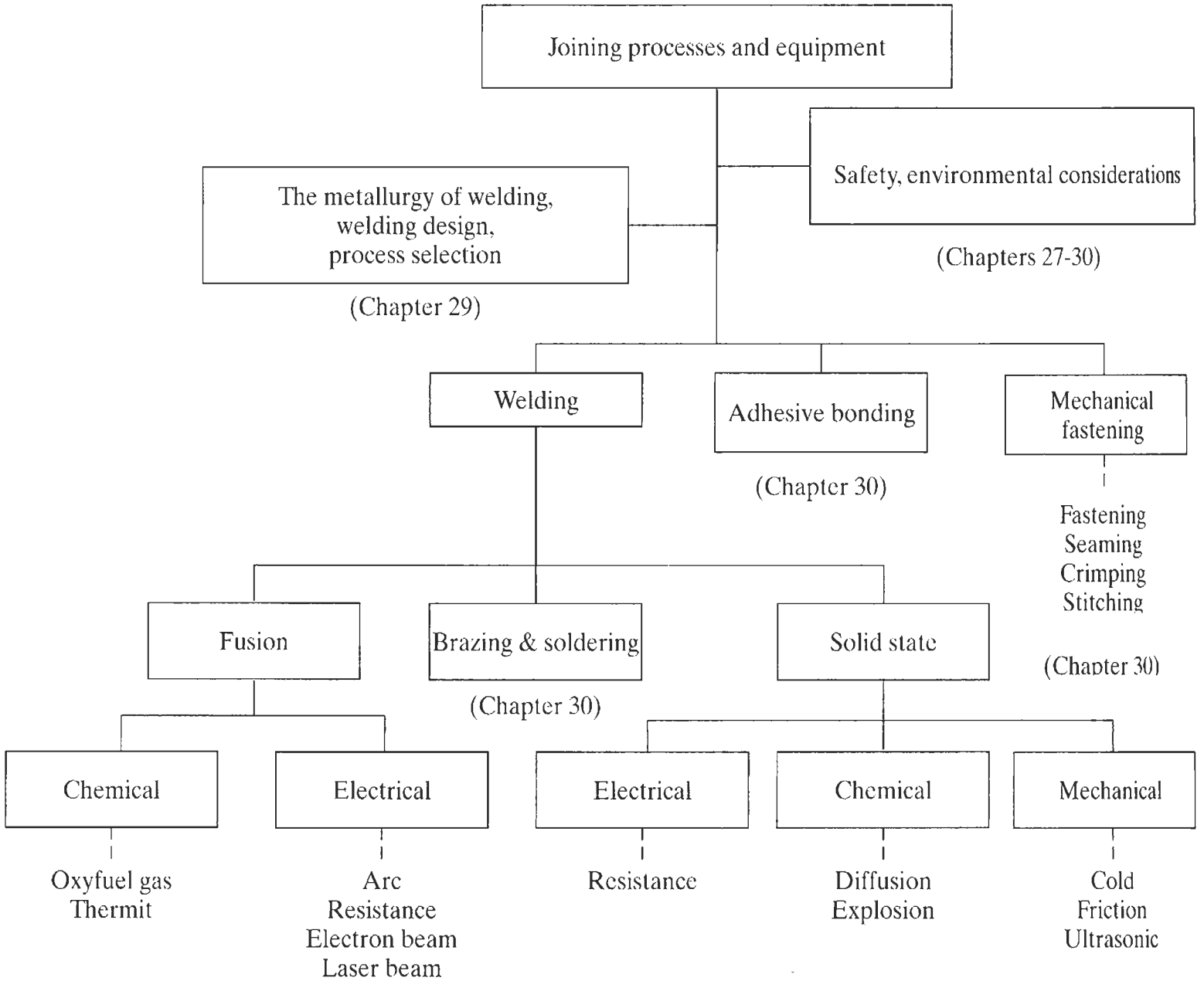
6. JOINING PROCESSES



Joining

- Welding
- Brazing
- Soldering
- Diffusion bonding
- Adhesive bonding
- Mechanical bonding

