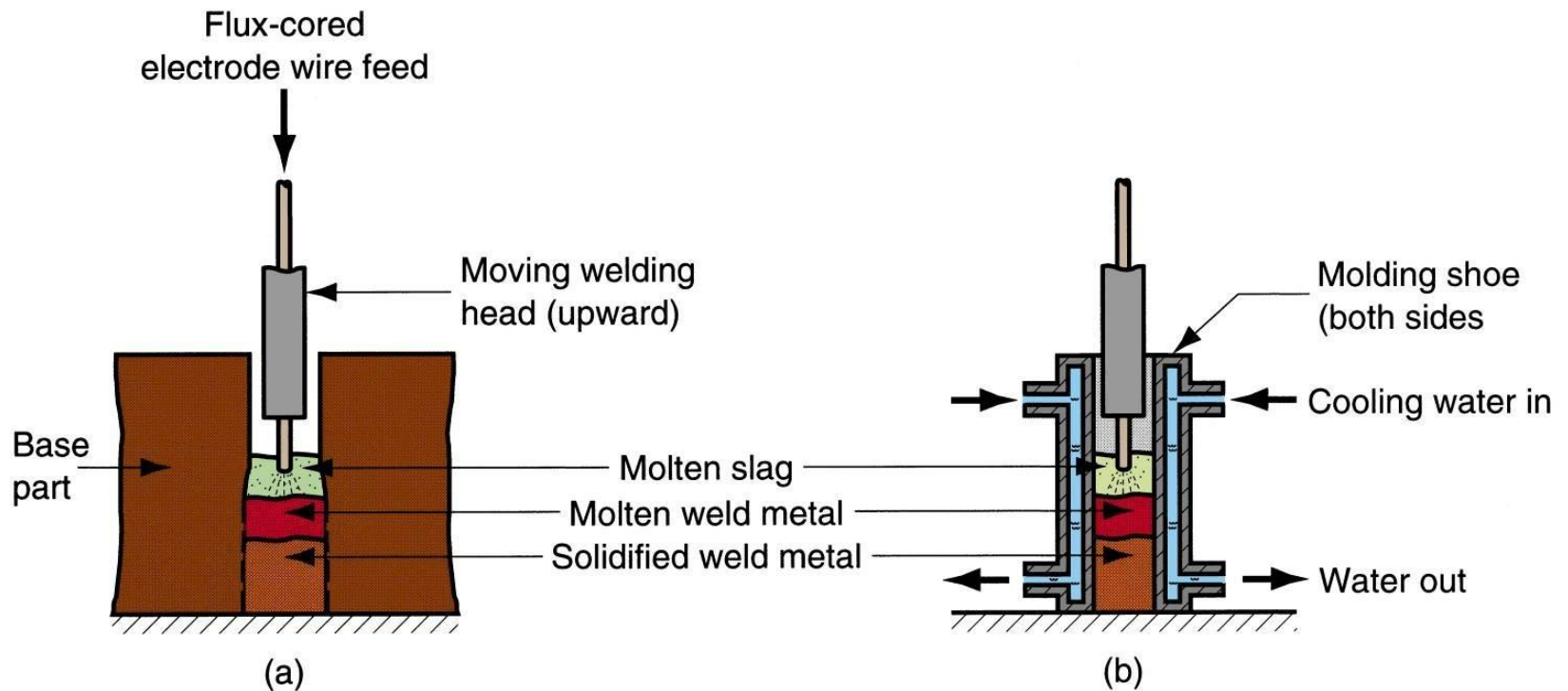


Figure Electrogas welding using flux-cored electrode wire:
(a) front view with molding shoe removed for clarity, and (b)
side view showing molding shoes on both sides.



