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Mission Generation Vehicular Equipment Maintenance Journeyman

Volume 4. Vehicle Body and Welding Fundamentals

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Author: MSgt Dylan V. Petersen
344th Training Squadron, Detachment 1
Vehicle Management School House (AETC)
344th TRS, Det 1/TTAD
480 West Road
Port Hueneme, California 93043
DSN: 551-1095
E-mail address: 344TRSDet1.CDC.Contact@us.af.mil

Instructional Systems Specialist: Todd Knowles

Editor: Marie Lacayo

Air Force Career Development Academy (AFCDA)
Air University (AETC)
Maxwell AFB-Gunter Annex, Alabama

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WELCOME TO Volume 4, *Vehicle Body and Welding Fundamentals*, of Career Development Course (CDC) Y2T35X, *Mission Generation Vehicular Equipment Maintenance Journeyman*, in which you will learn about vehicle body and welding fundamentals. While you are unlikely to frequently exercise these skills, it is important to understand the underlying concepts and fundamental procedures so that you can accomplish the job competently, should the need arise. You will begin by learning about general auto body repair and then move to other components like glass, plastics, and trim. After that, you will gain a fundamental understanding of metalworking concepts. To close the volume, you will learn about painting, corrosion control, and damage estimating.

Unit 1 will cover general auto body repair. This will include concepts like understanding dents to determining the best way to repair them, along with basic techniques to execute the repair.

Unit 2 will discuss automotive glass, plastics, trim, hardware, and upholstery. This will prepare you to remove, repair, or replace these components.

Unit 3 will teach you about the oxyacetylene torch and plasma cutter. These tools are commonly used for cutting metals in a vehicle maintenance shop.

Unit 4 will cover shielded metal arc, gas metal arc, and gas tungsten arc welding. These are the three most common types of welding, and being familiar with them is important for a Vehicle Maintenance Journeyman.

Unit 5 will discuss auto body refinishing, corrosion control, and damage estimating. This final unit will explain the basic processes to keep our fleet looking sharp.

A glossary is included for your use.

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For Guard and Reserve personnel, this volume is valued at 36 hours and 9 points.

NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

Page

Please read the menu for Unit 1 and begin ➔

Unit 1. General Auto Body Repair

AS A VEHICLE MAINTENANCE AIRMAN, you may be asked to accomplish many types of repairs, including repairing a vehicle's body. In this volume, you will learn about vehicle body construction, body shop tools, how to identify and repair body damage, automotive trim, hardware, glass and upholstery, welding techniques, auto body refinishing, and estimating vehicle accidents. Although body maintenance is often contracted out, a basic knowledge surrounding these operations is invaluable to a Vehicle Management flight.

1–1. Auto Body Construction

Auto body construction refers to how the vehicle is designed and built. If you understand how a vehicle body is "put together," then you will be better prepared to repair it properly. The following two lessons will take you from the "ground up" on auto body construction, including the auto frame and the sections. It will provide you with information needed to identify parts used in vehicle body construction.

601. Auto body frames

The automotive frame is the core of any vehicle. All automotive components are attached to the frame either directly or indirectly. Through the years, the automobile frame has taken on new and weight-saving transformations. In this lesson, we will discuss frame construction, the two types of frames, and common misalignment problems.

Frame construction

While there are many frame designs, they all function the same regardless of size or type. Figure 1–1 is a typical example of the components that make up a frame. As you can see, the frame has two basic components: side members and cross members. We will consider each in the following table.

Frame Construction	
Component	**Description**
Side members	The side members, also called side rails, run the length of the vehicle and are the most important parts of the frame. Since they are subjected to great bending stress, they are made from pressed steel and shaped as channel iron with the open side turned inward. For passenger cars, the channel depth is normally constant over the middle third and decreases toward both ends.

Frame Construction	
Component	**Description**
	This design provides more strength at the center of the frame where the stresses are greater. The tops of both side members must have the same horizontal plane for proper alignment of vehicle components. The side members on most passenger car frames extend out beyond the end of the cross members shown on figure 1–1. These side-member extensions, referred to as *frame horns*, support the front and the rear bumpers on most vehicles. The frame horns sometimes serve as a point of attachment for the front forward and rear rearward leaf spring brackets.
Cross members	As you can see on figure 1–1, the cross members unite with the side members to form a box-like structure. Most frames have several cross members riveted or welded to the side members. The cross members may have channel iron, I-beam, or pan-type construction and come in various shapes to facilitate the mounting of the chassis components.

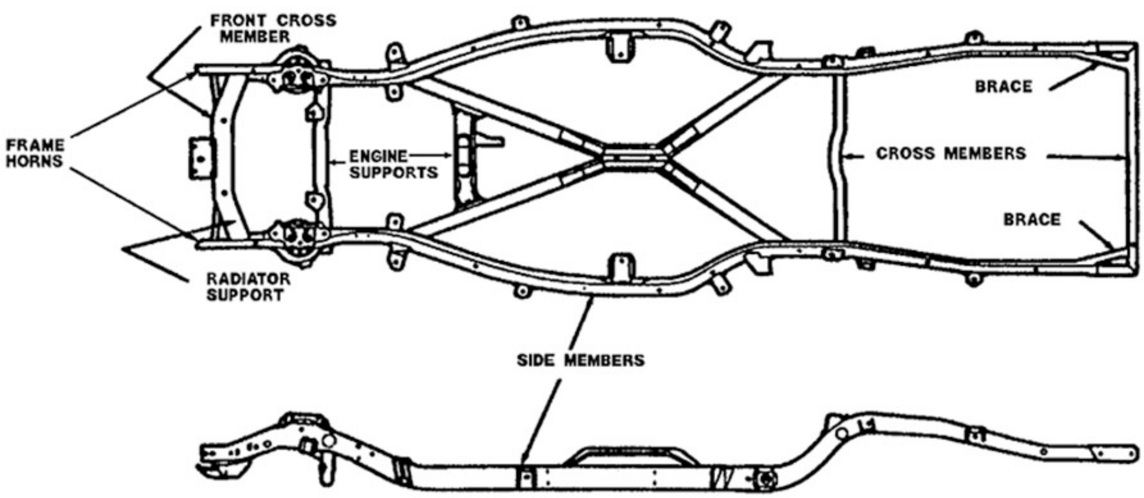


Figure 1–1. Full frame.

Frame types

The types of frames you will most likely work with are full frame and unitized body. The following paragraphs will provide you with some general knowledge of each type.

Full frame

Commonly known as "body over frame," the full frame has the body and chassis parts bolted to the frame. Most full frames are wide at the rear and narrower at the front. The narrow front-frame construction provides extra clearance and allows the front wheels to make sharper turns while the wider rear-frame construction provides better support for the body. Most full frames are designed to withstand some overloading and rough treatment. These frames are very durable and seldom become misaligned unless the vehicle is used for the wrong purpose (overloading, running over curbs or parking area concrete stops, and repeatedly operating on very rough terrain—unpaved roads or no roads) or is involved in an accident.

Often designed with additional bracing members, such as the "X" member at the frame center in figure 1–1, increases the full frame's torsional rigidity, or resistance to bending. You will also see that the center section of the frame sets lower to the ground, making the floor or pan of the body closer to the ground. The ends of the frame have an extra curvature to provide the proper clearance above the axles.

Keep in mind that frame alignment has a direct bearing on the other vehicle components. This means you will need to check the frame in the event steering problems or misalignment of vehicle components cannot be corrected. Although the unibody construction has become more common, full-frame construction can still be found on some full-size sedans, most full-size pickup trucks, and some small pickups.

Unitized body

The concept of the unitized body or unibody construction was first proven in the aircraft industry, where light weight, high strength fuselages were needed. It is a manufacturing process where sheet metal body parts are combined with stress-bearing elements to form the body and chassis as a single piece (fig. 1–2), as opposed to attaching body parts to a frame. Strength is achieved through the shape and design of individual parts instead of their mass and weight. No separate heavy-gauge steel frame is needed. The use of lightweight, high strength, steel alloys, or aluminum, versus the old cold-rolled steels, gives the unibody a lighter weight advantage over the "full frame" construction. Most passenger cars and some light trucks are of the unibody construction.

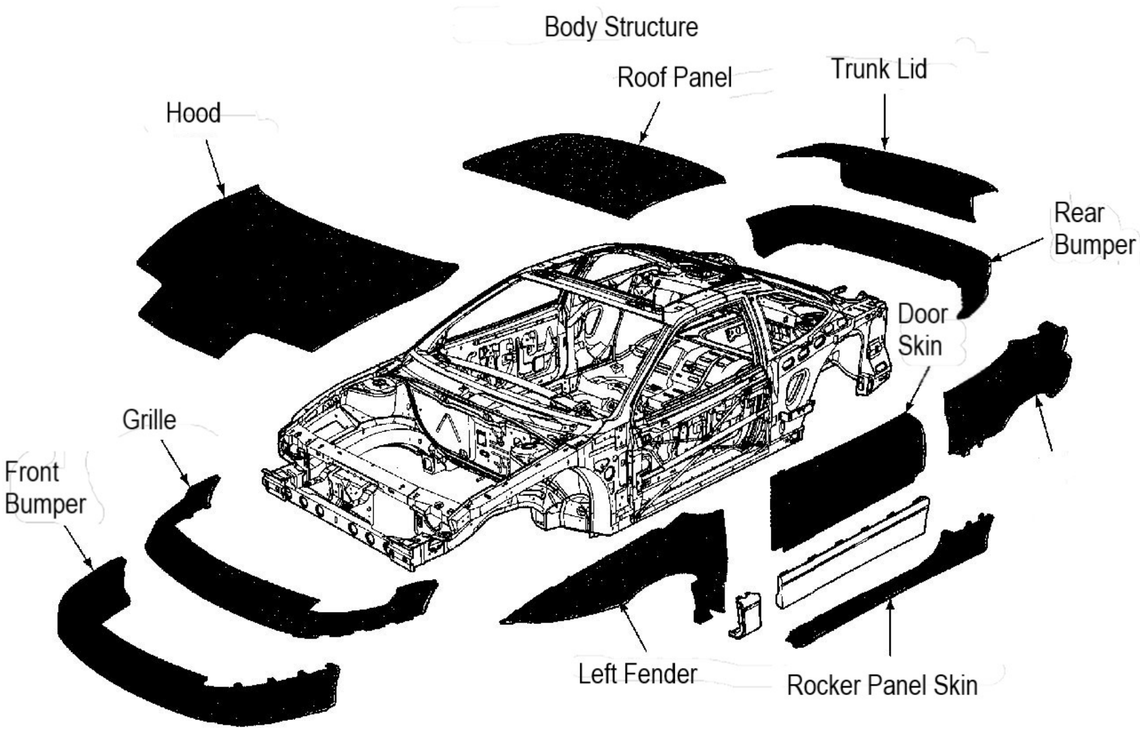


Figure 1–2. Unitized body frame.

Frame misalignment

The most common types of frame misalignment are diamond, sag, and side-member sway.

<table>
<tr><th colspan="2">Common Frame Misalignment</th></tr>
<tr><th>Type</th><th>Description</th></tr>
<tr><td>Diamond</td><td>A diamond condition (fig. 1–3) normally results from an impact parallel to the front or rear of the frame. In other words, the cross members of the frame no longer form right angles with the side rails. In some instances, the frame may become twisted along with the diamond condition.

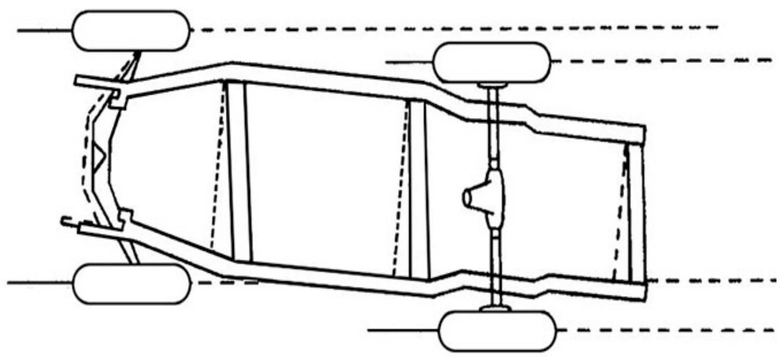



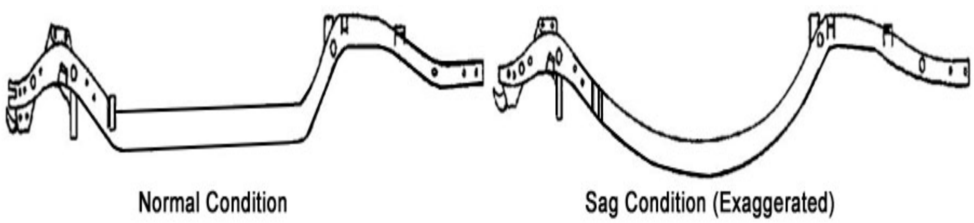
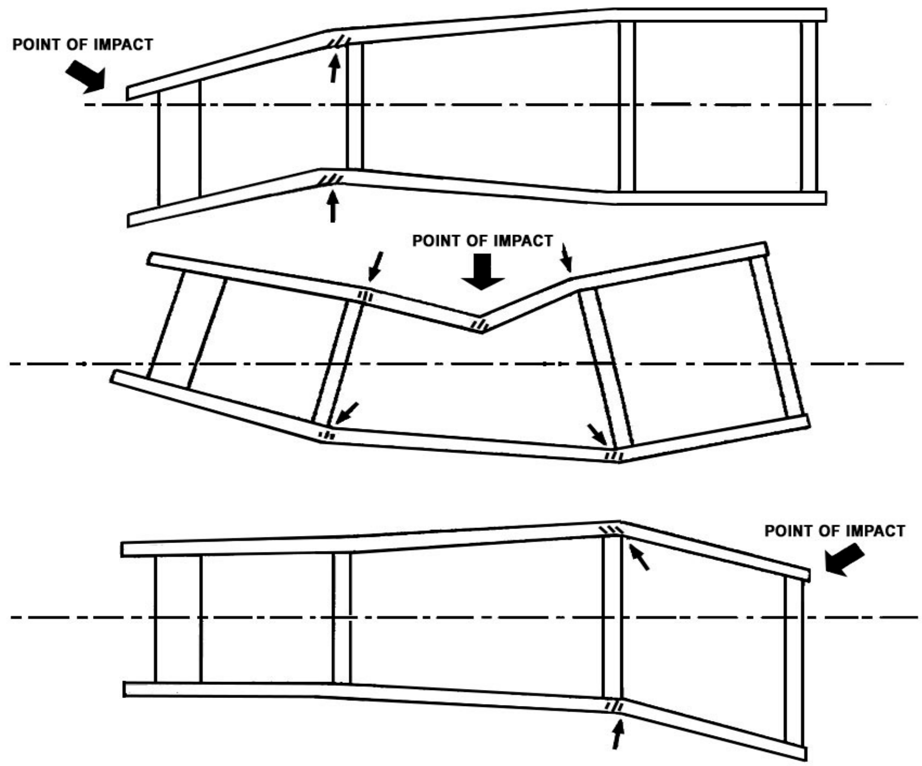
Figure 1–3. Diamond condition.</td></tr>
<tr><td>Sag</td><td>A sag condition (fig. 1–4) is usually caused by overloading a vehicle’s frame. Notice how the side rails bend down in the center because of the excessive weight the vehicle carried.