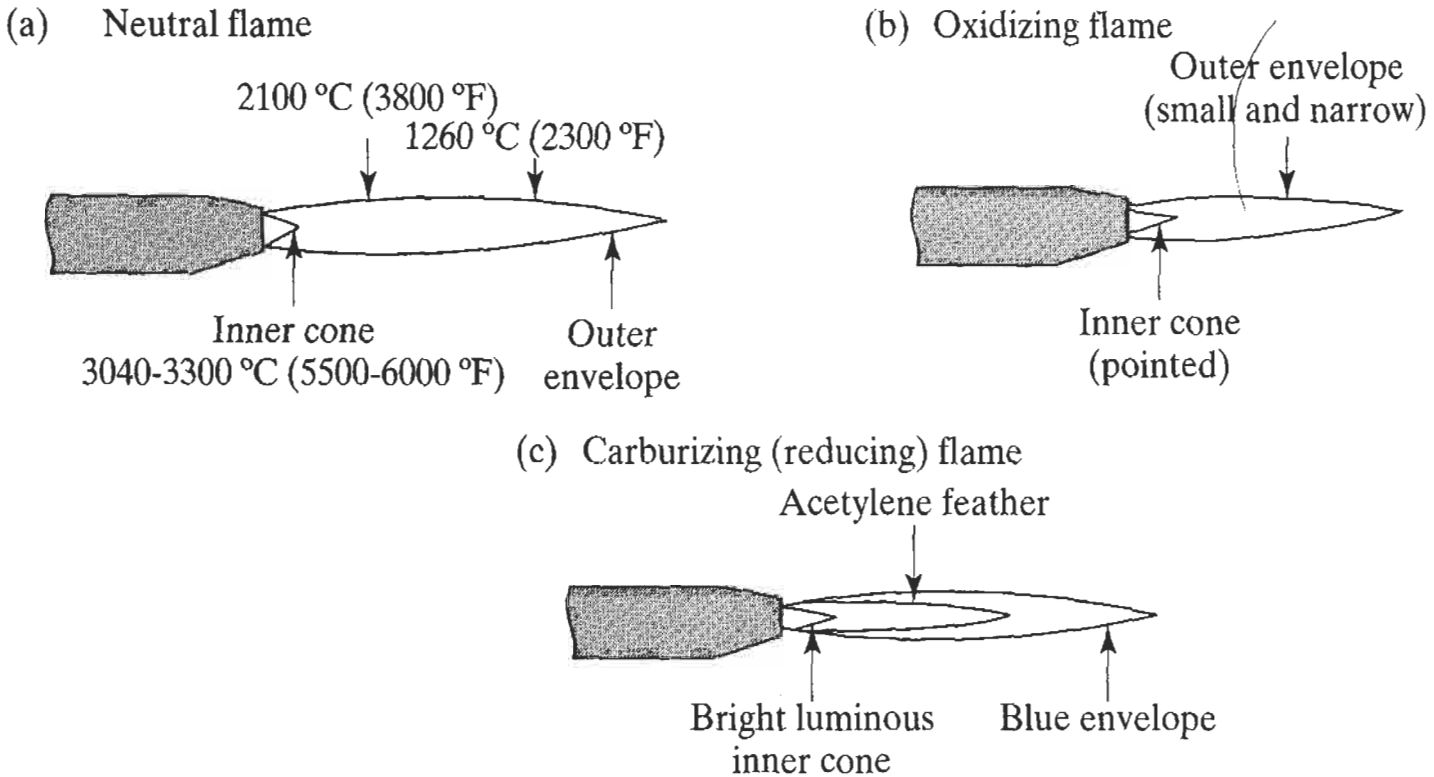
FREDERICK INSTITUTE OF TECHNOLOGY	***Title:*** **Joining processes and equipment**		
	SUBJECT: Manufacturing Processes		
Instructor: Dr. A. Lontos	**Mechanical Engineering Department**	**File:**	**Figure 1-a**

General Characteristics of Fusion Welding Processes

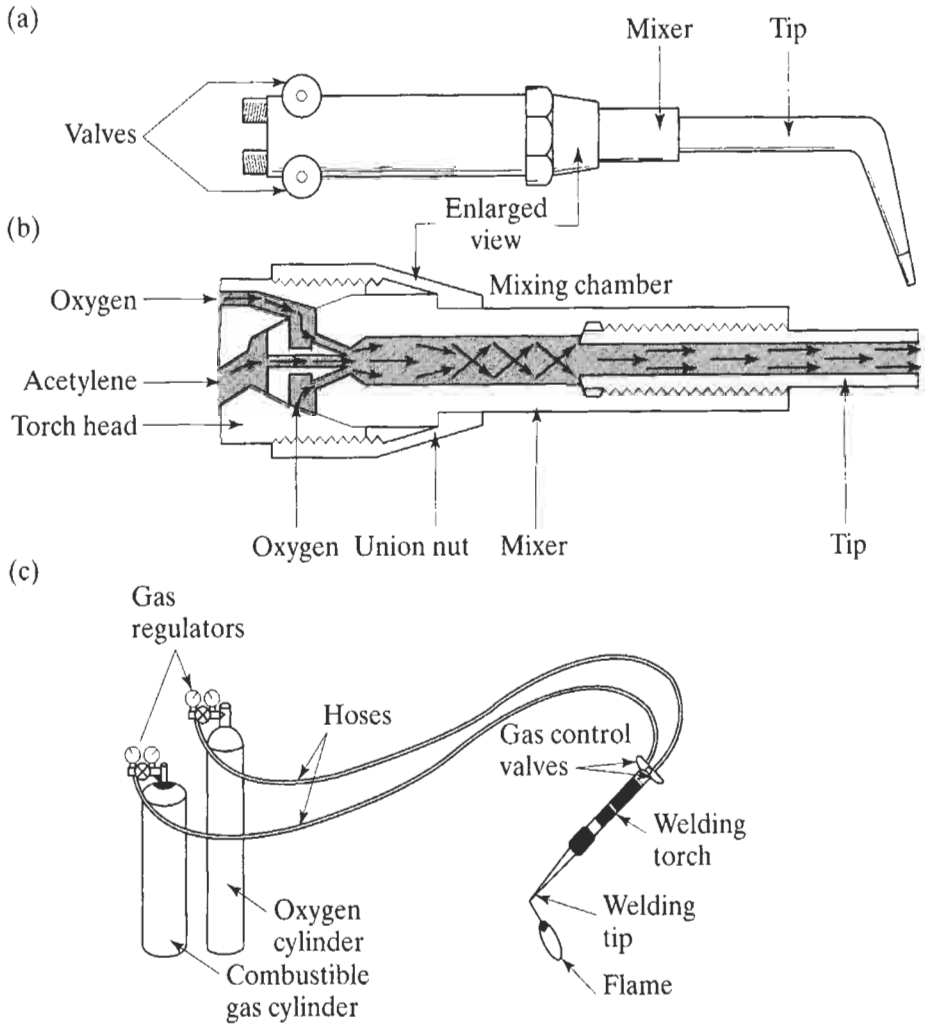
Joining process	Operation	Advantage	Skill level required	Welding position	Current type	Distortion*	Cost of equipment
Shielded metal-arc	Manual	Portable and flexible	High	All	ac, dc	1 to 2	Low
Submerged arc	Automatic deposition	High medium	Low to horizontal	Flat and	ac, dc	1 to 2	Medium
Gas metal-arc	Semiautomatic or automatic	Most metals	Low to high	All	dc	2 to 3	Medium to high
Gas tungsten-arc	Manual or automatic	Most metals	Low to high	All	ac, dc	2 to 3	Medium
Flux-cored arc	Semiautomatic or automatic	High deposition	Low to high	All	dc	1 to 3	Medium
Oxyfuel	Manual	Portable and flexible	High	All	—	2 to 4	Low
Electron-beam, Laser-beam	Semiautomatic or automatic	Most metals	Medium to high	All	—	3 to 5	High

* 1, highest; 5, lowest.

