10. Tool Design for Joining

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Joining

- The joining processes are generally divided into two classes: mechanical and physical.
- Mechanical joining does not ordinarily involve changes in composition of the workpiece material. The edges of the pieces being joined remain distinct.
- In the physical joining process, parts are made to join along their contacting surfaces through the application of heat or pressure or both. Often a filler material is added, with the edges losing their identity in a homogeneous mass.

Joining

- Two pieces of wood nailed together are joined mechanically.
- The same two pieces of wood could be joined physically by an adhesive. At the exact center of the joint, only the adhesive would be found. The adhesive would penetrate into the pores of the wood for some distance, and the workpiece edges would no longer exist as true entities but would have become a blend of wood and glue.

Joining

- Joining processes may require tooling to hold the parts in correct relationship during joining.
- Another function of the tooling is to assist and control the joining process.
- Often, several parts may be joined both mechanically and physically.
- Thus, two workpieces may be bolted together to assure alignment during subsequent welding.
- Mechanical joining at times may be considered as the tooling method for the final physical joining.

Physical Joining

- Physical joining processes generally cannot be performed without tooling, because the high temperatures required usually make manual positioning impractical.
- The tooling must hold the workpieces in correct relationship during joining, and it must assist and control the joining process by affording adequate support.

Physical Joining

- Tooling used for hot processes must not only withstand the temperatures involved, but in many cases must either accelerate or retard the flow of heat.
- Hot fixtures must be designed so that their heat-expanded dimensions remain functional.

Fig 10-1 Degree of heat input

Heat Input	Process
High	Gas Tungsten-arc welding
	Shielded Metal-Arc Welding
	Gas Metal-Arc Welding
	Flux Cored Arc Welding
	Submerged Arc Welding
Low	Laser Welding

Design of Welding Fixtures

- The purpose of a welding fixture is to hold the parts to be welded in the proper relationship both before and after welding.
- Many times a fixture will maintain the proper part relationship during welding, but the part will distort after removal from the fixture.
- Good fixture design will, of itself, largely determine product reliability.

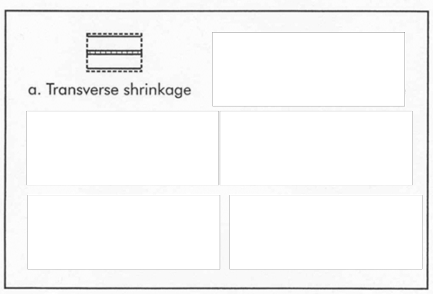


Figure 10-2. Typical types of distortion occurring during welding.

Fig 10-3 Distortion potential

Distortion Potential	Material
Lowest	Low carbon steel
	High Strength steel
	Nickel-copper alloys
	Copper alloys
	Stainless steel
Highest	Aluminum

Design of Welding Fixtures

- Major fixture design objectives:
  - (1) to hold the part in the most convenient position for welding,
  - (2) to provide proper heat control of the weld zone,
  - (3) to provide suitable clamping to reduce distortion,
  - (4) to provide channels and outlets for welding atmosphere,
  - (5) to provide clearance for filler metal,
  - (6) to provide for ease of operation and maximum accessibility to the point of weld.

Design of Welding Fixtures

- Other factors:
  - (1) cost of tool,
  - (2) size of the production run and rates,
  - (3) adaptability of available welding equipment,
  - (4) complexity of the weld,
  - (5) quality required in the weldment,
  - (6) process to be employed,

Design of Welding Fixtures

- Other factors:
  - (7) conditions under which the welding will be performed,
  - (8) dimensional tolerances,
  - (9) material to be welded,
  - (10) smoothness required,
  - (11) coefficient of expansion and thermal conductivity of both workpiece and tool materials.

Gas Welding Fixtures

Gas Welding Fixtures

- A minimum of heat loss from the welding area is required. If the heat loss is too rapid, the weld may develop cracks. Heat loss by materials, particularly aluminum and copper, must be carefully controlled.
- To accomplish this, large fixture masses should not be placed close to the weld line, however, the part may distort. The contact area and clamps should therefore be of the minimum size consistent with the load transmitted through the contact point.

Gas Welding Fixtures

- In welding copper and aluminum, the minimum contact surface often permits excessive heat loss, and prevents good fixture welds.
- This necessitates tack welding the fixtured parts at points most distant from the fixture contact points, with the rest of the welding done out of the fixture.
- With this method, excessive distortion may result, and subsequent stress relieving of the part may be required.