Figure 1–4. Sag condition.</td></tr>
<tr><td>Sway</td><td>Examples of a sway condition are shown in figure 1–5. The small arrows point out buckles in the side members of the frame. A side impact at any of the points shown normally causes the sway condition. When sway happens, the vehicle’s rear wheels will not track properly. Tracking means the rear wheels are following the front wheels if the front wheels are in the straight-ahead position.</td></tr>
</table>

Common Frame Misalignment	
Type	**Description**
	 **Figure 1–5. Sway condition.**

Checking frame alignment

When checking the frame for misalignment, use the measuring rods and gauges furnished with aligning equipment. You use these same rods and gauges during the actual straightening to determine when you have made the correction. The idea is to check, straighten, and recheck the frame until the measurements conform to technical order (TO) specifications.

NOTE: Many frames can be straightened *without* disassembling the vehicle.

When checking frame alignment, you must take careful measurements with special frame-machine gauges at designated points on the frame. If there is an indication of vehicle frame misalignment, you will have to position yourself under the vehicle and make a careful inspection. Check every segment of the cross members and side members for the following:

- Kinks.
- Bends.
- Rips or tears on the side members.
- Loose rivets, bolts, and body support brackets.
- Cracks in welded connections.

Knowing the location of damage helps considerably when interpreting measurements and gauge readings. If specialized equipment is not available, you can use the *plumb bob method* to check frame alignment by transferring checkpoints to a level floor.

To do this, take the steps provided in the following table.

Using Plumb Bob to Check Frame Alignment	
Step	**What To Do**
1	Select a place where the floor is clean and level. With lifting device(s), elevate the vehicle to a workable level, ensuring its weight is resting firmly on the device(s) you use.
2	Position yourself under the vehicle. Select checkpoints like those marked “K” in figure 1–6. Notice that frame and cross-member intersections, vehicle wheels, and body bolts or rivets are selected as checkpoints. Transfer the checkpoints to the floor where you can make measurements with greater ease and more accuracy. For each checkpoint you select on one side of the frame, you must select a corresponding checkpoint on the opposite side.
3	To transfer the checkpoints to the floor, hold the string of the plumb bob on the center of the checkpoint with the plumb bob barely touching the floor. Mark this point of contact on the floor and repeat the process at the remaining checkpoints. You must mark points on the floor directly below the selected checkpoints of the frame very carefully to obtain reliable results. You can use tape, felt tip marker, pencil, chalk, or anything you feel comfortable with to mark where the plum bob makes contact with the floor.
4	After you mark each measurement point on the floor, draw the diagonal connecting lines as shown by the dotted lines in figure 1–6. Notice that a centerline, parallel to the side rails, is drawn through the intersections of the diagonals (“AA,” “BB,” “CC,” and “DD”). Diagonals of a true rectangle are equal as shown in figure 1–6. In contrast, a distorted rectangle, or misaligned frame, has unequal diagonals.
5	Measure the distance from the centerline to the corresponding checkpoints on each side of the frame over the entire length of the chassis. These measurements should not vary more than $^1/_8$ inch at any point. The same applies to measurements of pairs of diagonals. The point where each of the pairs of diagonals intersects should be within $^1/_8$ inch of the centerline. If the measurements are within $^1/_8$ inch, consider the part of the frame between the points of measurement in satisfactory alignment. You may have to set up diagonal checkpoints covering less area than those indicated in figure 1–6. Compare all measurements with technical order specifications.

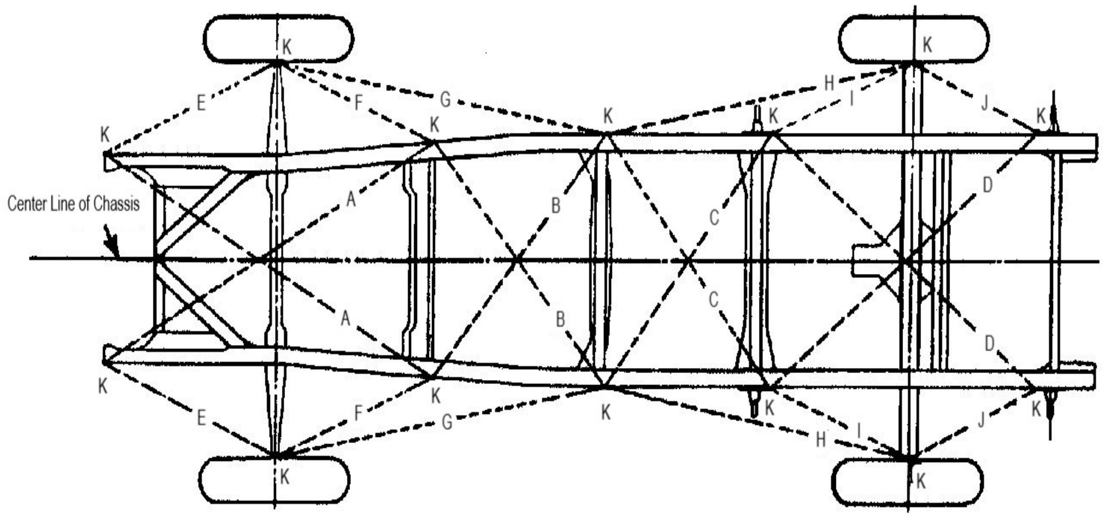


Figure 1–6. Frame measuring points.

Most Air Force vehicle maintenance shops are not equipped to do any extensive frame repair work. Any major repair is normally performed through contract maintenance. However, you need to know how to check frame damage and determine whether repairs are necessary.

602. Auto body sections

The easiest way to communicate collision repair is to divide the vehicle into three body sections. It is important to understand how these sections are constructed to properly repair them. In this lesson, we first turn our attention to the basic shapes and methods that manufacturer's use to reinforce body sheet metal parts. You will then move on to the three major sections and look at the key components in each section.

Basic shapes

In auto body repair, we commonly call a curved surface a crowned surface or crown. An example is the graceful curvature of the front fender of an automobile. These lines help enhance the beauty and style of the automobile. Function is also involved here. A flat sheet of thin-gauge steel is very flexible; that is, it flexes and bends as you pick up one end. When you lay it back down, it flexes again and returns to a flat sheet. However, if you force this same sheet of thin-gauge steel into a *crowned surface*, it adds considerable strength and rigidity. Thus, we can conclude that the crowns formed into auto body sheet metal have a great deal to do with body strength.

While there is some variation, crowns are divided into four basic types:

1. Low-crown.
2. High-crown.
3. Combined high- and low-crown.
4. Reverse crown.

These are each discussed in the following table.

Crown Types	
Type	**Description**
Low	Panels described as low-crown group have very little crown because they are almost straight lengthwise. For practical purposes, treat these panels as if they were flat. Late-model automobiles have many low-crown areas. Good examples are the lower door panels, hoods, and deck lids, shown in figure 1–7, View A.

Crown Types	
Type	**Description**
	It is difficult to specify exactly when a curvature ceases to be a low-crown and becomes a high-crown. It is much easier to think of it in terms of flexing ability. An undamaged low-crown panel flexes out of shape if you apply pressure and then snaps back when you release the pressure.
High	Panels described as high-crown have enough curvature to give the impression that the round shape of the panel goes in both directions. The curvature may not be the same in both directions, but it is enough to be obvious. True high-crowns in modern automobiles are very rare because of design trends. Examples of a true high-crown are the rounded section on the front of some hoods, the rear end of some quarter panels, and the rounded corners on roof panels (fig. 1–7, View A). Ordinarily, compared to the total area of the panel, the high-crown surface is only a small portion of concern. High-crowned surfaces do not bend by hand pressure as low-crown surfaces do. If you apply enough force to push a high-crown out of shape, it does not spring back as you release the pressure. As metal is formed into high-crowned areas, it imparts additional strength for resisting force.
Combined High and Low	The rounded edges of many low-crown areas, such as front fenders and doors, are actually low-crowned in one direction and high-crowned in another. For example, most front fenders are nearly flat lengthwise but curve sideways; note the front fender in detail in figure 1–7, View A. Surfaces of this type have the strength characteristics of a high-crown. Although almost flat in one direction, the short radius of the curvature in the other direction provides bracing to resist force.
Reverse	A reverse crown is an inside curve because the center point of the curve is on the side from which you view it. You may find the reverse crown around the taillights or headlights of some automobiles. Because of the strength of a reverse crown, the metal surface must collapse before a bend occurs. As a result, damage occurring in a reverse crown is usually more severe when compared to a high or low-crown.

With these thoughts in mind, let us now turn our attention to other means of adding strength to the automobile body.

Reinforcing methods

While the crowned surfaces of the body panels provide some strength, it is not enough. The body must hold the alignment of the parts and carry desirable loads. These requirements mean that additional strength must be added. However, the weight has to be kept as low as possible.

In the search for a workable solution (additional strength with minimal additional weight), manufacturers developed lightweight reinforcements made of formed sheet metal. This was a major step forward in automobile body construction. These reinforcements are either formed on the surface of an inner or outer panel or welded to a panel.

Formed reinforcements

Reinforcements formed in panels include flanges, grooves, and ridges. They are found on the inside of the door panels and on floor pans. Notice the ridges in figure 1–7, View B; these are primarily stiffeners.

Welded-on reinforcements

Welded-on reinforcements are normally box sections or channels, which serve as structural members. These occur as crossbars on the underside of the floor pan, roof rails under the hood or deck lid, and in many other places. Figure 1–7, View C shows crossbars welded to the underside of a deck lid.

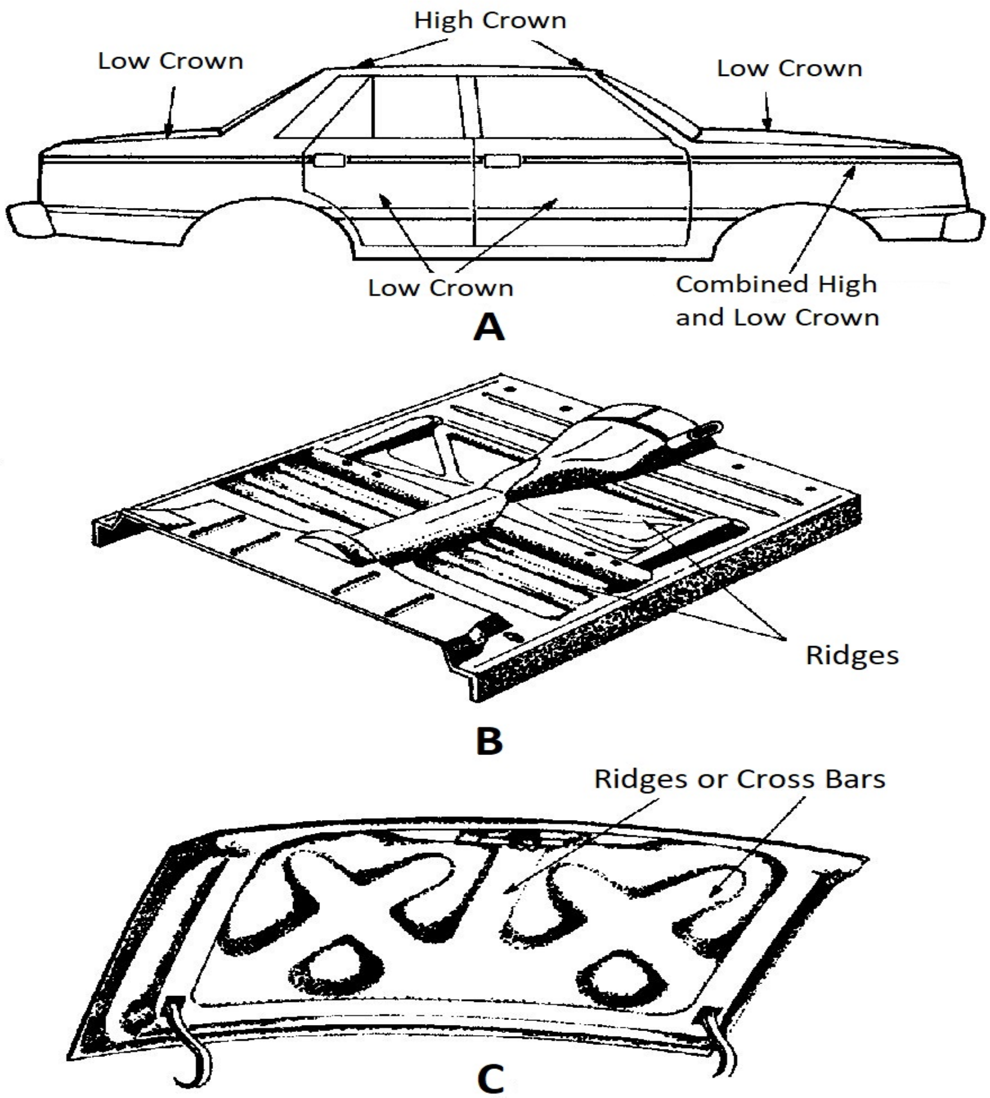


Figure 1–7. Sheet metal shapes and reinforcement.

Front section

The front section (fig. 1–8) is commonly called the “front clip.” It includes everything between the front bumper and the firewall. We discuss some of the key components in the following paragraphs.

Bumper assembly

The bumper assembly bolts to the front frame horns or rails and absorbs minor impacts.