Submerged Arc Welding (SAW)

Uses a continuous, consumable bare wire electrode, with arc shielding provided by a cover of granular flux

- Electrode wire is fed automatically from a coil
- Flux introduced into joint slightly ahead of arc by gravity from a hopper
 - Completely submerges operation, preventing sparks, spatter, and radiation

Submerged Arc Welding

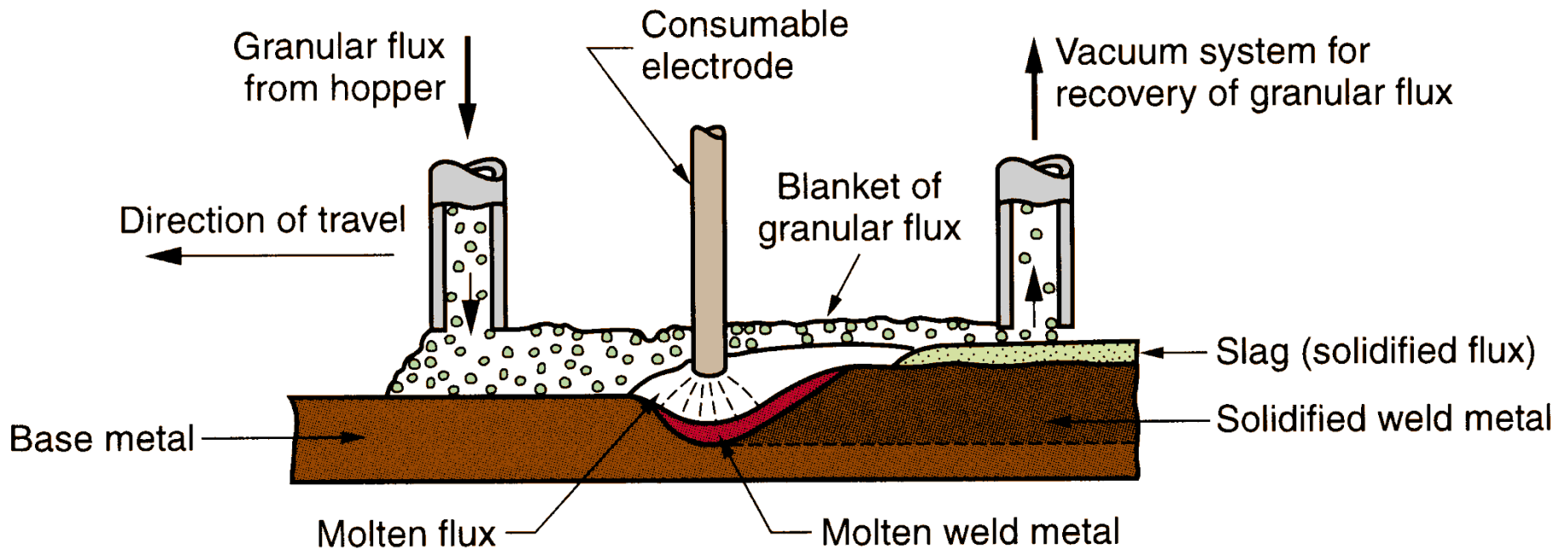


Figure Submerged arc welding.



SAW Applications and Products

- Steel fabrication of structural shapes (e.g., I-beams)
- Seams for large diameter pipes, tanks, and pressure vessels
- Welded components for heavy machinery
- Most steels (except hi C steel)
- Not good for nonferrous metals



Non-consumable Electrode Processes

- Gas Tungsten Arc Welding
- Plasma Arc Welding
- Carbon Arc Welding
- Stud Welding



Gas Tungsten Arc Welding (GTAW)

Uses a non-consumable tungsten electrode and an inert gas for arc shielding

- Melting point of tungsten = 3410°C (6170°F)
- A.k.a. Tungsten Inert Gas (TIG) welding
 - In Europe, called "WIG welding"
- Used with or without a filler metal
 - When filler metal used, it is added to weld pool from separate rod or wire
- Applications: aluminum and stainless steel most common