Gas Welding Fixture

- One of the simplest fixtures for gas welding is a gravity-type fixture shown in Figure 10-4.
- This design eliminates excess fixture material from the weld area to minimize heat loss, while providing sufficient support and locating points.
- The design also permits making welds in a horizontal position, which is generally advantageous.

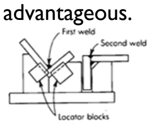
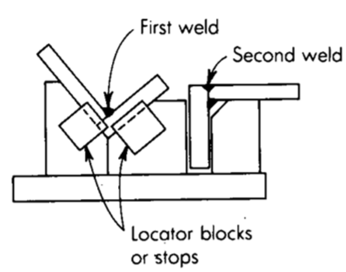


Fig 10-4 Simple welding fixture using gravity to help locate parts



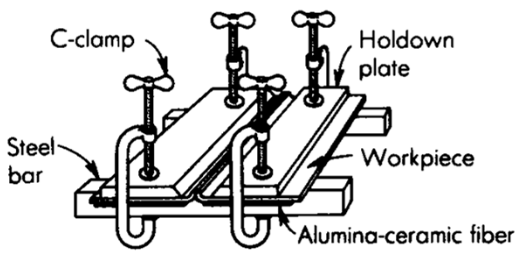
Gas Welding Fixture

- *Figure 10-5* shows another simple form of gas welding fixture which holds two flat sheets for joining.
- C-clamps hold the workpieces to steel support bars.
- Alignment is done visually or with a straight edge.
- A heat barrier of alumina-ceramic fiber is placed between the workpieces and the steel bars.

Gas Welding Fixture

- Hold down plates are used to keep the workpieces flat and to prevent distortion.
- If the parts to be welded have curved surfaces, the supporting bar and hold down plates may be machined to match the part.

Fig 10-5 Workpieces with simple fixturing for gas welding operations



Gas Welding Fixtures

- Simple parts may be properly located or positioned in a fixture visually.
- As workpiece shape becomes complex, or the production rate increases, positive location is desirable.
- The same locating methods used in work holder design can readily be adapted for the design of welding fixtures.

Gas Welding Fixtures - Materials

- The selection of material for gas welding fixtures is governed by these factors:
- (1) part print tolerances;
- (2) material heat resistance;
- (3) heat transfer qualities, and
- (4) the fixture rigidity required to assure workpiece alignment accuracy.

Gas Welding Fixtures - Materials

- The fixture material should not be affected in the weld zone and should prevent rapid heat dissipation from the weld area.
- Some of the fixture materials commonly used are
  - cast iron,
  - carbon steel, and
  - stainless steel.

Arc Welding Fixtures

Arc Welding Fixtures

- Arc welding concentrates more heat at the weld line than gas welding.
- The fixtures for this process must provide support, alignment, and restraint on the parts, and also must permit heat dissipation.

Arc Welding Fixtures

- Some of the more important design considerations for arc welding fixtures are as follows:
- (1) the fixture must exert enough force to prevent the parts from moving out of alignment during the welding process, and this force must be applied at the proper point by a clamp supported by a backing bar;
- (2) backing bars should be parallel to the weld lines;

Arc Welding Fixtures

- (3) backing bars should promote heat dissipation from the weld line; and
- (4) backing bars should support the molten weld, govern the weld contour, and protect the root of the weld from the atmosphere.

Arc Welding Fixtures

- Backing bars are usually made from solid metal or ceramics. A simple backup could be a rectangular bar with a small groove directly under the weld. This would allow complete penetration without pickup material by the molten metal. In use, the backup would be clamped against the part to make the weld root as airtight as possible.
- Some common shapes are shown in *Figure 10-6*.
- *Figure 10-7* shows a backing bar in position against a fixed workpiece.