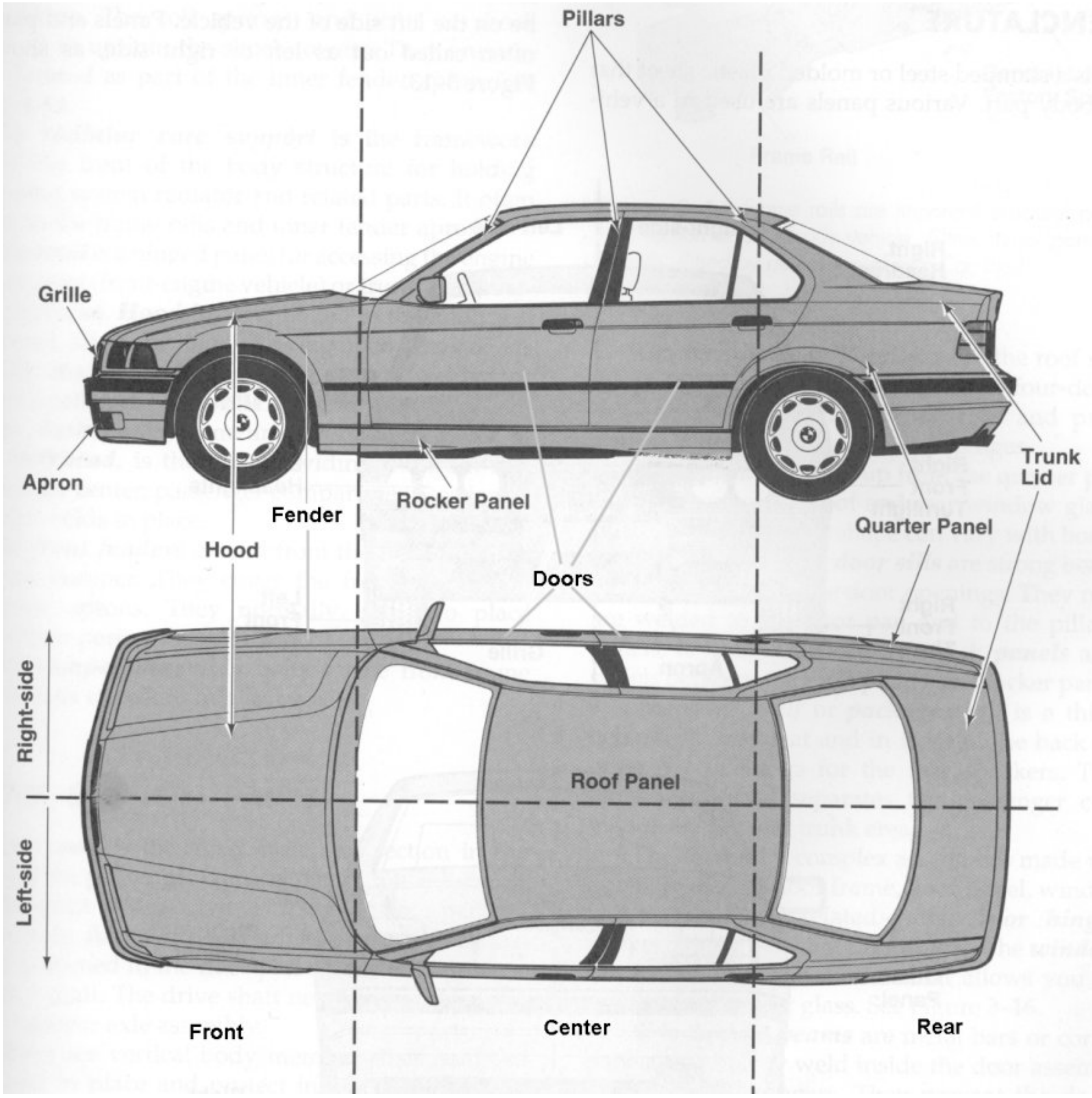


Figure 1–8. Body sections.

Cowl

This cowl is located near the rear of the front section underneath the front windshield and provides added airflow for the engine compartment and mounting points for the hood hinges.

Firewall

Normally welded in place, this firewall acts as a barrier between the engine compartment and the passenger section. It also separates the front section from the center section.

Frame rails (horns)

These box frame members extend out near the bottom of the front section. They provide an anchor point for the bumper and radiator supports.

Front fender aprons

These are the inner panels that surround the wheels and tires to keep out the road debris. They are often bolted or welded to the frame rails and cowl.

Front fenders

Normally bolted in place, the front fenders extend from the front door to the front bumper. They cover the front suspension and inner aprons.

Hood

The hood is a hinged panel that allows access to the engine compartment. It is normally made of two or more panels welded or bonded together to prevent flexing and vibration.

Radiator supports

Usually bolted to the frame rails and inner fender aprons, this is the framework around the front of the body structure for holding the radiator and related components.

Shock/strut towers

Normally formed as part of the inner fender apron, these are reinforced body areas for holding the upper parts of the suspension system. The coil springs and struts or shock absorbers fit up into the shock towers.

Center section

The center section (fig. 1–8) includes body parts that form the passenger compartment. We will discuss some of the key components in the following paragraphs.

Dash assembly

This assembly includes the soft dash pad, instrument cluster, radio, heater, air conditioning (A/C) controls, vents, and similar parts.

Doors

Doors are complex assemblies made up of an outer skin, inner doorframe, door panel, window regulator, glass, and other related parts.

Floor pan

The floor pan is the main structural component in the lower portion of the passenger compartment.

Pillars

These components are vertical body members that hold the roof panel in place and provide some passenger protection in case of a vehicle rollover. There are three types of pillars:

1. Front/A-pillars.
2. Center/B-pillars.
3. Rear/C-pillars.

Rear bulkhead panel

The rear bulkhead panel separates the passenger compartment from the trunk area.

Rocker panels

Welded to the floor pan and the pillars, rocker panels are strong beams that fit at the bottom of the door openings.

Roof panel

Normally welded to the pillars, this large multi-piece panel fits over the passenger compartment.

Side impact beams

These components are either metal bars or corrugated panels that bolt, or are welded, to the inside of the door panels. They provide passenger protection and prevent the door from coming open during an impact.

Rear section

The rear section (fig. 1–8), also known as the “rear clip,” contains all the components between the rear bulkhead panel and rear bumper. We will discuss some of the key components in the following paragraphs.

Deck lid

Known also as the “trunk lid,” this hinged reinforced panel closes over the rear storage compartment.

Inner wheel housing

These components surround the rear wheels and prevent road debris from hitting the underside of the passenger and trunk compartments.

Lower rear panel

This component fits in between the trunk floor panel and the rear bumper, connecting the back of the rear quarter panels.

Quarter panels

Welded in place, the quarter panels form a vital part of the rear section. The panels are large, side-body sections that extend from the side doors back to the rear bumper.

Rear shock towers

The rear shock towers provide anchor points for the top of the rear suspension.

Trunk floor panel

Welded to the rear frame rails, inner wheelhouses, and rear panel, this component is a stamped steel part that forms the bottom of the rear storage compartment.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

601. Auto body frames

1. Name the most important part of a vehicle’s frame.

2. Where would you find the most stress on a vehicle’s frame?

3. What do you call the side-member extensions used to support front and rear bumpers on most vehicles?

4. How are the cross members attached to the side members on a vehicle frame?

5. Why are frames narrower at the front?

6. What are some causes of frame misalignment?

7. Briefly describe a unitized body.

8. What is the advantage of a unitized body-type construction for a passenger car?

9. Match the misalignment type in column B with the description in column A. The types in column B may be used once, more than once, or not at all.

Column A	*Column B*
____ (1) An impact to the left side of vehicle.	a. Sway.
____ (2) A parallel impact to the front.	b. Diamond.
____ (3) Overloading the vehicle's frame.	c. Tracking.
____ (4) An impact to the right side of vehicle.	d. Sag.
____ (5) A parallel impact to the rear.	

10. What are some conditions you should look for during your preliminary inspection of a frame?

11. If special equipment is not available, what alternate method can you use to check frame alignment?

12. What is the purpose of transferring the measurements to the floor?

13. What is the maximum allowable difference at intersecting points?

602. Auto body sections

1. Why are crowns used in vehicle bodies?

2. List the four basic crowns.

3. What will a low-crown do if you press and release it by hand?

4. Does a high-crown surface bend easily when you apply hand pressure?

5. Which reinforcements are used in door panels and floor pans, and serve as structural members?

6. In which body section can the firewall be found?

7. Which center section component provides main structural support for the passenger compartment?

8. What is another term used for deck lid?

1–2. Auto Body Tools

You can repair body panels or fenders with hand tools or in some cases with special power-driven equipment. In this section, we discuss some of the most common auto body tools and equipment you will use in automotive body repair. These include various types of repair hammers, dolly blocks, spoons, and caulking tools that you will find in a typical shop.

603. Repair hammers

In the automotive body repair shop, you use various hammers with a wide range of sizes, shapes, and weights. Although you may hear these called by many names, body shop personnel normally use just three types of hammers:

1. Bumping hammers.
2. Dinging hammers.
3. Pick hammers.

In addition to these three, you will also use the cross-peen hammer, which we will discuss later in the unit. An important point to remember here is that you should maintain a smooth, polished face on all striking tools. To keep the face of the hammer like a mirror finish, hone it with fine water-resistant sandpaper whenever it becomes rough or marred. Start the honing process with 220- or 260-grit paper and finish with 400-grit paper.

Bumping hammers

Normally the largest and heaviest of the various hammers you will use, bumping hammers come in various sizes and shapes, with either round or square heads or crowned or flat faces. One end of the hammer ordinarily has a flat face and the other end a crowned face or pick end. In the case of the crown face, the hammer may have a low- or high-crown. This requires that you select the hammer with a crown best suited for the job at hand. The width of the face varies, depending on the type of hammer; a width of $1^1/_2$ inches is average.

The bumping hammer's large, flat face spreads the impact over a larger area than that of a small-faced hammer. As you use the hammer, round off the outer edges of the flat face enough to prevent marks on the metal in case you strike the metal surface with the hammer at a slight tilt. The bumping hammer (fig. 1–9) has a round head and square head, but both ends have crowned faces. These hammers are available in various combinations as well as sizes.

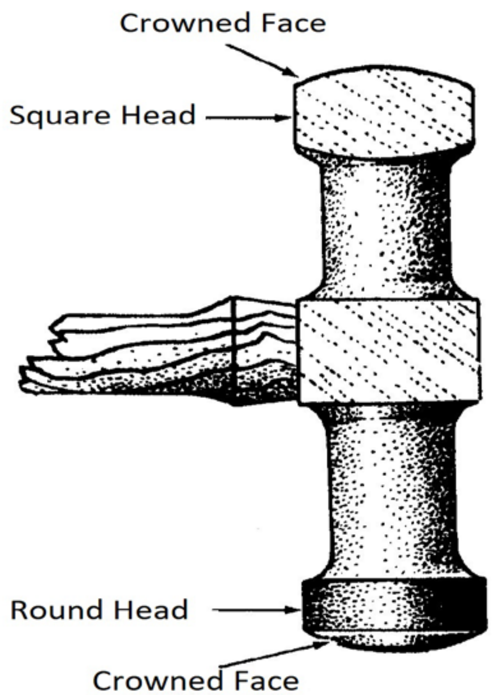


Figure 1–9. Bumping hammer.

Figure 1–10 shows four applications of bumping hammers—two correct and two incorrect. The top left drawing shows a convex surface being bumped with a flat-face bumping hammer—the correct method. Here, a greater area of the hammer face makes contact with the convex metal surface because a flat-face hammer is used rather than a crowned-face hammer. In the top right drawing, the same convex surface is bumped with a crowned-face bumping hammer. This is incorrect because only a small area of the crown-face hammer makes contact with the convex surface. This creates a low spot in the metal where the crown of the hammer makes contact with the metal surface.

Notice the concave surface in the lower left and right drawings in figure 1–10. The bottom left drawing shows this surface being struck with a crowned-face bumping hammer, which is correct. The crown of the hammer face should match, as nearly as possible, the curvature of the surface being struck. The bottom right drawing incorrectly shows the same concave surface being struck with a flat-face bumping hammer. If you complete this stroke, the only place the hammer makes contact with the metal surface is where the face corners meet the concave surface. This damages the metal surface at the four contact points. You normally use the bumping hammer in conjunction with the dolly block (covered later in this unit).

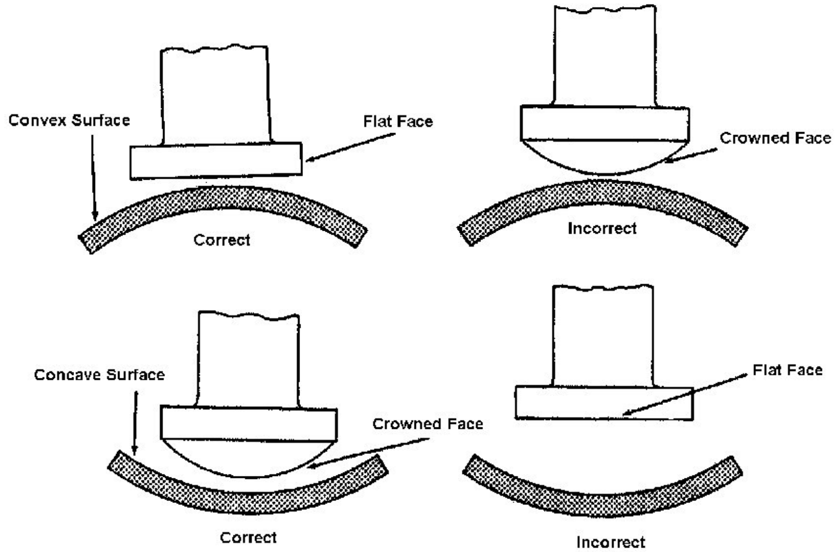


Figure 1–10. Use of crown and flat-face hammers.

Dinging hammers

The only difference between a dinging hammer and a bumping hammer is that the dinging hammer is smaller. Some body mechanics refer to the dinging hammer as a lightweight bumping hammer. The dinging hammer (fig. 1–11) has both a round head and a square head, each with flat faces. Sometimes, dinging hammers may have a crowned face on one head while the other head has a flat face. Notice that the dinging hammer in figure 1–11 is of lighter construction in comparison to the bumping hammer in figure 1–9. Use the dinging hammer for finishing work after you have used the larger bumping hammer to rough out the work, or where using too large of a hammer might cause metal overstretching.