Three basic types of oxyacetylene flames used in oxyfuel-gas welding and cutting operations: (a) neutral flame; (b) oxidizing flame; (c) carburizing, or reducing, flame. The gas mixture in (a) is basically equal volumes of oxygen and acetylene.

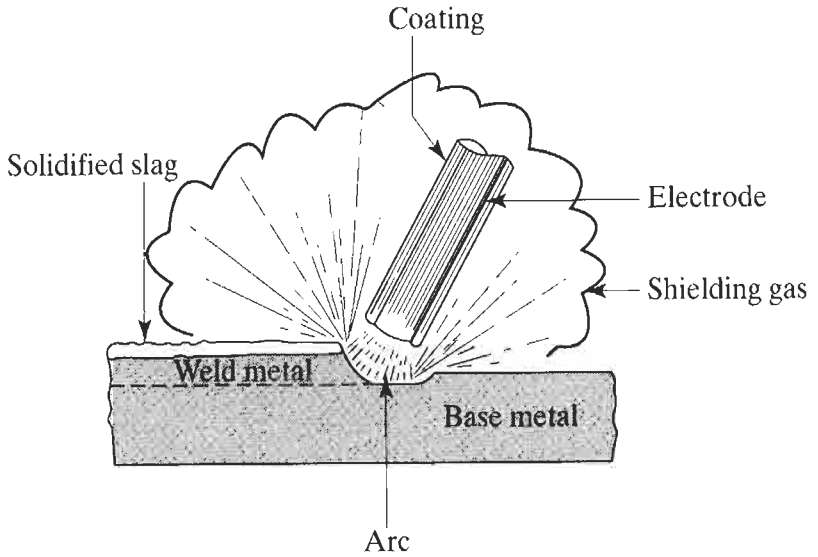


FREDERICK INSTITUTE OF TECHNOLOGY	*Title:* **Basic types of oxyacetylene flames**		
	SUBJECT: Manufacturing Processes		
Instructor: Dr. A. Lontos	**Mechanical Engineering Department**	**File:**	**Figure 3-a**

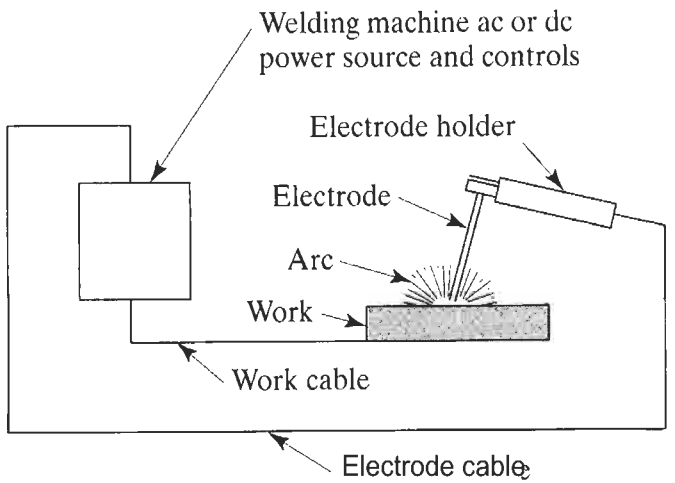


(a) General view of and (b) cross-section of a torch used in oxyacetylene welding. The acetylene valve is opened first; the gas is lit with a spark lighter or a pilot light; then the oxygen valve is opened and the flame adjusted. (c) Basic equipment used in oxyfuel-gas welding. To ensure correct connections, all threads on acetylene fittings are left-handed, whereas those for oxygen are right-handed. Oxygen regulators are usually painted green, acetylene regulators red.

FREDERICK INSTITUTE OF TECHNOLOGY	***Title:*** **Oxyacetylene welding**	
	SUBJECT: Manufacturing Processes	
Instructor: Dr. A. Lontos	**Mechanical Engineering Department**	**File:** **Figure 4-a**

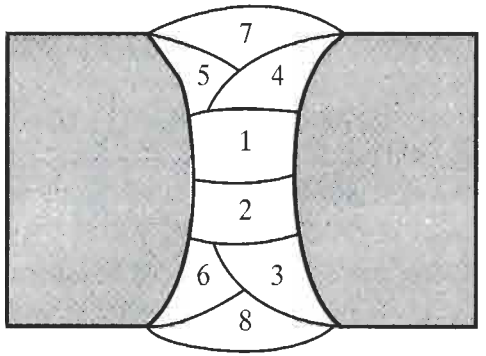


Schematic illustration of the shielded metal-arc welding process. About 50% of all large-scale industrial welding operations use this process.