Fig 10-6 Typical backing bars (Courtesy Alloy Rods Division, Chemetron)

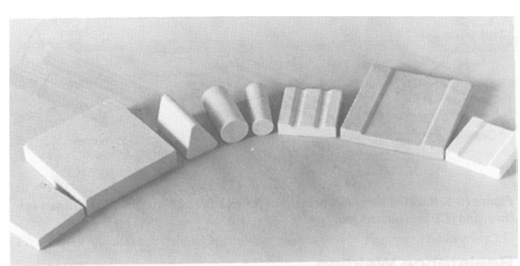
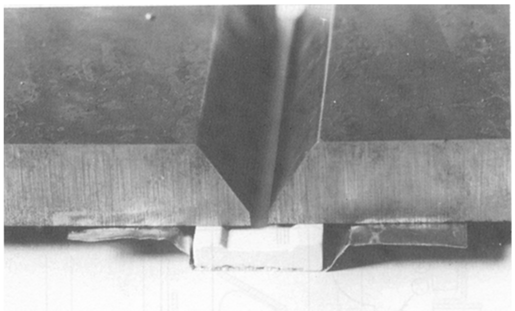


Fig 10-7 Workpiece with simple fixturing for arc welding operation (Courtesy Alloy Rods Division, Chemetron)



Backup Bar

- The size of the backup bar is dependent upon the metal thickness and the material to be welded.
- A thin weldment requires larger backup to promote heat transfer from the weld.
- A material with greater heat-conducting ability requires less backup than that required for a comparable thickness of a poor conductor.

Backup Bar

- Backup bars may be made of
- copper
- stainless steel (used for tungsten inert gas)
- titanium ceramic, or
- a combination of several metals (sandwich construction).

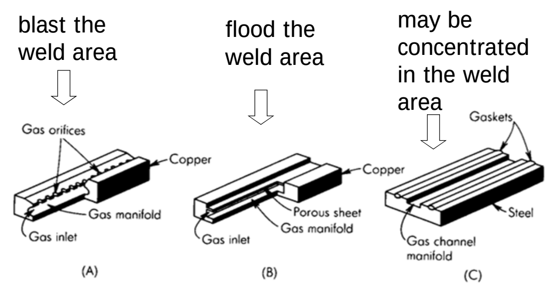


Figure 10-5. Backing bars with provisions for (*A*) directed gas flow, (*B*) diffused gas flow, and (*C*) pressurized gas.

Resistance Welding

Resistance Welding

- Spot welding
- Projection welding
- Seam welding
- Pulsation welding
- Flash butt welding
- Upset butt welding

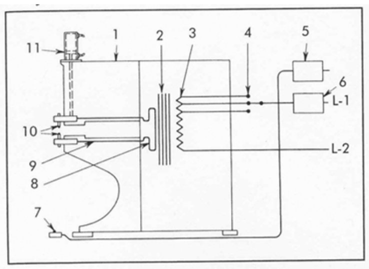


Figure 10-9. Elements of a typical resistance welder: (1) housing; (2) low-voltage, high-current transformer; (3) primary coils; (4) tap switch; (5) welding timer; (6) power interrupter; (7) foot switch; (8) secondary loop; (9) bands from electrodes to secondary; (10) electrodes; (11) cylinder that exerts pressure on work.

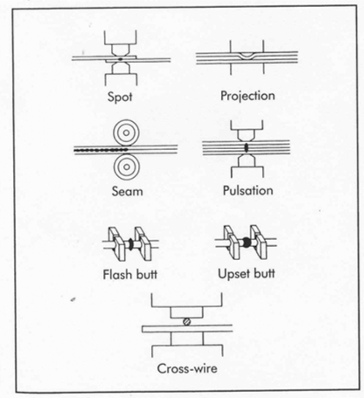


Figure 10-10. Resistance-welding methods.

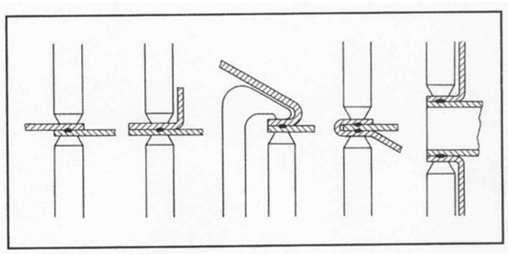


Figure 10-11. Typical spot-welded joints.

Resistance Welding Fixtures

- There are two general types of fixtures for resistance welding.
- The first type is a fixture for welding in a standard machine having a single electrode.
- The second type is a fixture and machine designed as a single unit, usually to attain a high-production rate.