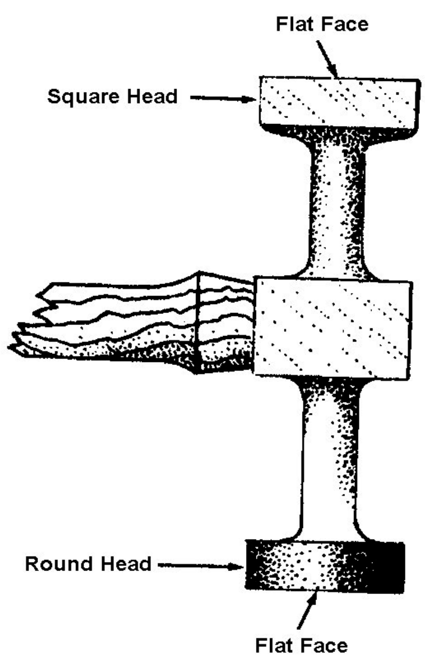


Figure 1–11. Dinging hammer.

Pick hammers

Several types of pick hammers are illustrated on figure 1–12. As you can see, these are combination hammers with a bumping or dinging head on one end and a pick on the other. Notice the hammer on the left has a short, blunt, pick end, whereas the others have longer, sharper picks. You use pick hammers to pick out small dents in panels and other hard-to-get-at places where you cannot use a dolly block. The pick hammer is extremely useful in picking out dents in rocker panels or other panels having a high-crown or curved surface.

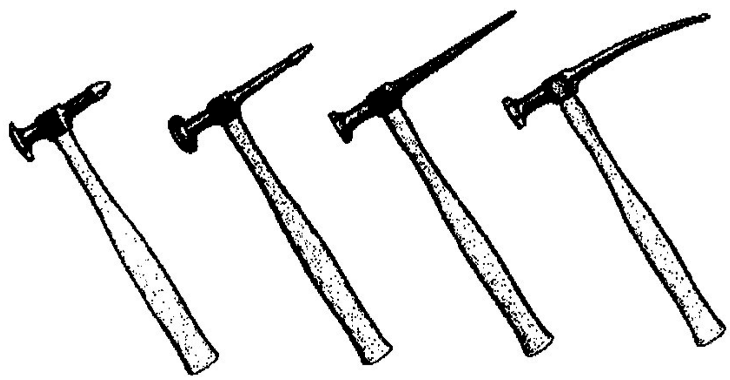


Figure 1–12. Pick hammers.

604. Dolly blocks

Dolly blocks are available in so many different sizes and shapes that no general description can be applied to them. You use a dolly block as a striking tool or as a backup tool when using hammers. In either case, the dolly block is used on the underside of the fender, hood, truck lid, or on the inside of a panel. In this lesson, we will devote our attention to the different types of dolly blocks and their uses.

Types

The dolly block is designed to act as a rest when the hammer strikes the metal surface. Some of the most common types of dolly blocks are shown in figure 1–13. When selecting a dolly block, one factor you must consider is its weight. Normally, the dolly block's weight should be at least three times the weight of the hammer you are using. This extra weight provides the inertia for the block to resist the impact of the hammer blow.

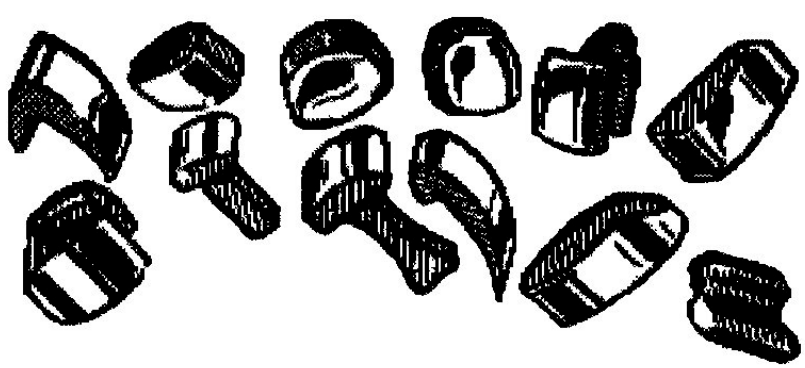


Figure 1–13. Dolly blocks.

Use

When used as a backup tool, the dolly block provides a reaction to the impact of the hammer blow. In essence, the dolly block tends to raise the spot of metal that is in contact with its working face. This is true whether the dolly is directly under the spot struck by the hammer or a short distance away. To use the dolly, hold it firmly against the underside of the panel and strike the metal directly above or near the dolly with the bumping hammer. The inertia of the dolly stops the hammer blow, and the hammer snaps back to start the next blow. The impact from the hammer blow transfers through the metal to the dolly, driving it away from the underside of the panel. Holding the dolly in place stops the movement of the dolly and snaps it back against the underside of the panel. This impact tends to drive the metal surface up.

You have probably used a hammer to drive nails or used it with punches and chisels. Most of the time, you grip the hammer handle firmly throughout the stroke. As the hammerhead hits the surface of the nail, punch, or chisel, your hand is still exerting a downward force, which adds effectiveness to the hammer blow. While this is acceptable for the situation we have described, it is not appropriate for use with a dolly block. Why? Because it upsets the timing, interferes with the rebound action of the dolly, and may cause denting.

When using the dolly block, it is important to do the following:

- Hold the bumping hammer lightly.
- Let your grip slacken as the hammer descends.

This keeps you from exerting excessive downward force as the hammer strikes the metal surface. You can do this by gripping the handle with the third and fourth fingers only, keeping the thumb parallel along the upper side of the handle. Your thumb helps start the blow, and your first two fingers help snap the hammer back after you have struck the metal surface. When working with the dolly block, start the hammer blow with a snap of the wrist rather than with a full-arm movement.

Hammer-on-dolly and hammer-off-dolly are two popular methods for using dolly blocks.

Hammer-on-dolly

In this configuration (fig. 1–14), you hold the dolly block on the underside of the body panel directly under the spot where the hammer will strike. Though this may seem like an impossible task, it is only a matter of hand-and-eye coordination. As you gain experience and practice more, you will be able to do it with great ease. You use the hammer-on-dolly method to increase an area in size and raise it above the level of the surrounding metal surface. Each time you strike the hammer against the metal surface, the following occurs:

- The inertia of the dolly stops the hammer blow and subjects the metal caught between the hammer and dolly faces to a compressive force, which tends to spread it. At this time, the hammer snaps back so you can execute the next hammer blow.
- Impact from the hammer blow transfers through the metal, thus driving the dolly away from the underside.
- Your firm hold of the dolly block against the underside of the panel stops the dolly and drives it back against the metal (which has now been stretched) and raises it above the surrounding metal surface area. The amount of metal you raise is proportional to the amount of hand pressure you apply to the dolly block.

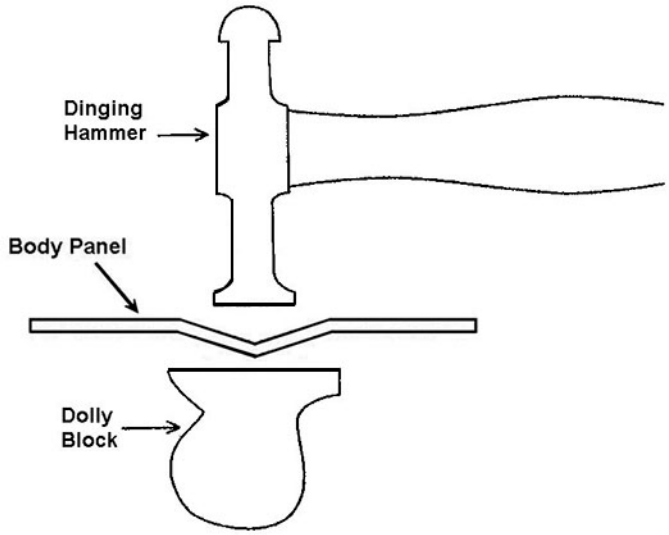


Figure 1–14. Hammer-on dolly.

You can use this lifting action combined with the stretching action to raise large areas by properly spacing hammer-on-dolly blows. The following three factors must be considered to obtain the desired results when using the hammer-on-dolly method:

1. Force of the hammer blow.
2. Amount of hand pressure you apply to the dolly block.
3. Crown of the dolly block (low or high).

It should be obvious to you that the impact of the hammer blow affects the stretching action and the movement of the dolly away from the underside. The amount of hand pressure you apply to the dolly block determines the amount of impact it will have when driven back against the metal and controls the raising of the metal surface.

If you use a dolly with a low-crown working face, the impact of the hammer blow spreads over a large area. This causes minimum stretching and almost eliminates the lifting effect of the dolly block striking the reverse side of the metal surface. On the other hand, if you use a dolly block with a high-crown (resulting in a small area of metal contact), you confine the impact of the hammer blow to a small area. This produces more of a stretching action resulting in an increased lifting action. The smaller area also has less resistance than a larger one. Although the impact of the hammer blow is the most obvious, you should see that all three factors are of equal importance.

Overstretching can occur from using the hammer-on-dolly method. When overstretching does occur, it is always the result of using the method too much or in areas where you should not use it at all. You must learn to recognize where and how much to use the hammer-on-dolly method.

Hammer-off-dolly

The hammer-off-dolly method (fig. 1–15) is normally used to remove dents in a combination high- and low-crown. In most cases, if you force a dent into a crown of this type, the metal raises around the dent. The idea of the hammer-off-dolly method is to place the dolly under the low spot of the dent and let the hammer blow fall on the high spot. You drive the high spot down because the dolly does not support it. This movement of the metal transfers the impact of the hammer blow to the dolly and causes it to rebound (in much the same manner as with the hammer-on-dolly method), causing the low spot to rise. In this way, you drive down the high spot and raise the low spot with a single hammer blow. Remember that you never strike metal unless you raise it above the proper level. To do otherwise causes a low spot that you have to raise. In addition, direct the first hammer blows to the high spots farthest from the dent and work progressively inward.

When using the hammer-off-dolly method, you have to develop the ability to judge exactly where to place the dolly block to obtain the desired results. It is also essential that you learn to place the dolly in the correct spot without looking. As shown in figure 1–15, always place the dolly close to, but slightly away from, the exact location where the hammer blow will fall.

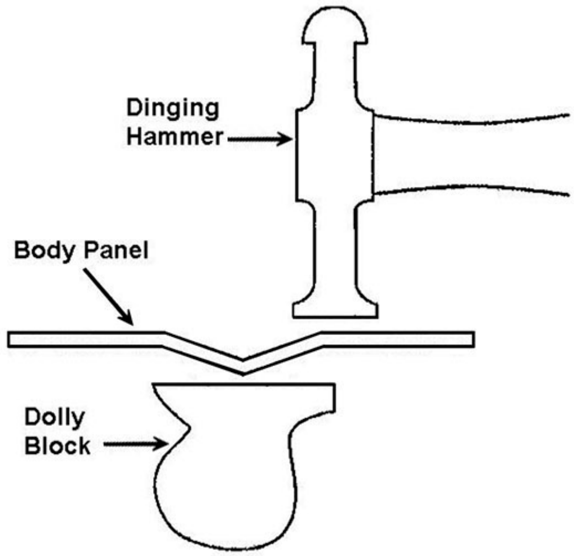


Figure 1–15. Hammer-off dolly.

605. Repair spoons and caulking irons

As you might expect, there are situations where dolly blocks and hammers are not appropriate. This suggests the question, what do you use in their place? To answer this, we need to introduce two more tools you will use in the body shop: spoons and caulking irons.

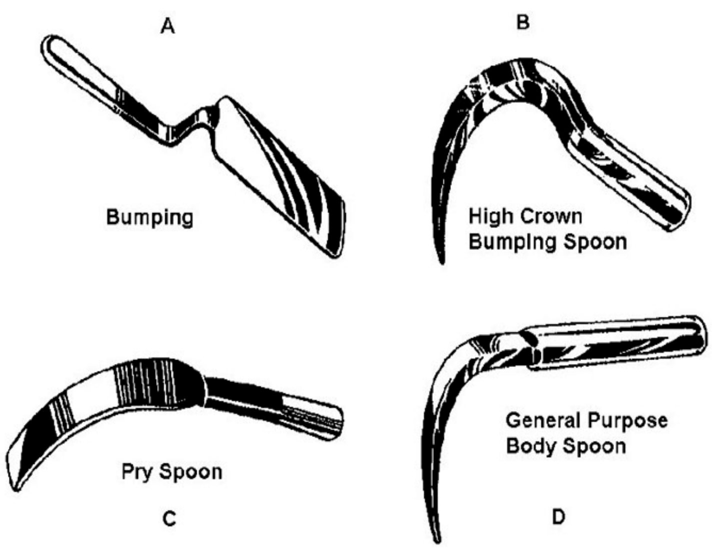


Figure 1–16. Spoons.

Spoons

It is difficult to accurately define the term *spoon* as it applies to auto body repair tools. For our purposes, a spoon is *usually* a bar of steel with one of the following characteristics:

- Forged flatter at one end than the other.
- Flatter at both ends than in the middle.

These bars are bent into a variety of shapes depending on their use. The spoon's flat face is the working face; the rest of the bar serves as the handle. There are two types of spoons: bumping spoons and body spoons (fig. 1–16).

Bumping spoons

The bumping spoon is best suited to straighten long, relatively smooth buckles where the distortion is comparatively light but spread over a large area. You can straighten these types of buckles with the hammer alone, but you would have to strike the metal surface many times. Not only would this take much longer, but it also would leave hammer marks on the metal.

Using a bumping spoon and hammer requires less skill than a dolly block and hammer. The main difference is that the spoon acts as a part of the hammer blow, whereas the dolly block provides a secondary reaction to it. In essence, you are using the spoon to spread the impact of the hammer blow over a much larger area than the hammer face can cover. To accomplish this, perform the following:

1. Place the center of the working face of the spoon on the metal surface you want straightened.
2. Direct the hammer blow to the spoon as shown in figure 1–17.