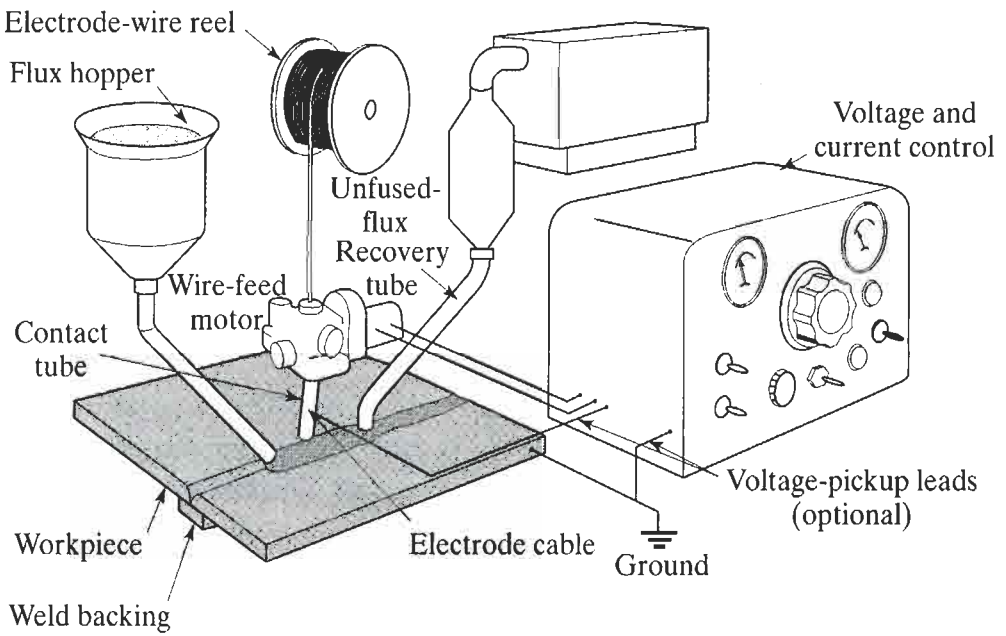
Schematic illustration of the shielded metal-arc welding operation (also known as stick welding, because the electrode is in the shape of a stick).

FREDERICK INSTITUTE OF TECHNOLOGY	*Title:* **Metal arc welding**		
	SUBJECT: Manufacturing Processes		
Instructor: Dr. A. Lontos	**Mechanical Engineering Department**	**File:**	**Figure 5-a**



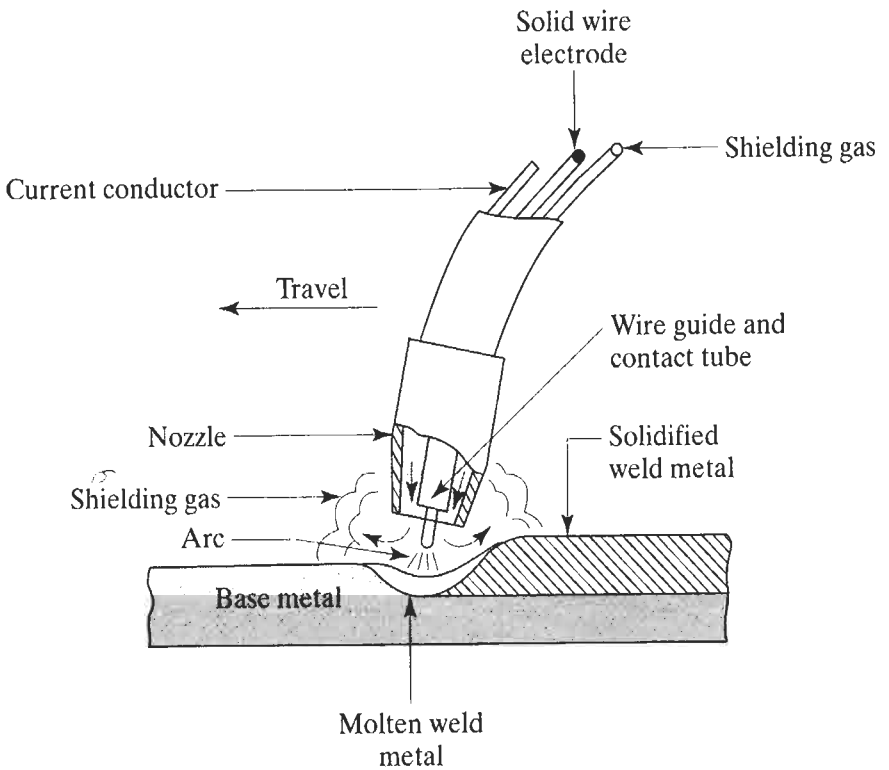
A deep weld showing the buildup sequence of individual weld beads.

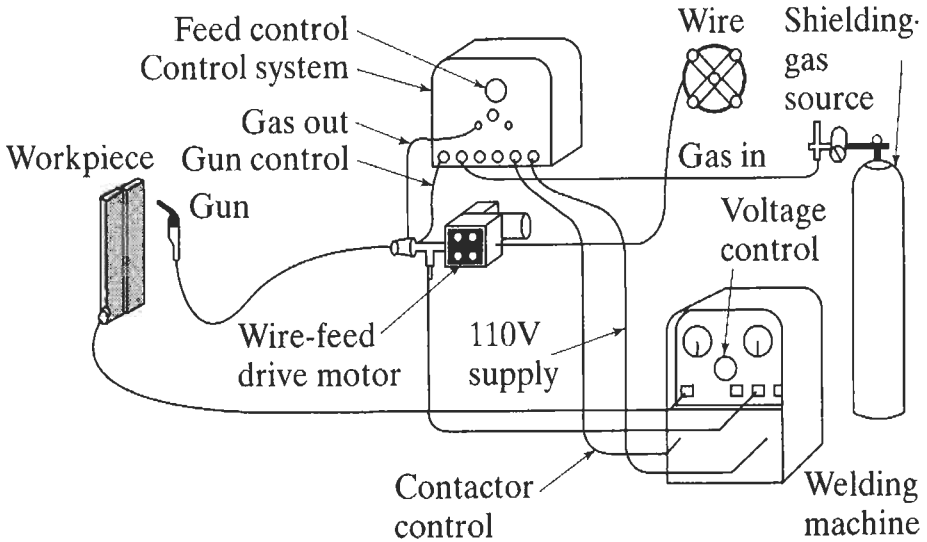
Schematic illustration of the submerged-arc welding process and equipment. The unfused flux is recovered and reused. *Source*: American Welding Society.