Resistance Welding Fixtures

- Certain design considerations apply to fixtures for resistance welding:
- (1) keep all magnetic materials, particularly ferrous materials, out of the throat of the welding machine;
- (2) insulate all gage pins, clamps, locators, index pins, etc.;
- (3) protect all moving slides, bearings, index pins, adjustable screws, and any accurate locating devices from flash;

Resistance Welding Fixtures

- (4) give consideration to the ease of operation and protection of the operator;
- (5) provide sufficient water cooling to prevent overheating; and
- (6) bear in mind that stationary parts of the fixture and work are affected by the magnetic field of the machine. Work holder parts and clamp handles of nonmagnetic material will not be heated, distorted, or otherwise affected by the magnetic field.

Resistance Welding Fixtures

- 1. The fixture loop or throat is the gap surrounded by the upper and lower arms or knees containing the electrodes and the base of the machine that houses the transformer.
- This gap or loop is an intense magnetic field within which any magnetic material will be affected. In some cases, materials have actually been known to melt or puddle.
- Power lost by unintentional heating of fixture material will decrease the welding current and lower the welding efficiency.
- This power loss may sometimes be used to advantage; e.g., if the current is burning the parts to be welded, the addition of a magnetic material in the throat will increase the impedance, lower the maximum current, and halt the burning of parts.

Resistance Welding Fixtures

- 2. The throat of the machine should be as small as possible for the particular job.
- 3. Welding electrodes should be easily and quickly replaceable.
  - Water for cooling should be circulated as close to the tips as possible.
  - Provide adjustment for electrode wear. If the electrodes tend to stick, knockout pins or strippers may be specified.
  - Current-carrying members should run as close to the electrodes as possible, have a minimum number of connections or joints, and be of adequate cross-sectional area.

Resistance Welding Fixtures

- 4. Provide adjustment for electrode wear.
- 5. Check welding pressure application.
- 6. Have knockout pins or strippers if there is a tendency of the electrode to stick to the electrode face. These may be leveraged or air operated.

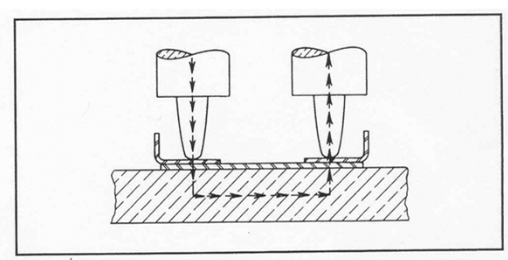


Figure 10-12. Assembly showing series-welded joint.

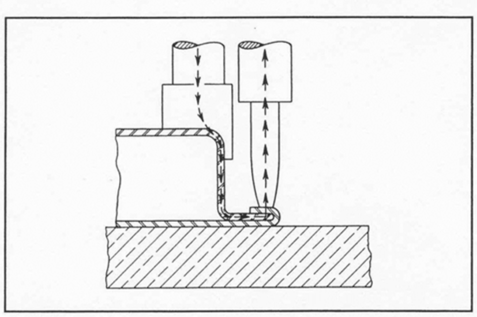


Figure 10-13. Spot-welded assembly showing a typical joint design for an indirect weld.

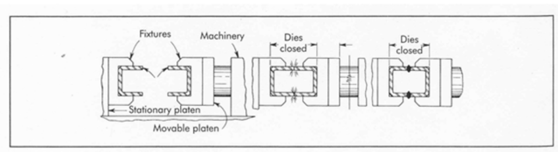


Figure 10-14. Flash-butt welding.

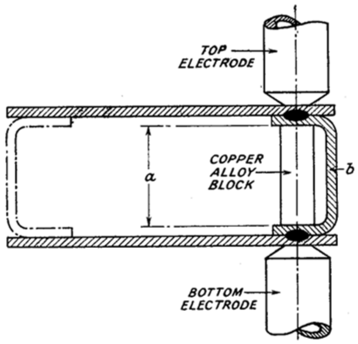


Fig. 13.11

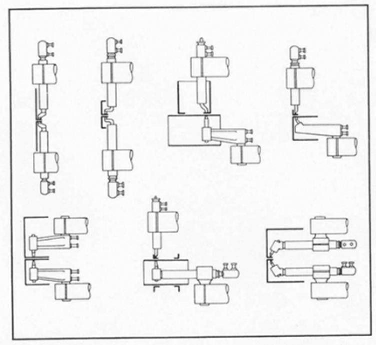


Figure 10-15. Typical standard electrode tips and operations.