Gas Tungsten Arc Welding

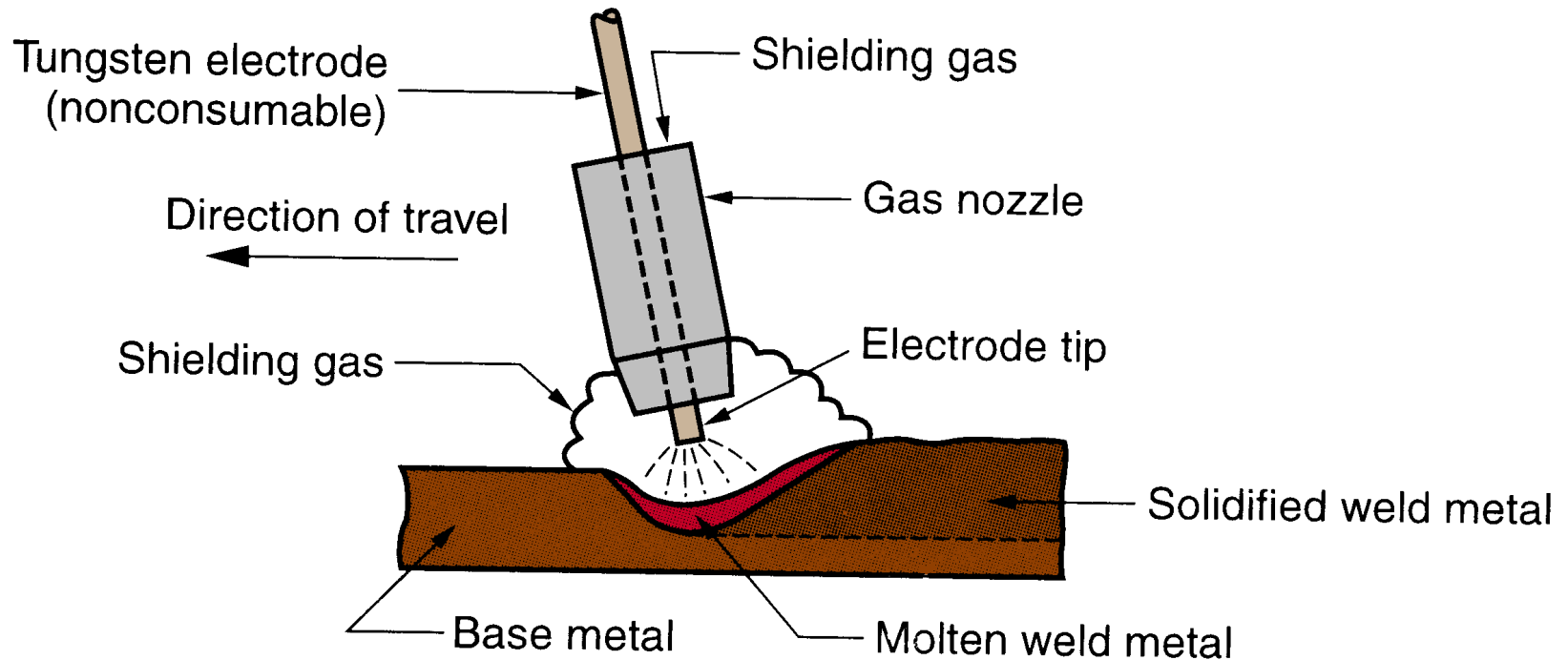


Figure Gas tungsten arc welding.



Advantages / Disadvantages of GTAW

Advantages:

- High quality welds for suitable applications
- No spatter because no filler metal through arc
- Little or no post-weld cleaning because no flux

Disadvantages:

- Generally slower and more costly than consumable electrode AW processes



Plasma Arc Welding (PAW)

Special form of GTAW in which a constricted plasma arc is directed at weld area

- Tungsten electrode is contained in a nozzle that focuses a high velocity stream of inert gas (argon) into arc region to form a high velocity, intensely hot plasma arc stream
- Temperatures in PAW reach 28,000°C (50,000°F), due to constriction of arc, producing a plasma jet of small diameter and very high energy density