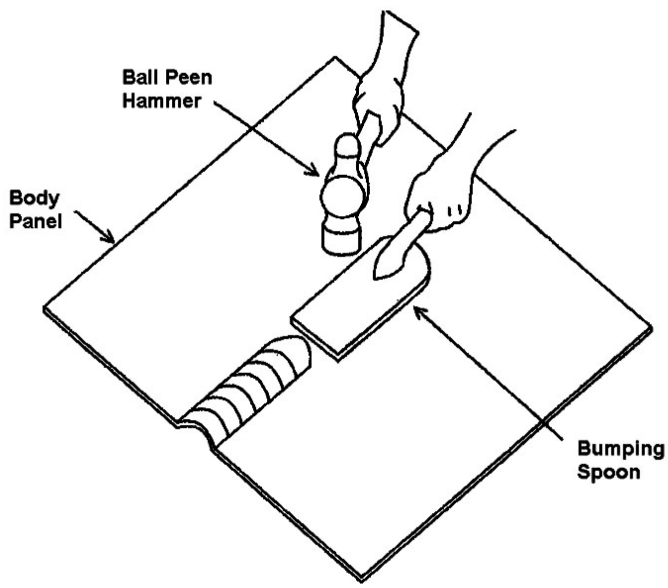


Figure 1–17. Using the bumping spoon.

As you can see in figure 1–17, the bumping spoon is placed between the hammer and the metal. As the hammer hits the spoon, the impact of the blow travels over the area of the spoon in contact with the metal. Use a ball-peen hammer for this work (*never use one of your good bumping hammers*). As you work, hold the handle of the spoon with a light grip so your hand will not resist the movement of the spoon when you strike it with the hammer. The shape of the bumping spoon crown determines its use.

Use the flat, low-crown spoon (fig. 1–16, View A) when working high-crown or combination high- and low-crown areas. These areas are ordinarily stiff and require considerable force to relieve the distortion caused the buckle.

Use a high-crowned bumping spoon (fig. 1–16, View B) for straightening buckles in low-crowned areas. The metal on either side of the spoon is normally springy and not stiff, like it is with high-crown panels.

The high-crowned spoon is in contact with only a small area and directs the impact of the hammer blow on it. In contrast, the low-crowned spoon contacts a large area and has a tendency to spring the entire buckle.

The following are two things to remember about using bumping spoons:

1. Start at the point of least distortion when using a spoon on any buckle.
2. Do not use a bumping spoon on a buckle that forms a ridge.

Body spoons

Body spoons, while quite heavy in comparison to bumping spoons, are multi-purpose tools. You can use them as a dolly block, driving tool, or pry tool. You normally use the body spoon on the underside or inside the panel as a pry tool or as a dolly block. However, you *never* use the body spoon to repair a panel if you can apply a dolly block to the inner surface. You can straighten a panel better and faster with a dolly block. Using the body spoon requires more skill than using the bumping spoon.

There are many body spoons available for repairing body damage, but they are too numerous to discuss each one separately (and we do not have the space). The main thing to remember is that you must choose the spoon that can correctly accomplish the body repair most effectively. To give you an idea of what we are referring to, let us focus on two of the body spoons. Figure 1–16, View C shows a pry spoon with a long, thin curved blade. You can insert this spoon into very narrow spaces to pry out dents. However, the pry spoon is not intended to serve as a dolly block because of its lightweight construction. The spoon in figure 1–16, View D is a general-purpose body spoon that may be used as a dolly block or a pry tool. This spoon is sometimes called a turret-top spoon because of the long working face, which you can insert between the roof rail and the roof panel.

Caulking irons

The caulking iron is another tool, which is very important in the body shop area. Caulking irons are used to straighten auto body sheet metal. While there are many different caulking irons, we will focus on the two most popular: the basic caulking iron and the offset caulking iron.

Basic caulking iron

The basic caulking iron (fig. 1–18, View A) looks like a blunt, wide-blade chisel. Use it for straightening and reshaping short-radius bends on narrow, flat surfaces such as a pillar post (fig. 1–18, View B).

Offset caulking iron

The offset caulking iron is shown in figure 1–18, View C. Note that it curls in opposite directions at each end. Look closely at each end and you will see a heavy, built-up area where the hook opening starts. This is where you strike the tool with the hammer once you hook the end on the flange that needs straightening.

As previously mentioned, your shop may have a variety of these tools for your use. Your own experience will reveal which one works best.

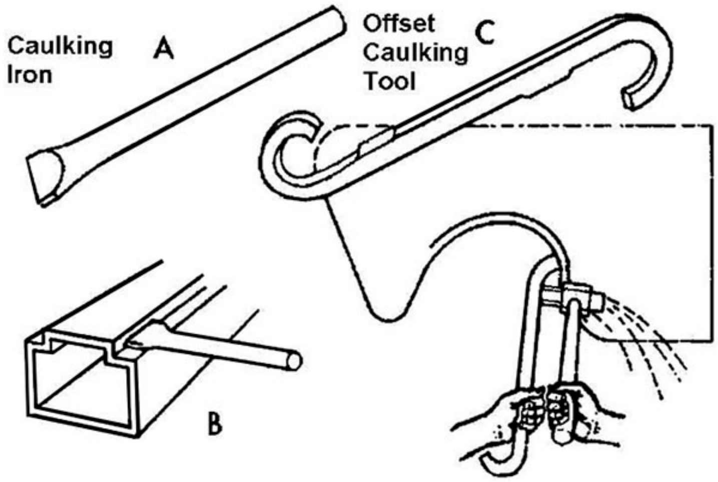


Figure 1–18. Caulking tools.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

603. Repair hammers

1. What three types of hammers do you use in body repair?

2. Which hammer spreads the force of impact over a large area?

3. Which drawings in figure 1–10 show the correct use of a bumping hammer?

4. Which hammer do you use to prevent overstretching a metal surface?

5. What is the purpose of pick hammers?

604. Dolly blocks

1. Should a dolly block weigh more or less than the hammer you are using?

2. How do you hold the bumping hammer when using a dolly block?

3. What method do you use to increase the size of an area if you place the dolly block directly under the point where the hammer will strike?

4. Which method specifies that you place the dolly block close to but away from the area where the hammer will strike?

605. Repair spoons and caulking irons

1. Describe the construction features of a spoon.

2. How is the bumping spoon best used?

3. What spoon do you use for straightening buckles in low-crown areas?

4. What three auto body tools may be replaced by a body spoon?

5. When can you use the basic caulking iron?

1–3. Identifying and Repairing Collision Damage

Now that you are familiar with vehicle body construction, we will consider how to break the body components into three sections and the common tools used for their repair. First, let us look at the types of damage and some common repairs.

606. Identifying collision damage

During an auto accident, at the time of impact there is a sequence of events, resulting in damage to the auto body. This damage is normally in the form of crumpling, creasing, or ripping. In repairing damaged components, you will have to identify the sequence of damage and conduct repairs in reverse order.

Sequence of events

A slow-motion video of a collision damaging a body panel would reveal this sequence:

1. A minor dent starts to push in at the impact point of the colliding objects.
2. As the impact continues, a larger area of the metal panel caves in.
3. At the same time this larger area caves in, a ridge buckles at the extreme edge of the cave-in. (This happens because the crown or arch of the metal must go somewhere. It normally kinks or buckles up at the outer edge of the cave-in because it cannot collapse or telescope.)
4. As the colliding object moves further across or deeper into the body panel, the buckled-up ridge travels ahead in much the same way a wave travels ahead of a boat.

5. As the collision reaches full intensity, this high ridge remains kinked up (locked) and becomes the extreme outer rim of the damaged area.
6. As the impact slows and stops, the damaged area springs back slightly but remains inflexible because of the locked ridge and inverted V-channels.

The various ridges and channels created by the collision's impact block the repair of damage. You cannot properly repair the damage until you relieve the major strains in the locked ridges.

Body damage

When a vehicle is involved in a collision, the force of impact spreads from the impact area throughout the panel involved and possibly into other panels. This creates damage by changing the shape of the affected areas. When you make a detailed examination of the damaged body area, you will normally find a combination of displaced areas, upsets, stretches, simple bends, and kinks or buckles. The damage to any panel is one or a combination of these conditions, and depends on the severity of the impact. These conditions are described in the following table.

NOTE: You will also find tears or rips, but these are not basic conditions and we will not consider them here.

Body Damage	
Type	**Description**
Displaced Areas	Ordinarily, checking any panel damage reveals that bending, buckling, or other distortion does not affect the entire panel. Some areas considered part of the damage have simply been pushed out of position. An elastic strain may be holding them in the displaced position. If you release this strain, the area snaps back into shape. To help in planning repairs, learn to recognize displaced areas. If you properly remove the buckles holding them out of place, you can release large displaced areas with very little repair work.
Upsets	An upset occurs when opposing forces apply pressure to an area of metal and cause it to yield. As the surface area reduces, the thickness increases proportionally. The forces causing an upset may come from two opposite directions or from several directions. An upset has a gathering or drawstring effect on the adjoining metal, particularly in a low-crown section.
Stretches	A stretched area is the exact opposite of an upset area. Tension, instead of pressure, causes stretching. This results in an increase in surface area. Metal is considered stretched whether the increase in area is caused by an increase in length, width, or both.
Simple Bends	A simple bend is an area of metal that serves as a pivot for movement without breaking. To understand this process, picture what happens when you take a piece of soft wire 3 or 4 inches long and bring the ends together while attempting to keep the two halves the same length. The halfway point between the two ends—the pivot point—is a simple bend. As bending occurs, you apply tension (stretching) to the outside of the bend and compression (upset) to the inside.
Kinks or Buckles	A kink is a bend of more than 90 degrees (°) within a 3-millimeter (mm) distance. Kinks or buckles are the result of a severe bend where the metal buckles or kinks up at the pivot point (fig. 1–19). The upper portion of figure 1–19 shows an undamaged panel, and the lower portion shows the same panel after receiving damage. As the damage occurs, the crown caves in and a simple bend forms at the point of impact. However, the most damage the panel receives is the kinked-up ridge near the end of the panel away from the impact area. This is where the metal buckles up above the original arc. If you do not use the proper procedure in removing this kinked-up ridge, a small kink will remain after you straighten it.

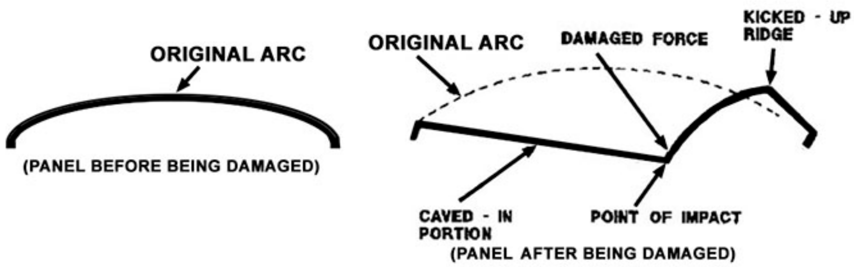


Figure 1–19. Simple damage.

Repair sequence

Before you can remove this series of distortion, you must locate all irregularities through sight and feel. Experience is the best teacher for this procedure. In essence, you must determine the sequence in which the damage occurred. Follow these steps:

Sequencing Repairs	
Step	**What To Do**
1	Prior to removing any distortions a body panel has received in a collision, determine the direction the damaging force came from and the point of impact. This indicates the sequence in which the distortions occur.
2	The last distortion to occur is the first distortion you remove. Notice the kinked-up ridge in the right corner of figure 1–19. This is where you must start the repair work. You must release this ridge and bump it down to its original arc (note the dotted lines). If you do this, you can begin work on the cave-in portion. Start at the point farthest from the point of impact. In figure 1–19, you start at the far left and work your way to the right.
3	The point of impact, where damage first occurs, is the last part you repair. Failure to use this reverse-order process may result in stretched metal, cracks, breaks, or additional unnecessary work.

607. Metal bumping and shrinking

In this lesson, we will look at the methods used in repairing the damaged areas of an auto body. Once you establish the correct repair sequence, you must then use the proper method in each step. Here we will discuss several methods, beginning with metal bumping as it is the most widely used repair method. In addition, we will discuss several methods for removing low spots. Since you need to be familiar not only with the correct methods to use but also with the incorrect methods to avoid, our discussion includes both. Almost any damaged body panel has some stretched areas that require shrinking; therefore, we will also cover the proper procedures for shrinking damaged metal surface areas.

Metal bumping

After you inspect and analyze the extent of the damage, the next step in body and fender repair is metal bumping. This action is best described as lowering the metal where it is raised, and raising the metal where it is low. Be sure to follow step-by-step procedures during bumping operations. If bumping is done carelessly or hurriedly, new lines of strain occur, stretching and bending the metal. Before beginning the bumping operation, always clean the metal to help remove any dust and grit that might otherwise stick to the face of the bumping hammer. Further, clean any tar, dirt, or undercoating from underneath the panel you are going to straighten. If you do not, this material may cause the panel to stretch during the repair operation. We will discuss the correct metal bumping procedures first, and then we will talk about the results of incorrect metal bumping.

Correct bumping procedures

Bringing the raised metal down first is very important. If you do this carelessly, the metal stretches and bends at such sharp angles that further correction is very difficult. For a better understanding of why you bring down the raised metal first, look at the damaged panel cross section in figure 1–20:

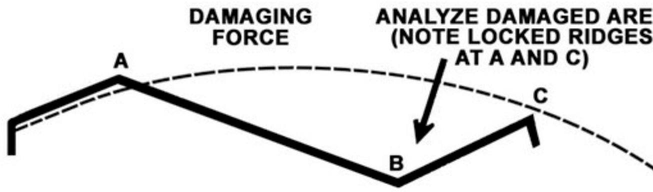


Figure 1–20. Correct bumping procedures.

- The dotted line indicates the original contour of the panel.
- A indicates the extreme outer rim of the damaged area.
- B indicates the point of impact.
- C indicates the flanged edge of the panel that is bent into a sharp angle.