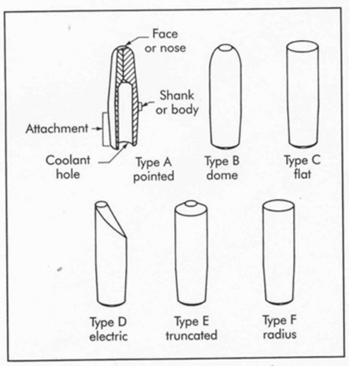


Figure 10-16. Standard types of electrode face or nose shapes. (Type D was formerly called "offset.")

General Fixture Design Considerations

- Simple fixtures may have the part located visually with scribed lines as a guide. This is quite similar to locating parts for gas welding.
- For higher production, a quicker locating method is needed. A locating land may be incorporated in the fixture to accurately establish the edge position of the part to be welded *(Figure 10-17)*.
- In some cases, setup blocks may be used in place of a locating land *(Figure 10-18)*.

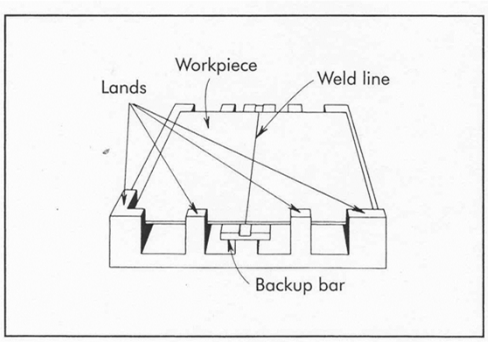


Figure 10-17. Locating lands.

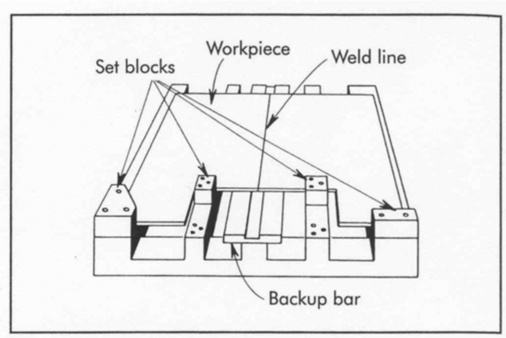


Figure 10-18. Set-block locators.

General Fixture Design Considerations

- When welding a variety of similar parts with different dimensions, setup blocks have a distinct advantage over the land method of locating.
  - With proper design, setup blocks can be interchangeable to accommodate varying workpieces.
  - Dowel pins may be used as locators *(Figure 10-19)*.
- Other means of locating are V -blocks, adjustable clamps, rest buttons and pads, spring plungers, and magnets where applicable.

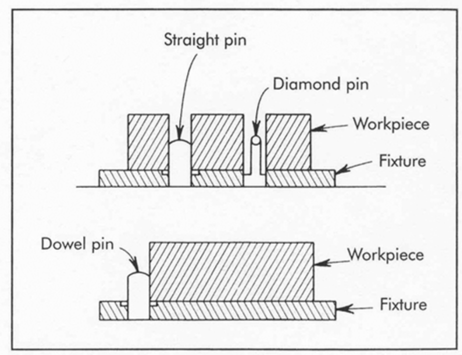


Figure 10-19. Dowel-pin locators.

Clamping Design Considerations

Clamping Design Considerations

- Clamps used in welding fixtures must hold the parts in the proper position and prevent their movement due to alternate heating and cooling.
- Clamping pressure should not deform the parts to be joined.
- Clamps must be supported underneath the workpiece *(Figure 10-20)*. Owing to the heat involved, deflection by clamping force could remain in the part.

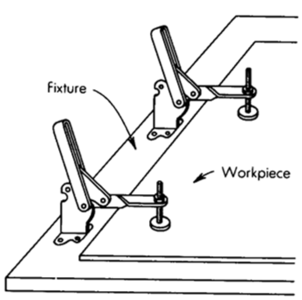


***Figure 10-17*. Typical clamp installation with the fixture supporting the workpiece directly beneath the clamps.**

Clamping Design Considerations

- Quick-acting and power-operated clamps are recommended to achieve fast loading and unloading.
- C-clamps may be used for low production volume.
- Power clamping systems may be direct acting or work through lever systems *(Figure 10-21)*.

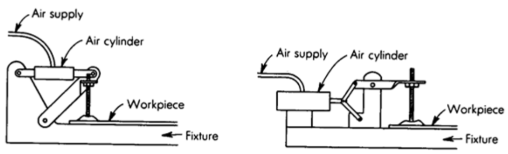


Figure 10-18. Air-actuated clamping methods.