FREDERICK INSTITUTE OF TECHNOLOGY	***Title:*** **Metal arc welding**		
	SUBJECT: Manufacturing Processes		
Instructor: Dr. A. Lontos	**Mechanical Engineering Department**	**File:**	**Figure 6-a**

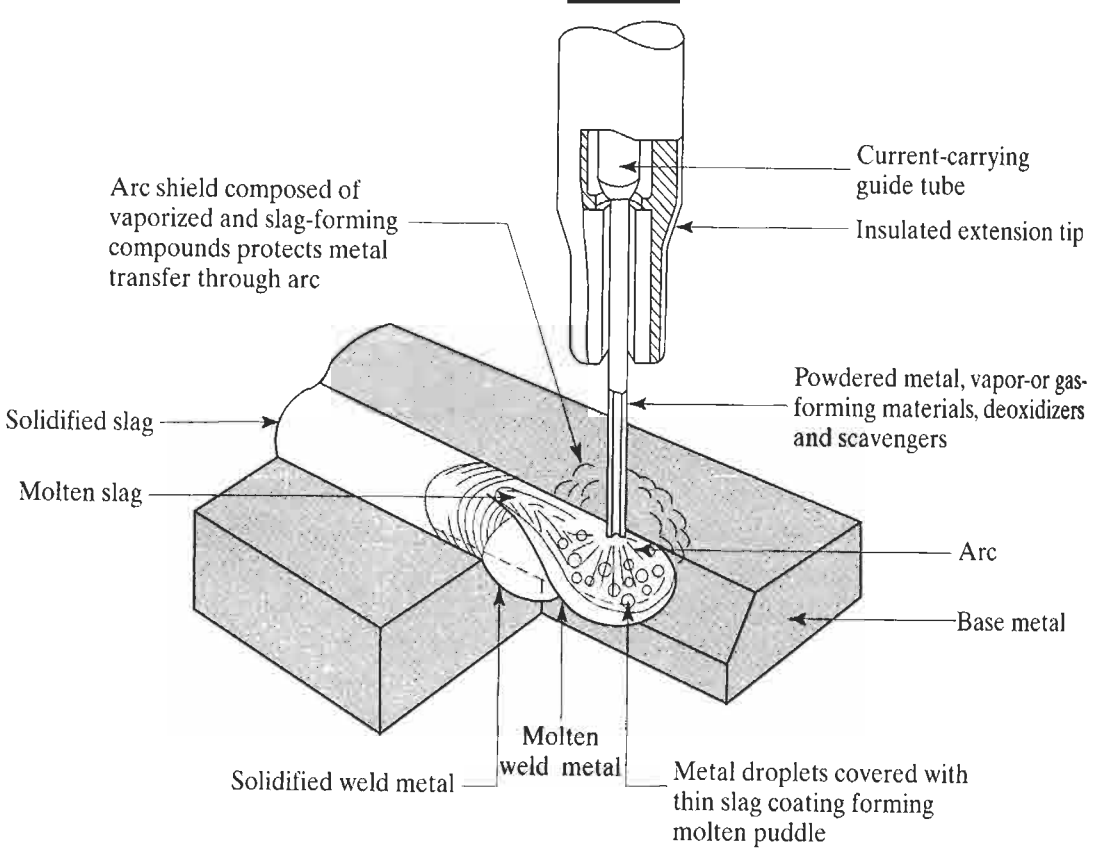
Schematic illustration of the gas metal-arc welding process, formerly known as MIG (for metal inert gas) welding.



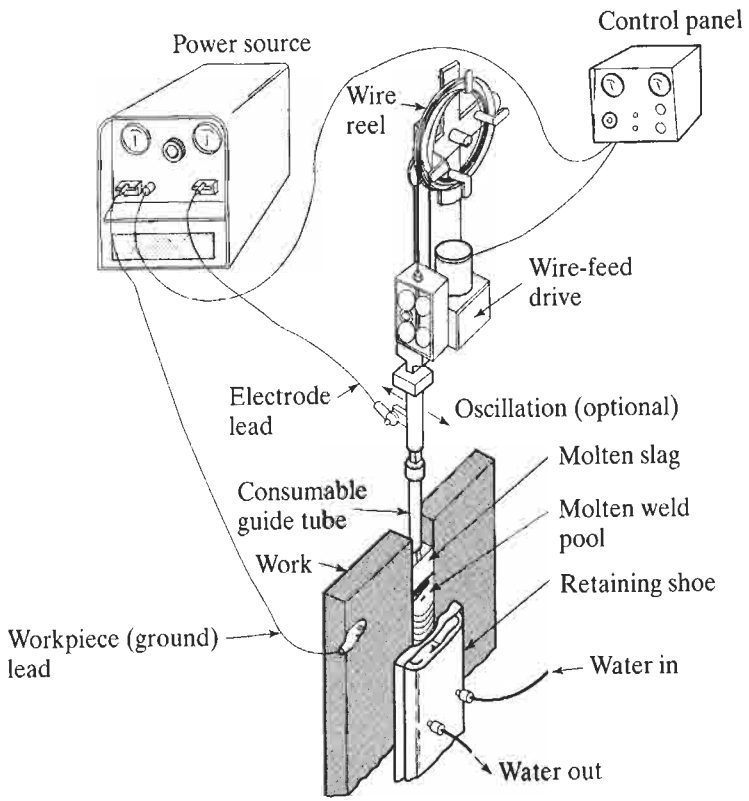


Basic equipment used in gas metal-arc welding operations.