Both points "A" and "C" in figure 1–20 are considered locked. The arrow indicates the direction of the colliding object. To repair this damage, take the steps presented in the accompanying table and follow along with figures 1–21 through 1–23:

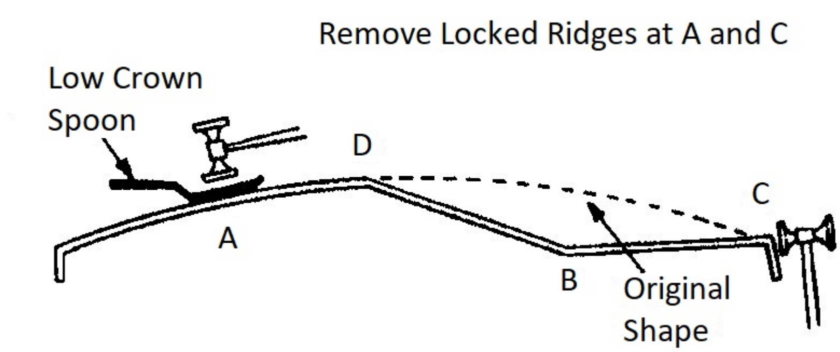
<table>
<tr><th colspan="2">Repairing Damage to Metal Components</th></tr>
<tr><th>Step</th><th>Procedures</th></tr>
<tr><td>1</td><td>Unlock the strain on the outer rim at point "A" (the last ridge to buckle up at the time of collision).
• You can unlock this strain by placing a low-crown bumping spoon on the ridge and striking the spoon sharply with a hammer.
• Direct the hammer blows straight at the ridge. This starts bringing the high metal back toward its original location.
• As you complete this operation, the metal at point "A" should be in the position shown in the figure 1–21.


Figure 1–21. Correct bumping procedures.</td></tr>
<tr><td>2</td><td>Remove the ridge at point "C": in a similar manner.
• The V-channels in figure 1–21 (between points D and B and B and C) are unlocked and ready to spring up to normal shape with very little help.
• You can accomplish this by bumping from the inside with a low-crown dolly block using two or three hammer blows (proceed from point D to B).
• This bumping action unlocks the kinked metal at the bottom of the V-channel DB.</td></tr>
</table>

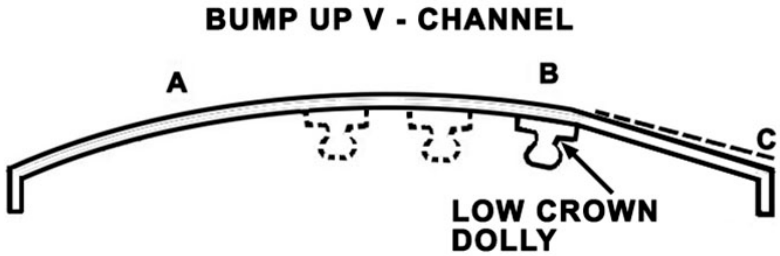
<table>
<tr><th colspan="2">Repairing Damage to Metal Components</th></tr>
<tr><th>Step</th><th>Procedures</th></tr>
<tr><td></td><td>The metal should now look like figure 1–22.


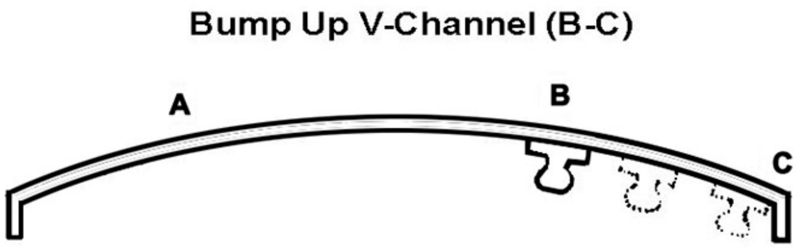
Figure 1–22. Correct bumping procedures.</td></tr>
<tr><td>3</td><td>Repeat the bumping-out procedure between points B and C.
• Begin the hammer blows near point C.
• Progress inward along the V-channel toward point B.
• The metal should now look like that in figure 1–23.


Figure 1–23. Correct bumping procedures.</td></tr>
</table>

The preceding steps illustrate what happens when you use the correct bumping procedure to repair damage to metal components. The metal simply flexes back to its original shape.

Incorrect bumping procedures

Bumping out body damage without first releasing the locked ridges is shown in figure 1–24. Notice how someone bumped out the caved-in metal by striking the underside at Y with a dolly block (fig. 1–24). This action forces up a large area of the dent to approximately its original shape. However, note that the strain in the ridge X has not been unlocked. This pulls the panel down abnormally between X and the extreme left of the body panel. Notice that the ridge X does not come down to its original location. This happens because the locked ridge X reinforces and strengthens the metal on either side of it. If you apply force upward at Y, the ridge acts as a fulcrum, pulling the metal down at the extreme left of the body panel. If you start bumping out the metal without releasing the locked ridge, the metal stretches to rise to its original level (shown by the dotted line).

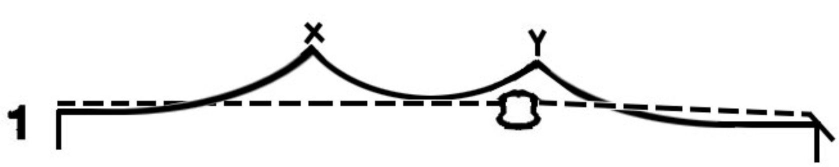


Figure 1–24. Incorrect method for repairing body damage.

Now you must use excessive force to bring it up, which causes humps and knots wherever you strike it with a dolly block (note the small humps above the dolly blocks in figure 1–25.) Equalizing all these humps and knots requires a lot of work.

Figure 1–25. Incorrect method for repairing body damage.

In figure 1–26, notice that the dent has been bumped out and the hammer and dolly are in place to start smoothing out the metal surface. In figure 1–27, the panel is again smooth, but it is a new shape. Not only has time been wasted in unplanned bumping, but the metal has also been stretched from the original contour (shown by the dotted lines). As a result, the entire width of the panel requires metal finishing.

Figure 1–26. Incorrect method for repairing body damage.

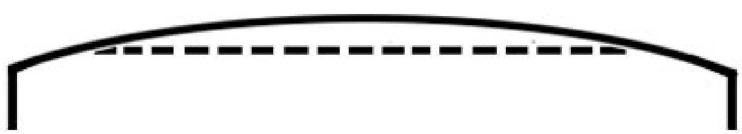


Figure 1–27. Incorrect method for repairing body damage.

Removing low spots

After bumping out minor body damage, you may have to raise some low spots in the metal surface. While there are several ways to do this, the following table provides a few to consider.

Removing Low Spots	
Method	**Description**
1	You can remove some low spots by striking the underside of the panel with a dolly block. • In this case, the dolly block is the striking tool. • As you use a dolly block in this manner, make sure you have the right dolly block crown for the panel you are repairing.
2	You can remove low spots by using hammer-and-dolly combinations. Use either the hammer-on-dolly or the hammer-off-dolly methods discussed previously.
3	You can remove small low spots by using the pick hammer, as shown in figure 1–28. It illustrates how to use a pick-end hammer with a sharp point to raise a very small low spot. **NOTE:** The line marked “after” shows a small knot-like dent after being struck with the pick hammer. • Use a body file to file down these knot-like dents level with the metal surface. • Be careful repairing body panels using a pick-end hammer with its sharp point. If you create a knot-like dent that is too high, you may end up with a hole or soft spot in the metal after you file it down.

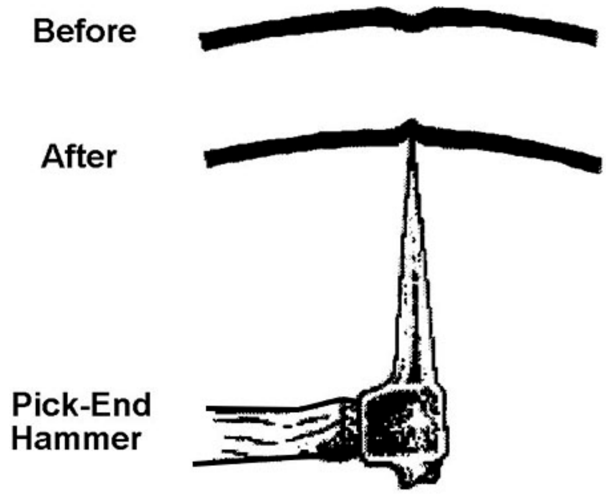
<table>
<tr><th colspan="2">Removing Low Spots</th></tr>
<tr><th>Method</th><th>Description</th></tr>
<tr><td></td><td>

Figure 1–28. Using a pick-end hammer.</td></tr>
<tr><td>4</td><td>You can raise a low spot by the use of a round-end hammer, as shown in figure 1–29. Compare the “before” line in this detail with the “before” line in figure 1–28. Notice how much larger the low spot is in figure 1–29.

Use the round-end hammer if you have more metal to raise. In the “after” line (fig. 1–29), the knot-like dent is much larger than the “after” line of figure 1–28.
Normally, you do not file down a knot-like dent of this size; instead, you use the bumping hammer to complete the repair.
Be sure you support the panel on the underside with a dolly block.
Be careful you do not stretch the metal too much when using the hammer and dolly block because this only causes extra work shrinking the overstretched metal.

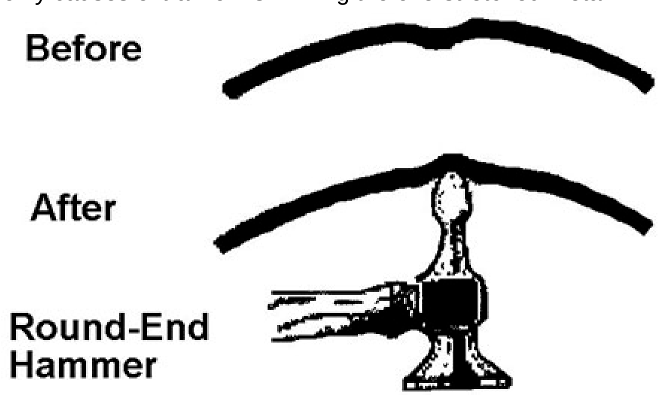


Figure 1–29. Using a round-end hammer.</td></tr>
</table>

Metal shrinking

Sometimes you may stretch a body panel too much from hammering or the panel receives collision damage that requires metal shrinking. There are two methods you can use for shrinking metal: cold shrinking or hot shrinking.

Cold shrinking

You can release a stretched area by forming a groove across it with a cross-peen hammer and a shrinking dolly (fig. 1–30).

Make this groove as described in the following steps:

1. Hold the shrinking dolly underneath the stretched area.
2. Use a cross-peen hammer and strike the metal exactly over the groove formed in the dolly block (fig. 1–31). Since the cross-peen of the hammer is slightly smaller than the groove in the dolly, you stretch the metal and drive it into the groove. The line representing the surface metal is shown in figure 1–32. Figure 1–33 shows how this groove looks on the fender or other panel of an automobile.

Figure 1–30. Shrinking dolly.

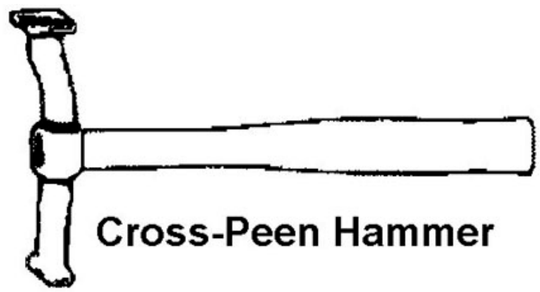


Figure 1–31. Cross-peen hammer.

Figure 1–32. Metal formed into groove.

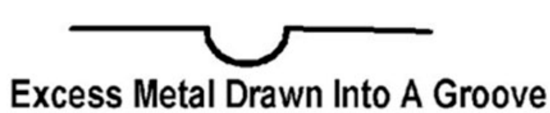


Figure 1–33. Shrinking groove on body panel.

3. If another groove is necessary, form it at a right angle to the first groove (fig. 1–34).
4. After you complete work on the panel and it is ready for finishing, fill these grooves with filler.

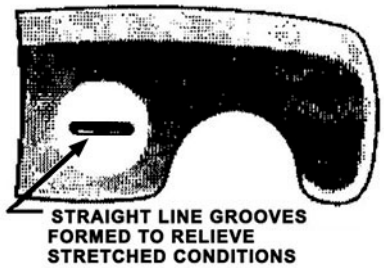


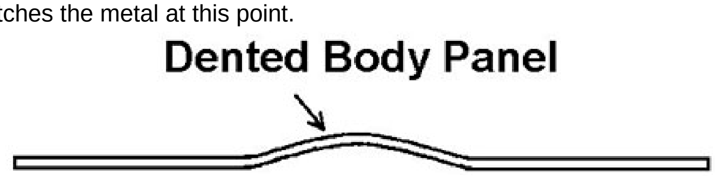
Figure 1–34. Shrinking grooves on body panel.

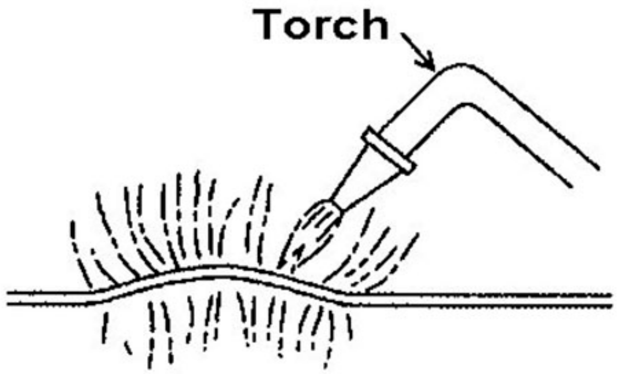
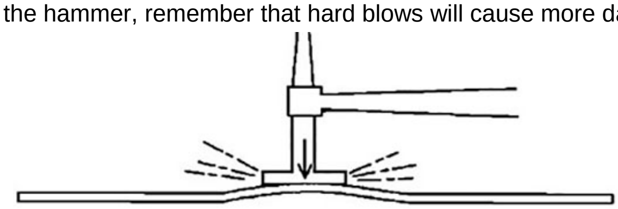
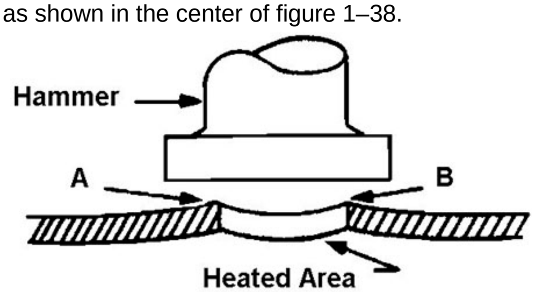
Hot shrinking

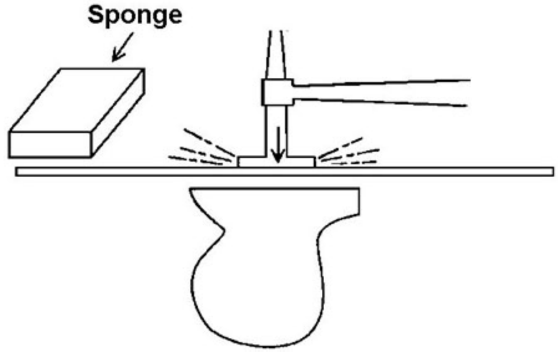
This process requires good timing to accompany proper tools like the following:

- A welding torch.
- A flat-faced hammer.
- A dolly block.
- A sponge with water.