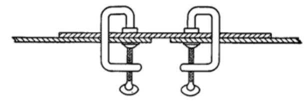


Fig. 19-11. C clamps.

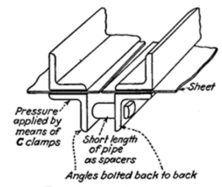
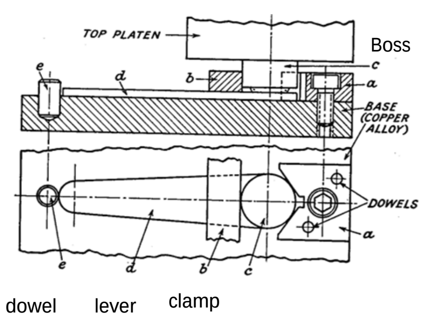


Fig. 19-12. Angle-iron bars.

Projection welding fixture



Clamping Design Considerations

- In heavier plate applications, urethane tip or spring-loaded clamp spindles are recommended to compensate for plate thickness variations.
- Where weldments change in size and quantity, and where weldment tolerances are not critical, welding platens and their stock tooling can be used *(Figure 10-22)*.

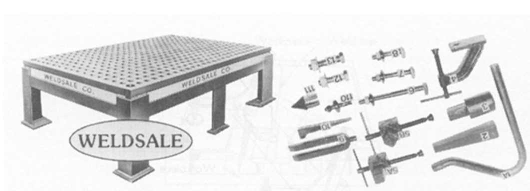


Figure 10-19. Welding platen and tooling. (*Courtesy, Weldsale Company*)

Clamping Design Considerations

- Where weldment tolerances are critical, specially designed fixtures are used. These fixtures use all standard jig and fixture components *(Figure 10-23)*.

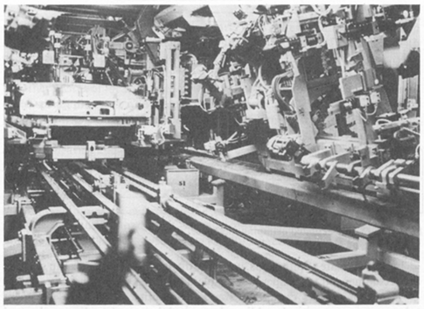


Figure 10-20. Typical example of sophisticated, extensive weld tooling and fixturing. Shown is Gilman framing, assembly robot line. Welding done on auto frames and car roofs, fully automated and computerized. (*Courtesy, The Milwaukee Journal.*)

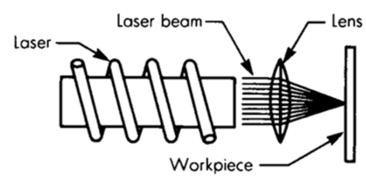
Laser Welding Fixtures

Laser Welding

- Because of the laser's high heat intensity, it can be used for welding.
- Since the laser delivers its energy in the form of light, it can be operated in any transparent medium without contact with the workpiece.
- In welding, the power is delivered in pulses rather than as a continuous beam.

Laser Welding

- The beam is focused through a lens, on to the workpiece, where the weld is to be made, and the intense heat produces a fusion weld.



Laser Welding

- Laser welding is limited to depths of approximately 0.175-0.200" (4.45-5.08 mm).
- Additional energy only tends to create gas voids and undercuts in the workpiece.

Laser Welding Fixtures

- The laser should be mounted in a firm structure to prevent vibration.
- The design should allow sufficient room between the work table and the focusing lens to accommodate various types of positioning devices.
- The tooling used to position parts for laser welding is similar to that used in other areas of welding. However, laser tooling is scaled down to accommodate smaller piece parts.

Laser Welding Fixtures

- In numerical control operations where more than one fixture is used, working heights of fixtures must be controlled in relation to each other to prevent accidental defocusing. This accidental defocusing causes poor quality.
- Because the laser energy is delivered to the workpiece without mechanical force, no fixturing is required on small piece parts. Use of mechanical force for these applications could induce strains and deformations.

Tooling for Soldering and Brazing

Tooling for Soldering and Brazing

- Soldering and brazing differ from welding in several respects.
  - The metal introduced to the workpiece for the joining operation is nonferrous, usually lead, tin, copper, silver, or their alloys.
  - The workpiece or base metal is not heated to the melting point during the operation.
  - The added metal is melted and usually enters the joint by capillary action.