Plasma Arc Welding

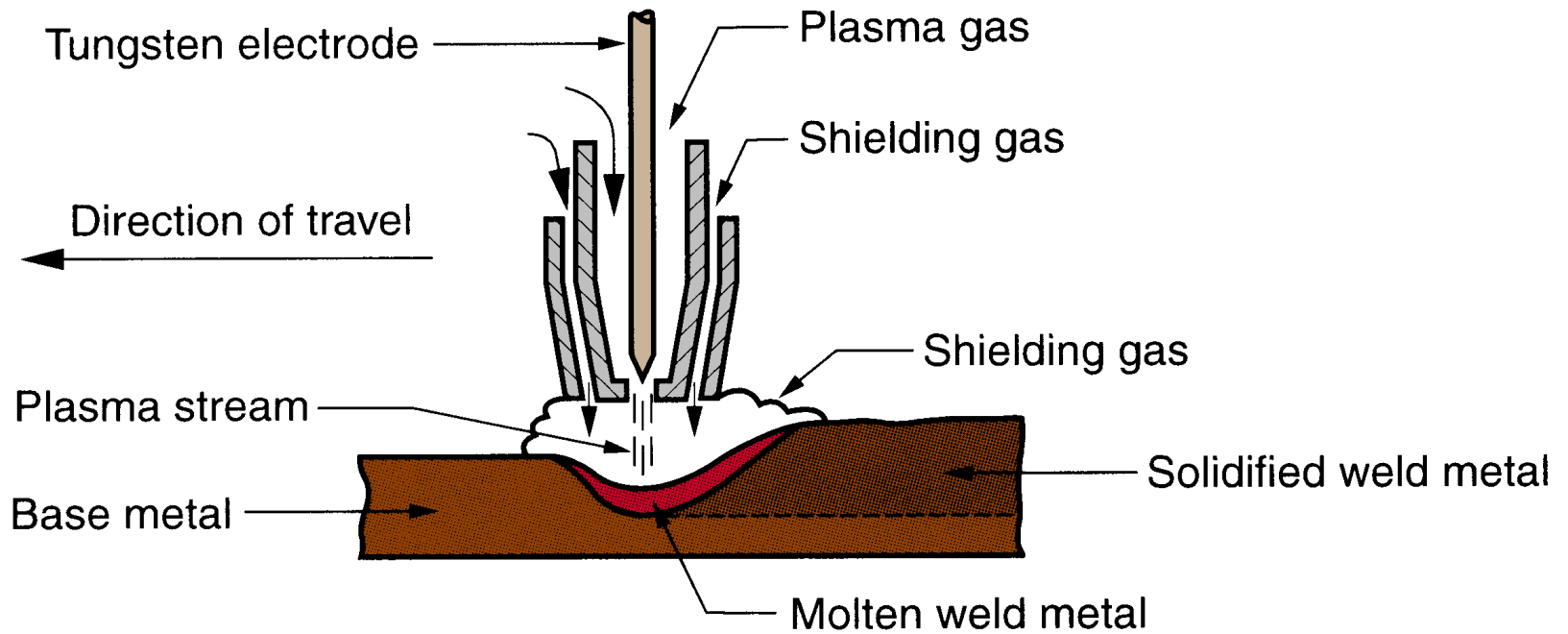


Figure Plasma arc welding (PAW).



Advantages / Disadvantages of PAW

Advantages:

- Good arc stability
- Better penetration control than other AW
- High travel speeds
- Excellent weld quality
- Can be used to weld almost any metals

Disadvantages:


- High equipment cost
- Larger torch size than other AW
 - Tends to restrict access in some joints



Resistance Welding (RW)

A group of fusion welding processes that use a combination of heat and pressure to accomplish coalescence

- Heat generated by electrical resistance to current flow at junction to be welded
- Principal RW process is resistance spot welding (RSW)



Capacity of a metal or combination of metals to be welded into a suitably designed structure, and for the resulting weld joint(s) to possess the required metallurgical properties to perform satisfactorily in intended service

- Good weldability characterized by:
 - Ease with which welding process is accomplished
 - Absence of weld defects
 - Acceptable strength, ductility, and toughness in welded joint