On the welding torch, use the same size tip that you would use for welding metal of the same thickness. The hot shrinking process is accomplished by following the steps in the accompanying table.

Hot Shrinking	
Step	**Procedure**
1	Locate the dent on the body panel (fig. 1–35). Whatever object collides with the body panel normally stretches the metal at this point.  **Figure 1–35. Dented body panel.**
2	Heat a spot about the size of a nickel on the high-dent area to a cherry red. • Move your torch in a circular motion. • Be very careful not to burn through the metal. • As the stretched area expands from the heat, the red spot rises to a peak (fig. 1–36).

Hot Shrinking	
Step	**Procedure**
	 **Figure 1–36. Heating dent with torch.**
3	As soon as you form this peak, strike it with the flat-faced hammer (fig. 1–37). • You do not have to place a dolly block under the body panel, but the dolly lessens the chance of further damage. • While using the hammer, remember that hard blows will cause more damage.  **Figure 1–37. Striking heated dent.** The hammer blow upsets the hot metal and shrinks it, leaving the center of the heated spot in the shape of a crater, as shown in the center of figure 1–38.  **Figure 1–38. Upsetting heated metal.** This figure illustrates why it is important that the hammer face be larger than the heated spot. You first strike the center of the hammer face against the peak of the heated spot and drive it down level with the cooler metal. The outer part of the hammer face strikes the cooler metal forcing the metal into the crater, making the center of the heated metal thicker as shown in points “A” and “B” in figure 1–38.
4	Take a dolly block and bumping hammer and bump this area smooth (fig.1–39). After four or five hammer blows, the heated spot will turn black and is ready for quenching.

Hot Shrinking	
Step	**Procedure**
	 **Figure 1–39. Smoothing and quenching the heated dent.**
5	As the heated spot turns from red to black, immediately quench it with a wet sponge. Quenching cools the hot metal quickly, reducing the possibility of annealing (softening) the metal. It also helps shrink the metal.

NOTE: *Never heat a larger area than necessary*. Doing so increases the risk of metal losing its rigidity and strength.

Dent pulling methods

Some simple dents may require you to use a pulling force to remove them. This is because the panels needing repair will have reinforcements behind them. Consequently, you will not be able to get any tools into the areas needed to act as the anvil for a striking force. The two recommended methods are suction cups and stud spot-welding.

Suction cups

This is one of the easiest and quickest ways to remove shallow dents. You wet the area and install the suction cup, whether hand-held or vacuum assisted.

Hand-held suction cups

When using one that is hand-held, pull back on the suction cup handle. If mounted on a slide hammer, use a quick blow to pop out the dent.

Vacuum-assisted suction cups

To remove larger, deeper dents, you can use a vacuum-assisted suction cup. This is a small pump powered version of the hand-held suction-cup; the pump creates the vacuum as it gently pulls the suction cup against the panel. Attached to a handle, simply pulling back on the device pulls on the suction-cup, pulling out the dent.

Stud spot-welding

This method involves spot-welding studs to key locations within dented areas; using a slide hammer facilitates systematically pulling the panel back out to the desired form. While this method may be accomplished by welding a piece of welding rod to the panel, it is more easily performed by using a stud spot welder. The stud spot welder kit comes with all the necessary tools and directions to complete this type of repair.

NOTE: The suction-cup and stud spot-welding methods enable you to pull dents without drilling holes for screws or other pulling devices.

608. Component repair

Most auto body repairs involve damaged fenders. The majority of these repairs can be made with the hammer and dolly block. Others may be so severely damaged that a hydraulic body jack and attachments must be used first to restore some of the original shapes and contours. Even more severe damage requires removing and replacing the fender.

Look at the exploded view of a typical front-end assembly (fig. 1–40). This illustrates the construction and gives you an idea of what is involved in removing and replacing these components. Typically, this is a "nuts and bolts" operation—remove enough nuts and bolts and the component comes off. In fact, the entire front-end sheet metal structure can be removed as one unit. In this lesson, we will look at the procedures used to repair the fenders, grilles, hoods, and other body components.

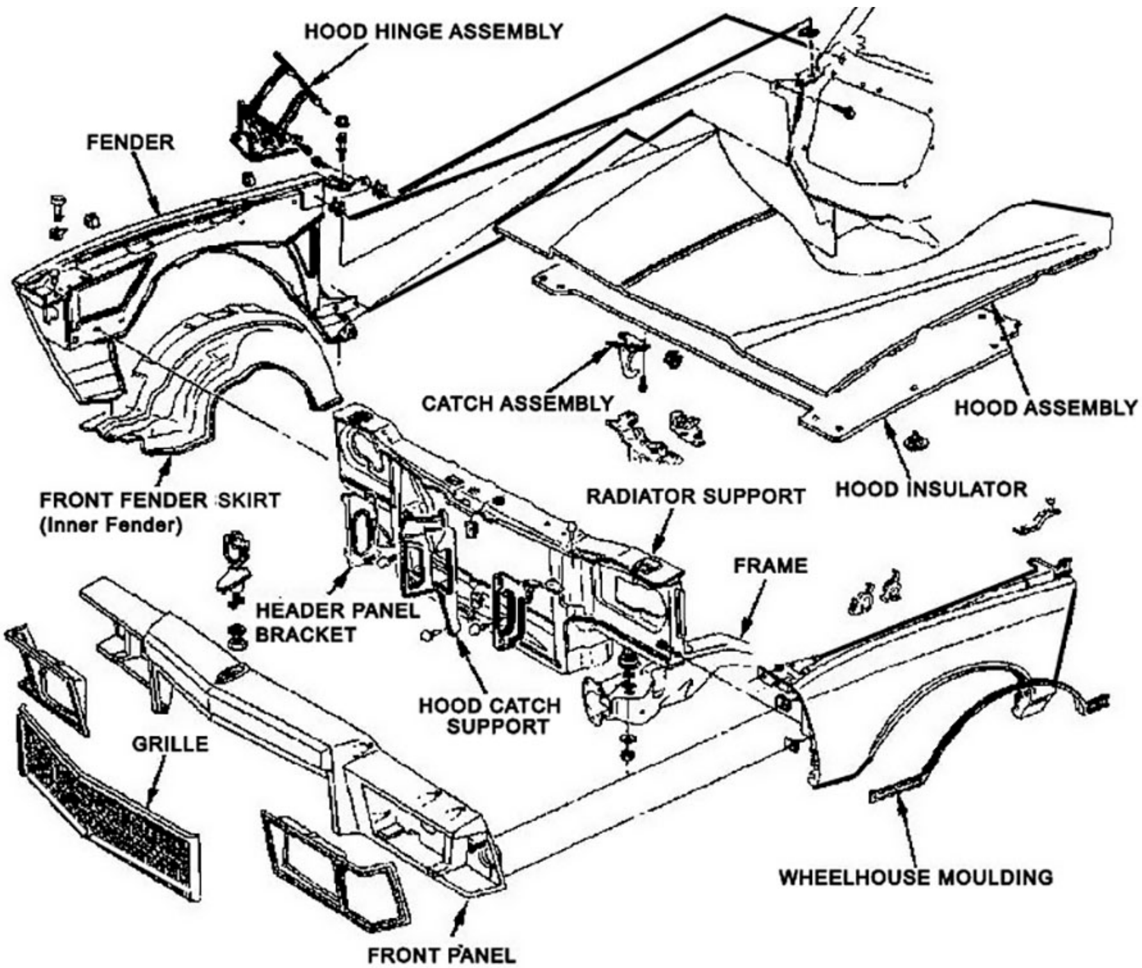


Figure 1–40. Front-end sheet metal.

As you progress through this lesson, you will encounter the term "X-check". X-checking is a measurement technique that involves taking measurements between control, or reference, points. The best control points are usually fixed and easy to precisely locate, such as corners, distinct joints, or bolt holes. Since most vehicle bodies are symmetrical, with the left and right halves being mirror images of one another, taking measurements and comparing them to corresponding dimensions on the opposite side can help to reveal damage and aid in aligning components. X-checks can also be performed on individual components or panels that are symmetrical; for instance, a hood or trunk lid.

Fenders

You can use the hydraulic body jack and attachments to push or pull a damaged fender. After the pushing-out (or pulling-out) operation, the remainder of the repair work consists of metal straightening and finishing operations. As we stated previously, always place the stationary end of the body jack on a solid part of the vehicle as you use it for pushing or pulling operations. A good solid part on the vehicle is the frame or axle; these parts are less likely to bend or bow during a straightening operation.

Notice that the front fenders bolt to the radiator support at the front and to the front of the vehicle bulkhead at the rear (fig. 1–40). The fenders receive strength from fender braces, splash panels (fender skirt in the illustration), and other supporting parts. Holes for the fender attaching bolts are normally elongated so you can move the fender either forward or rearward during the installation process. Proper alignment of the front fenders is very important because the hood and doors will not fit/operate properly if either fender is out of alignment. If you loosen the attaching bolts, the fender is not too difficult to reposition due to the elongated attaching holes.

In this particular example and many other vehicle applications, the hood hinge is mounted to the fender. For this reason, it may be best to remove the hood before removing the fender—but it is not necessarily required. The four easy steps to removing fenders are listed in the following table.

Four Easy Steps to Remove Fenders	
Step	**Procedure**
1	Remove fender bolts from hood-hinge assembly (fig. 1–40).
2	Remove bolts attached to radiator support.
3	Remove lower front and rear fender bolts from front fender skirt.
4	Remove fender.

Replace the fender by holding it in place and repeating the removal steps in reverse order. Simply put, replace the fender by installing the bolts that hold it in position, being careful that you have properly aligned the fender to ensure a good fit with the hood and doors of the vehicle.

Grilles

The grille (fig. 1–40) is normally the largest single unit of trim on the exterior of the vehicle body and sometimes consists of several parts. On most vehicles, it is made of high-impact plastic and is normally replaced when damaged. In many front-end accidents, grille damage is typical and may require replacement though there are some adhesive repair methods for minor problems. Again, removal is a nuts-and-bolts operation. The grille is typically secured with small screws, bolts, or plastic fasteners, which are reached from the backside of the grille. Since the grille can be adjusted to a small degree within its mounts, adjust it to present the best appearance whenever you replace the grille.

Hoods

Normally, minor hood damage is removed with a hammer-and-dolly block without removing the hood from the vehicle. However, most hood damage repair is much easier when you remove the hood (again, a nuts-and-bolts process) and place it in a holding device. For severe hood damage, you can use power equipment such as a hydraulic body jack. Once you have repaired the damage, you can reinstall the hood on the vehicle. A key part in reinstalling is aligning the hood.

Misalignment of the hood can come from radiator support, front panel, fender, or hood repairs. Ordinarily you can detect this misalignment by observation.

Look at how the closed hood fits at the hinge points and at the hood catch and latch (fig. 1–40).

A Properly Fitting Hood	An Out-of-Alignment Hood
• Opens and closes easily. • Presents a smooth contour in relation to the adjoining sections (front panel or front fenders). • Matches the contour of the cowl panel perfectly. • Has a uniform gap along each side for its full length.	• Has some places higher or lower than the surrounding panels.

To determine if the hood or hood opening is out of alignment, X-check the hood and the hood opening with a tram gauge, which is sometimes called a trammel.

- If the hood opening is out of alignment, you may need to align the front fenders or the front panel.
- If adjusting the front fenders does not help the alignment, you can correct it by using a hydraulic body jack.

To correct an improper fit of the hood at the radiator support:

- Loosen the attaching bolts holding the front-end sheet metal.
- Push or pull the radiator support with the hydraulic body jack.

Sometimes you may have to use shims to get the clearance you need between the hood and the grille panels.

You can also adjust the hood by adjusting its hinges either forward, rearward, and up or down.

- Loosen the attaching hinge bolts.
- Move the hood to the position you need.
- Retighten the bolts.

Other body components and panels

Much that is involved in repairing some vehicle body components such as doors, deck lids, center pillars, and rocker panels is similar: knowing how to repair a body panel or section. This is the common element in our discussion of these topics: removing, replacing, and fabricating panels; repairing doors; removing and replacing deck lids; repairing center body pillars; and repairing rocker panels.

Removing, replacing, and fabricating panels

Occasionally components may be so extensively damaged that you cannot repair them using the methods previously described. If this occurs, you may need to replace a complete panel or a portion of a body panel.

Removing, Replacing, and Fabricating Panels	
Step	**What To Do**
1	Straighten the damaged panel as closely as possible to its original shape. Doing this prior to making measurements allows you to make actual measurements that are more accurate and helps determine the exact amount of body panel to cut out.
2	Measure the damaged section from specific points before cutting it out. • Measure from a molding or the bead of a weld. • Make the same measurements on the replacement panel.
3	Cut replacement panel next to ensure closest possible fit.
4	Use the replacement panel as a template:

<table>
<tr><th colspan="2">Removing, Replacing, and Fabricating Panels</th></tr>
<tr><th>Step</th><th>What To Do</th></tr>
<tr><td></td><td>

- Place the replacement panel *over* the damaged section (fig. 1–41).
- Mark the body panel to use as a cutting guide (fig. 1–42).

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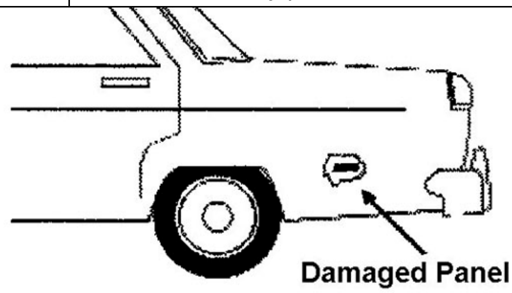

Figure 1–41. Damaged panel.

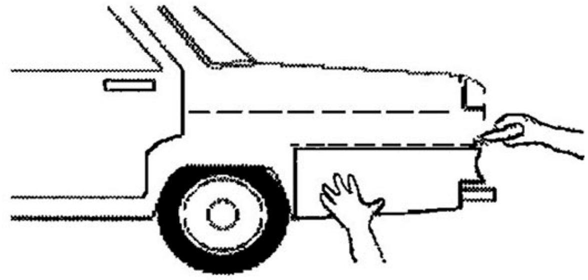

Figure 1–42. Marking damaged panel.