FREDERICK INSTITUTE OF TECHNOLOGY	*Title:* **Gas metal arc welding**		
	SUBJECT: Manufacturing Processes		
Instructor: Dr. A. Lontos	**Mechanical Engineering Department**	**File:**	**Figure 7-a**

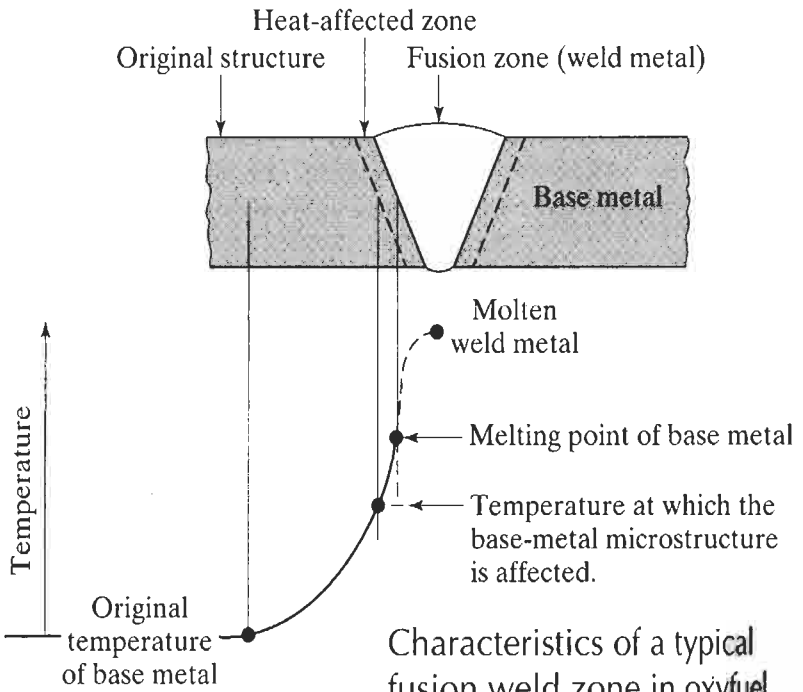


Schematic illustration of the flux-cored arc-welding process.

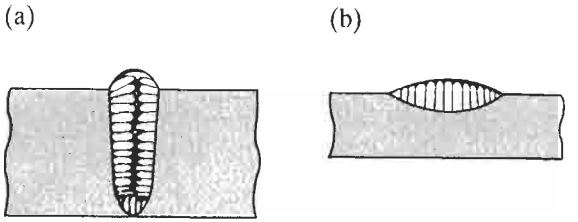


Equipment used for electroslag welding operations.

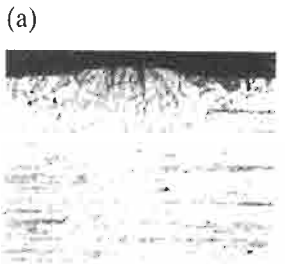
FREDERICK INSTITUTE OF TECHNOLOGY	*Title:* **Flux-cored arc welding - Equipment used for electroslag**		
	SUBJECT: Manufacturing Processes		
Instructor: Dr. A. Lontos	**Mechanical Engineering Department**	**File:**	**Figure 8-a**

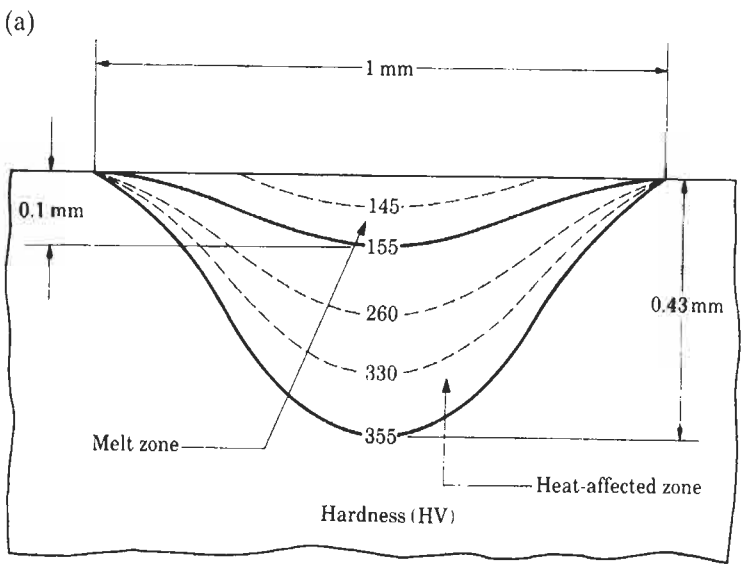


Characteristics of a typical fusion weld zone in oxyfuel gas and arc welding.



Grain structure in (a) a deep weld (b) a shallow weld. Note that the grains in the solidified weld metal are perpendicular to the surface of the base metal. In a good weld, the solidification line at the center in the deep weld shown in (a) has grain migration, which develops uniform strength in the weld bead.





(a) Weld bead (on a cold-rolled nickel strip) produced by a laser beam. (b) Microhardness profile across the weld bead. Note the lower hardness of the weld bead compared to the base metal.