Tooling for Soldering and Brazing

- Lead-tin soldering is called soft soldering and is conducted below 800°F (427°C).
- Silver soldering is called hard soldering and requires temperatures from 1100° - 1600°F (593° - 871°C).
- Copper brazing requires temperatures from 1900° - 2100°F (1038°- 1149°C).

Tooling for Soldering and Brazing

- The success of these processes depends on chemical cleanliness, temperature control, and the clearance between the surfaces to be joined.
- Cleanliness is usually obtained by introducing a flux which cleans, dissolves, and floats off any dirt or oxides.
- The flux also covers and protects the area by shielding it from oxidation during the process. It may to some extent reduce the surface tension of the molten metal to promote free flow.

Tooling for Soldering and Brazing

- The worst contamination is usually due to oxidation during the process. Many joining operations are conducted in a controlled atmosphere with a blanket of gas to shield the operation.
- Temperature control, although influenced somewhat by fixture design, is dependent primarily on the heat application method.

Tooling for Soldering and Brazing

- In a simple low- production process, the workman may hold a torch closer to the workpiece for a longer period of time.
- In a very precise high-production process, the instrumentation of a controlled atmosphere-type furnace may be adjusted.

Tooling for Soldering and Brazing

- Clearance between the surfaces being joined determines the amount of capillary attraction, the thickness of the alloy film, and consequently the strength of the finished joint.
- The best fitting condition would have about 0.003-0.015" (0.08-0.38 mm) clearance.
- Larger clearances would lack sufficient capillary attraction, while smaller clearances would require expensive machining or fitting.

Tooling for Soldering and Brazing

- Many soldering and brazing operations are conducted without special tooling.
- As with mechanical joining methods, many work holding devices can be used to conveniently present the faces or areas to be joined.
- An electrical connecting plug can be conveniently held in a vise while a number of wires are soldered to its terminals.

Tooling for Soldering and Brazing

- In many high-production assembly operations, parts are manually mated with a preformed brazing ring between them. They are then placed directly on the endless belt of a tunnel-type furnace, or on a gas-heater ring fixture.
- If the shape of the workpiece is such that it will not support itself in an upright or convenient position, a simple nesting fixture may be required. *Figure 10-22* shows a simple nesting fixture in which two workpieces and a brazing ring have been placed.

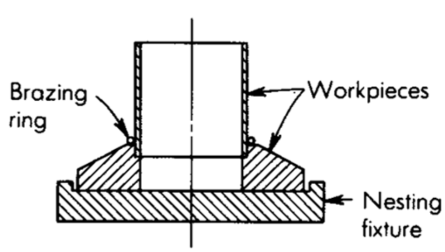


***Figure 10-22*. Simple nesting fixture with work in place.**

Tooling for Soldering and Brazing

- The fixture can be mounted on a table while an operator applies heat with a hand torch. The same fixture could be mounted on a powered rotating base in the flame path of a fixed torch, while a feed mechanism would introduce wire solder at a predetermined rate *(Figure 10-23)*.
- The same fixture could be attached in quantity to the belt of a tunnel furnace. A number of the fixtures could be attached to a rack for processing in a batch furnace.

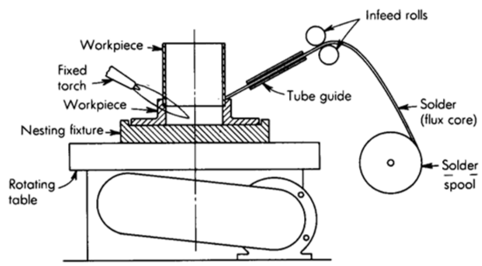
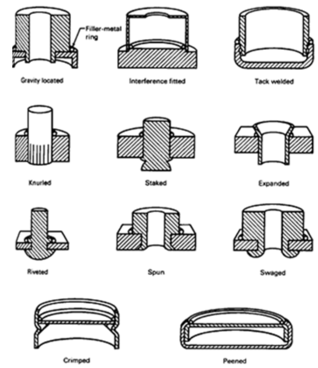