FREDERICK INSTITUTE OF TECHNOLOGY	*Title:* **Fusion weld zone**	
	SUBJECT: Manufacturing Processes	
Instructor: Dr. A. Lontos	**Mechanical Engineering Department**	**File:** **Figure 9-a**

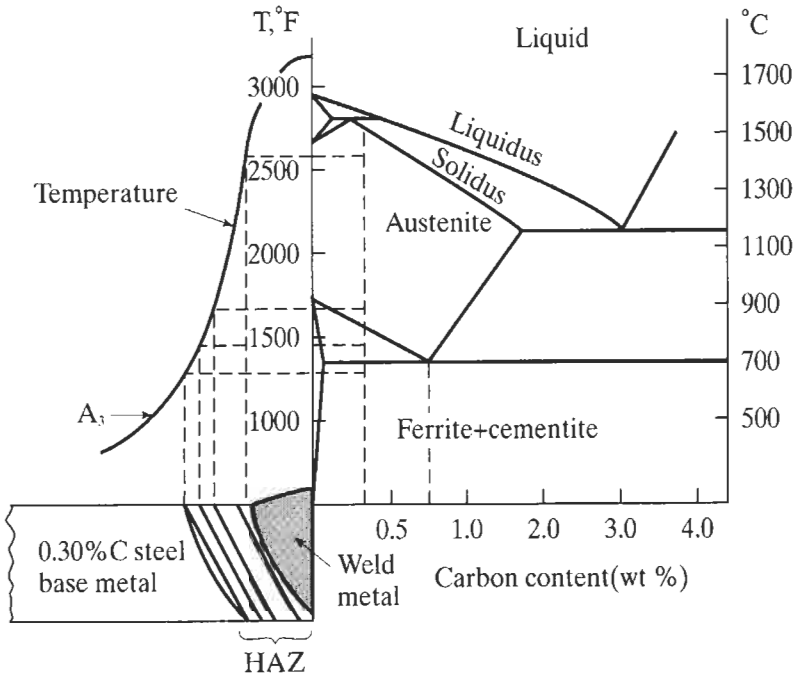
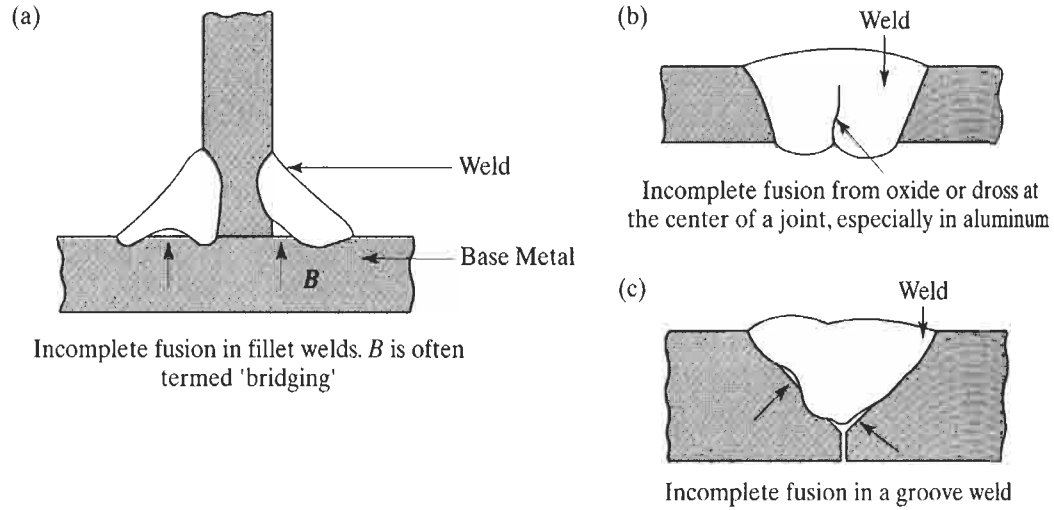


FIGURE 29.4 Schematic illustration of various regions in a fusion weld zone (and the corresponding phase diagram) for 0.30% carbon steel. *Source*: American Welding Society.

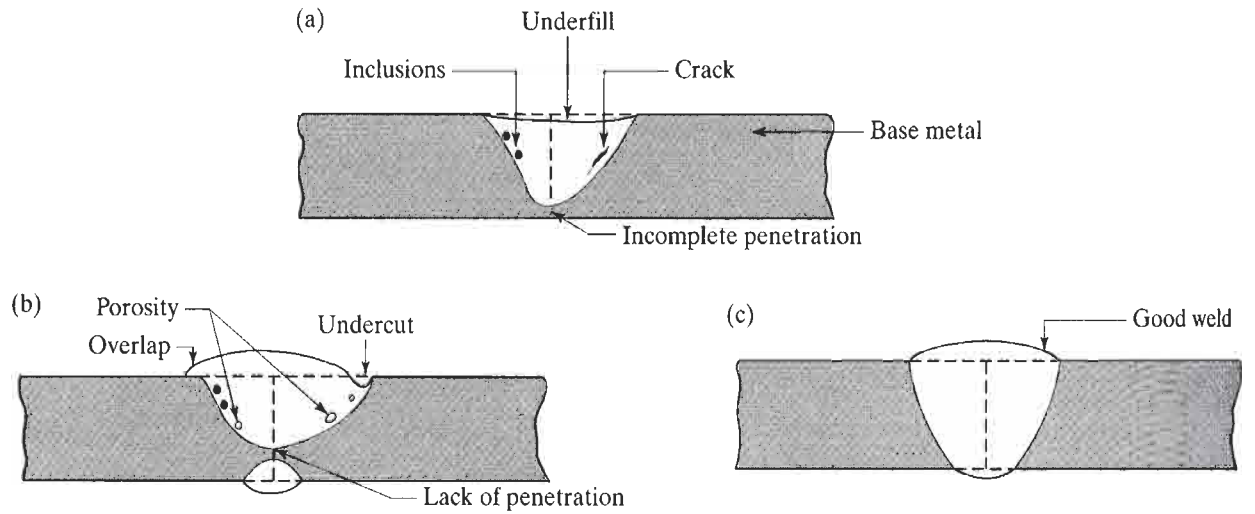
Intergranular corrosion of a 310-stainless-steel welded tube after exposure to a caustic solution. The weld line is at the center of the photograph. Scanning electron micrograph at 20×. *Source*: Courtesy of B. R. Jack, Allegheny Ludlum Steel Corp.