Figure 10-23. **Soldering machine using simple nesting fixture.**



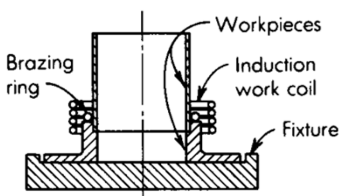


***Figure 10-24*. Nesting fixture for brazing with an external inductor.**

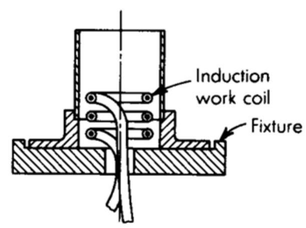


***Figure 10-25*. Nesting fixture for brazing with an internal inductor.**

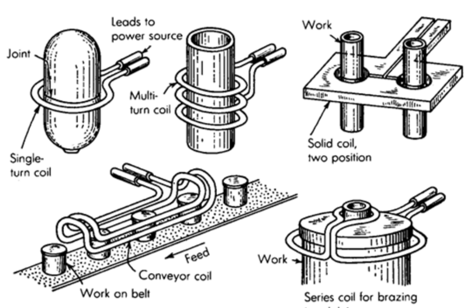
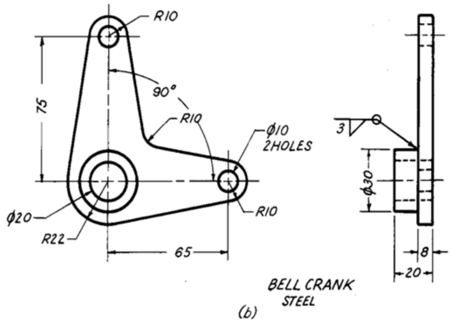
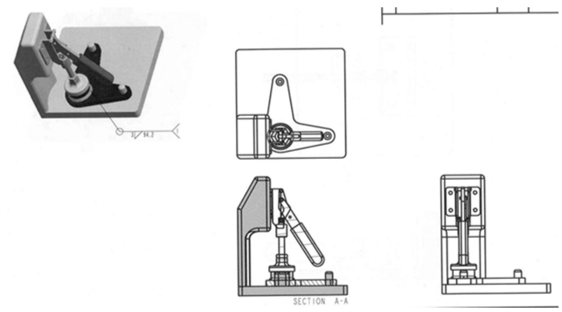
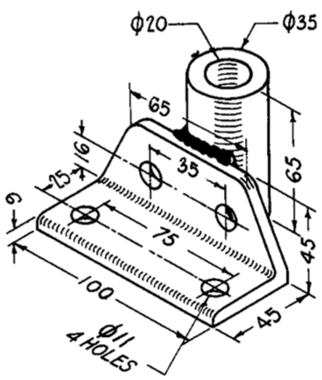


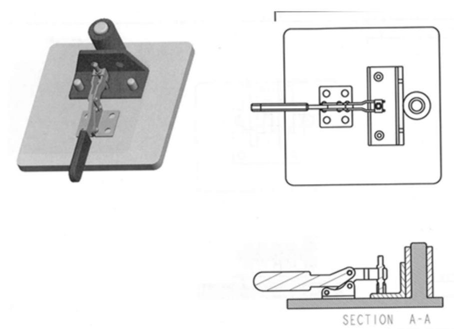
Figure 10-27. Designs of induction-heating coils for brazing.

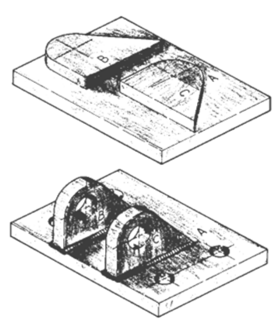
Examples

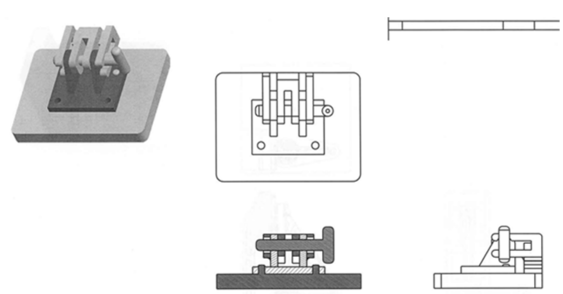

R10
90°
R10
Ø10
2HOLES
75
Ø20
R22
R10
65
3
Ø30
8
20
BELL CRANK
STEEL
(b)


SECTION A-A


Ø20
Ø35
65
16
25
35
65
6
75
45
100
45
Ø11
4 HOLES


SECTION A-A




SECTION A-A