FREDERICK INSTITUTE OF TECHNOLOGY	***Title:*** **Fusion weld zone**		
	SUBJECT: Manufacturing Processes		
Instructor: Dr. A. Lontos	**Mechanical Engineering Department**	**File:**	**Figure 10-a**



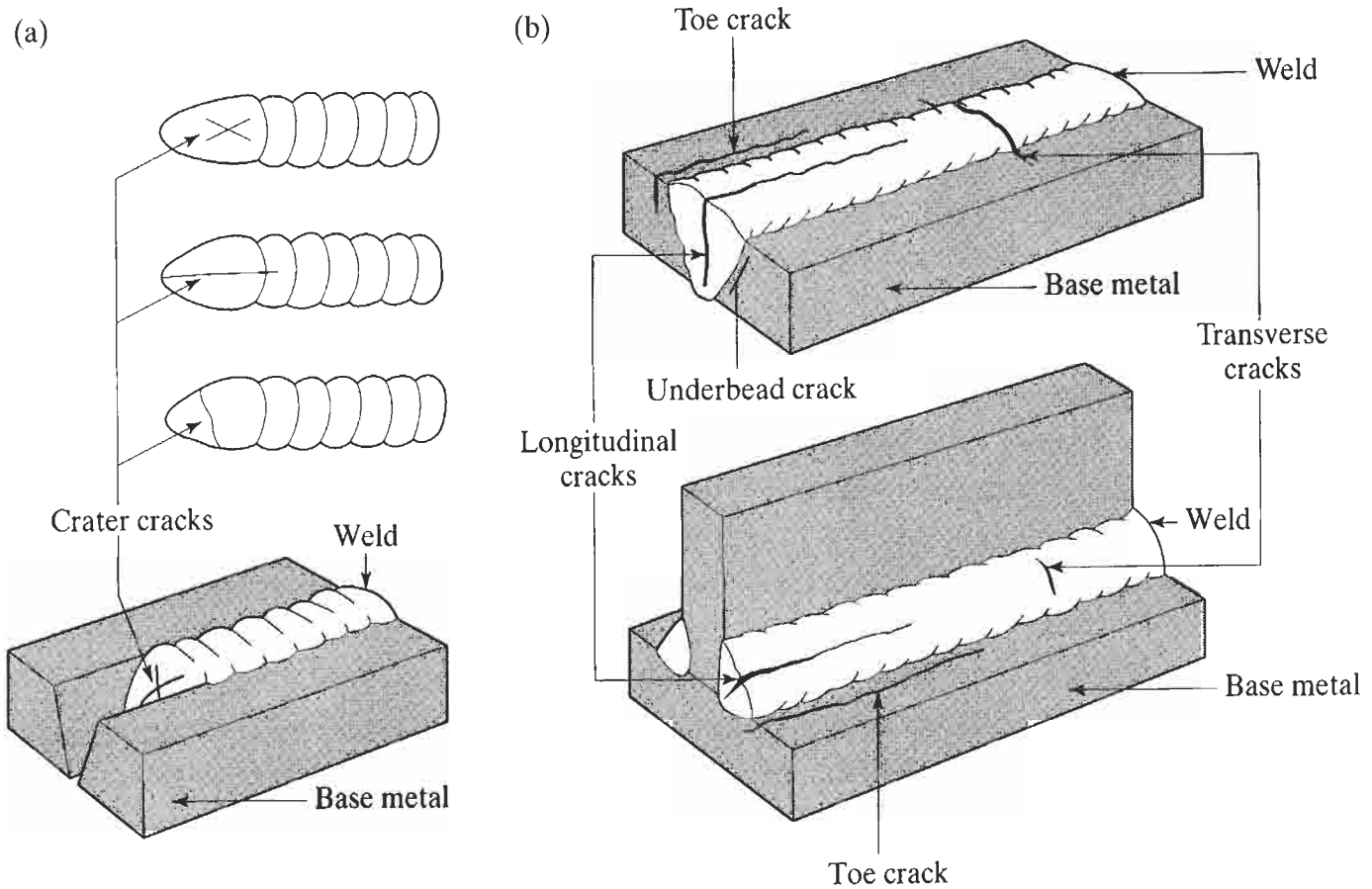
Low-quality weld beads, the result of incomplete fusion.

Schematic illustration of various discontinuities in fusion welds.



FREDERICK INSTITUTE OF TECHNOLOGY	*Title:* **Low quality welds**		
	SUBJECT: Manufacturing Processes		
Instructor: Dr. A. Lontos	**Mechanical Engineering Department**	**File:**	**Figure 11-a**

Types of cracks (in welded joints) caused by thermal stresses that develop during solidification and contraction of the weld bead and the surrounding structure. (a) Crater cracks. (b) Various types of cracks in butt and T joints.



FREDERICK INSTITUTE OF TECHNOLOGY	*Title:* Types of cracks in welded joints		
	SUBJECT: Manufacturing Processes		
Instructor: Dr. A. Lontos	Mechanical Engineering Department	File:	Figure 12-a