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<tr><td>5</td><td>

Cut the marked area (fig. 1–43) using a nibbler or power saw.

- To help the sawing, drill a hole at the corners of the scribed (dotted) lines.
- Make the hole large enough to insert a saw blade or the cutting blades of a nibbler.

NOTE: Using a cutting torch for panel replacement is not always advisable. It leaves ragged edges and may overheat the surrounding metal. In addition, applying too much heat may distort the metal, which causes a poor fit and additional unnecessary work.

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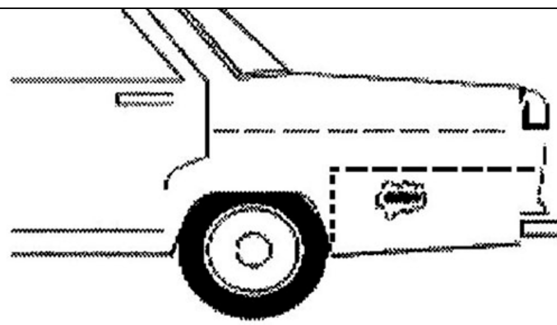

Figure 1–43. Portion of damaged panel to be cut.

</td></tr>
<tr><td>6</td><td>Remove any overlapping edges on the body and replacement panels. This makes it easier to blend in with the contour of the panel for finishing the repair.</td></tr>
<tr><td>7</td><td>

Install the replacement panel.

- Use the gas metal arc welding (GMAW) welding process (described later).
- Stagger the welds from one side of the panel to the other.
- Complete a continuous weld around the entire panel.

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</table>

The action in step 7 can help reduce distortion of a welded replacement panel. In addition to the foregoing, be careful that you do not apply too much heat in one area and cause excessive distortion of the metal.

The entire welding panel finishing operation is shown in the following figures. The weld bead is shown in figure 1–44. Recessing the weld below the surface (fig. 1–45) is achieved by using a shrinking dolly block and hammer.

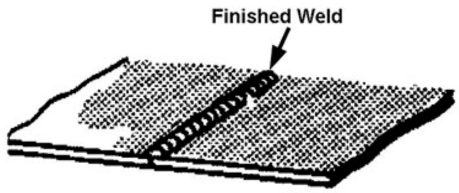


Figure 1–44. Weld bead.

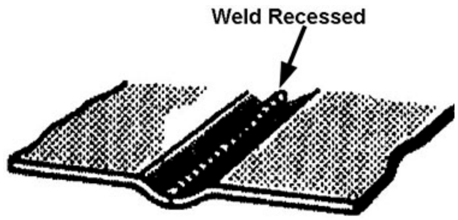


Figure 1–45. Weld recessed.

NOTE: You can use a disc sander and body file to grind the weld down. With this method, you must be careful not to take too much metal off the body panel and bead of the weld. If you do, you weaken the joining metals and may cause them to crack or separate.

How the metal surface contour should look when the process is complete is shown in figure 1–46. The important point to remember is that the initial step of metal finishing determines how well your replacement panel will look after you finish it. To be successful, you must file the adjoining metal surfaces smooth, they must be level, and you must produce the correct contour.

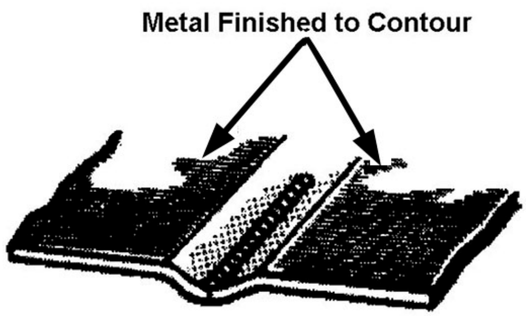


Figure 1–46. Metal finished to contour.

NOTE: Do not try to hide sloppy welding with filler because it always shows up after you finish the product.

Doors

Door repair normally involves any one or a combination of these tasks:

- Repairing dents and creases.
- Removing and replacing the door-locking and window-raising mechanisms.
- Straightening and aligning the entire door.

When repairing a door, it is a good idea to remove the damaged door and place it in a holding unit. The holding unit provides a firm, solid grip on the door and makes your job easier.

Occasionally, you must separate the outer panel, called a skin, from the inner construction of the door to make the necessary repairs. For example, if the outer panel is damaged beyond economical repair, replace it with a new outer panel (skin).

This is advisable only if the inner panel and construction are repairable or undamaged. If the inner panel is not repairable, replace the entire door with a new one. To separate the inner construction, take the steps indicated in the following table.

Removing and Installing a Door Skin	
Step	**What to Do**
1	Remove the door from the vehicle. Put it in the holding unit with the outer edges parallel to the ground.
2	Free the outer edges. Grinding around the outer edges of the door with a portable grinder can help you remove the damaged outer panel from the inner panel.
3	Remove the remaining portion, called the hem flange, with a cold chisel.
4	Tack-weld the replacement panel to the inner panel. Hem-flange the edges like the original.
5	Reinstall the door. • Place the door in the door opening and check for a correct fit. Warping in the middle of the door or a bent top section can cause misalignment. • If you suspect the door is misaligned, check it with the trammel. • If you detect misalignment, use a body jack to straighten the door opening or door.

You can move door hinges enough to correct minor door misalignment. Either the hinges or pillar posts have elongated holes that allow the hinges to be moved in, out, forward, or backwards. Use the fender's lower and upper attaching bolts to align the front fender with the contour of the front door. You may have to add or remove shims on the attaching bolts to get the correct contour.

Removing and repairing deck lids

The deck lid (trunk lid) is held in place by two hinges and a key-lock. The hinges are most likely secured to the body and the deck lid by bolts that have elongated (oblong) holes in the hinges. The easiest way to *remove the deck lid* is to undo the bolts securing the hinges to the deck lid.

To replace a deck lid, follow these procedures:

1. Remove the old deck lid.
2. Make repairs or replace it.
3. Install the new/repaired deck lid.
4. Insert the bolts and loosely tighten them.
5. Adjust as necessary.
6. When the fit is good, secure the bolts thoroughly.

If you are reinstalling a used deck lid, you can use the washer marks left in the paint as a reference point to make a good first-guess estimate of the proper adjustment.

Proper alignment of the deck lid is very important for keeping out water and dust. The lid should fit snugly against all points of the rubber weather stripping. After you repair or replace a deck lid and install it on the vehicle, carefully check for proper alignment and fit. A close look with the lid in the closed position will reveal most defective places around the weather stripping. Nevertheless, to be sure even small problems are eliminated; use the chalk method to locate them. This process is as follows:

1. Rub chalk around the flange of the lid.
2. Close the lid.
3. Then open the lid and check the weather stripping.

The chalk leaves marks on the weather stripping and easily indicates any spots that do not fit. Another good way to check the fit is to close the deck lid on strips of paper and then try to pull them out. If you identify problems with the fit (using either method), adjust the lid and check the fit again.

Repairing deck lids is similar to repairs we have already discussed, especially door repair. Deck lid construction is similar to doors—there is an inner construction for added strength. Working out dents and creases is difficult because some areas can only be reached using a body spoon or a long pick. Sometimes body mechanics cut out the inner construction, straighten the metal skin and inner construction, and then weld it back into place.

A rear-end collision usually damages the deck lid similar to the way a front-end collision damages a hood. The best way to repair this damage is to remove the lid and place it in a holding unit. This not only makes the repair easier, but it also prevents damage to the hinges, or hinge support panels if you use the hydraulic body jack to straighten and spread out dents.

Deck Lid Repairs	
Type	**What To Do**
Straightening	The surrounding panels may also need straightening. You can do this manually or hydraulically. **Manually:** Twist the deck lid by placing a rubber mallet under one side and pushing down on the other side. Use this method sparingly as too much twisting can damage the hinges. **Hydraulically**: Use the hydraulic body jack to straighten the deck lid (fig. 1–47). As you pull both sides, the damaged metal pops back into place and reduces the amount of finishing work. During this pulling operation, use a long-handled pick to pop out small dents.
Spreading Dents	To spread out a deep dent, use a small hydraulic wedge inside the deck lid (fig. 1–48). This wedge, sometimes called a wedgie, is small enough to insert between the outer metal and the inner construction (metal with round holes).

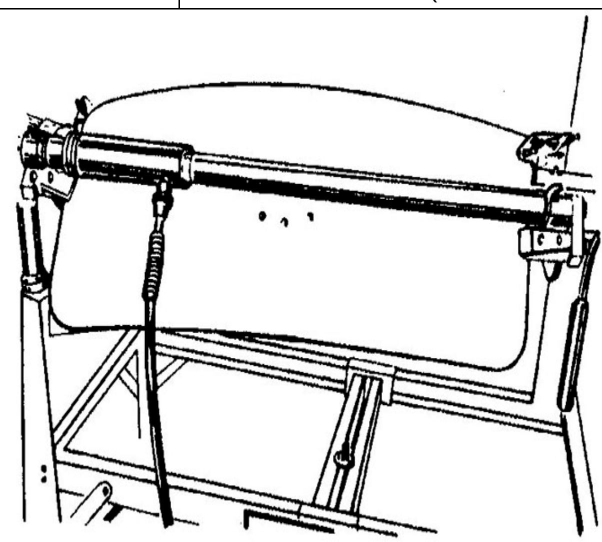


Figure 1–47. Straightening deck lid.

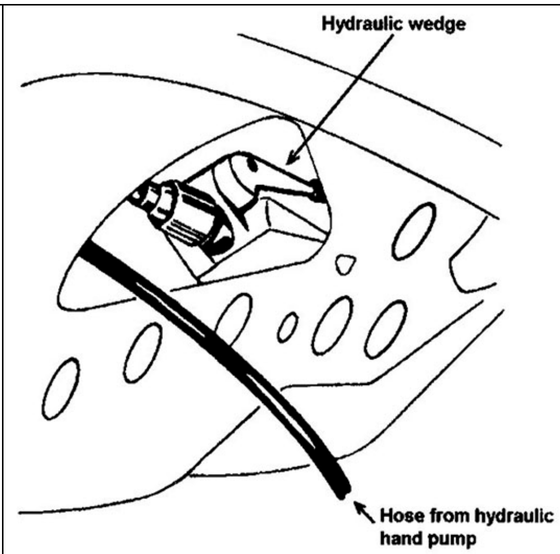


Figure 1–48. Popping out dent in deck lid.

Repairing center body pillars

The center body pillar is an important vehicle section, especially for the four-door sedan. It provides support for the top panel as well as a hinge post for the rear door and serves as a lock pillar for the front door. The center body pillar is made of three pieces of stamped metal spot welded together to form a rigid brace between the rocker panel and the top panel. In this position, it receives a high amount of stress, taking more abuse and shock than any other body section. Because it serves as a hinge post and a latch post for the doors, the pillar alignment must be perfect for the doors to fit their openings correctly.

Center body pillar repairs vary according to the type and amount of damage. Slightly or partially damaged pillars can be repaired by cutting out the damaged section and welding in a replacement section.

You can straighten a center body pillar that bows in or out, but is not severely damaged, with a hydraulic body jack.

Once you have repaired the damage and straightened the pillar, you need to check the curvature. A simple way to do this is to use a template prepared from an undamaged center pillar. Simply compare the repaired pillar with the template to determine the correct curvature. Adjust as necessary until achieving the proper curvature. Then X-check the pillar with a trammel to determine alignment for the door opening.

To Correct A BOWED-IN Pillar	To Correct A BOWED-OUT Pillar
• Fit the hydraulic body jack with a rubber ″flex″ head and extension tubes. • Position it from the middle of the pillar curvature to the bottom of the opposite center pillar. • Apply pressure.	• Cut a piece of channel iron or a thick piece of wood (4 × 4; 4 inches wide and 4 inches thick) the length of the pillar. • Place the iron or timber (wood) on the inside of the bowed pillar post. • Push the bow back into alignment with a rubber flex head and toe attachment (fig. 1–49).

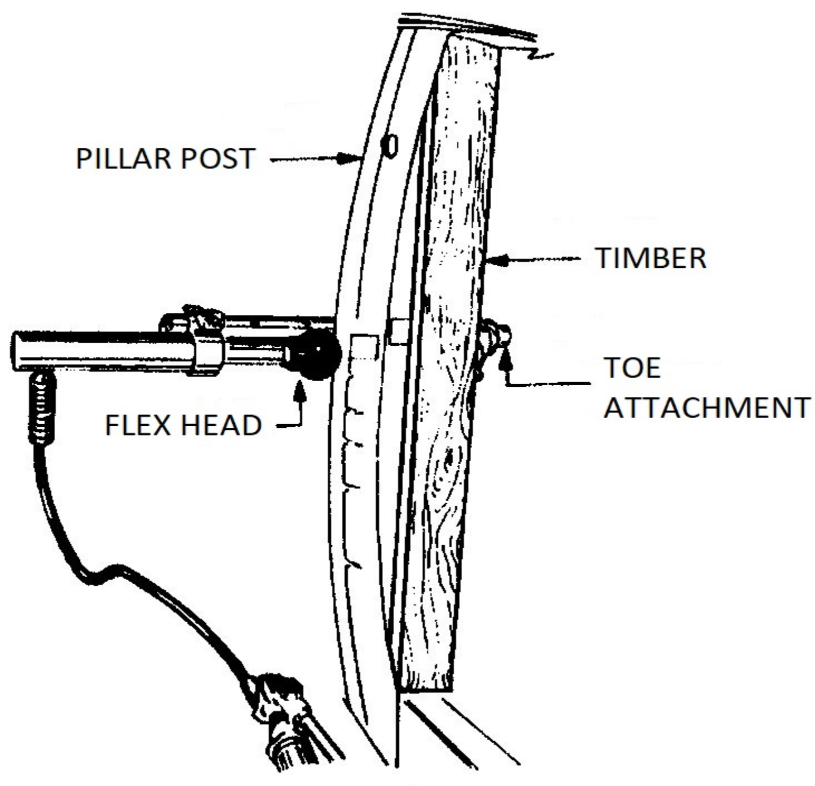


Figure 1–49. Aligning center pillar.

Repairing rocker panels

The rocker panel is used to form the bottom of the door opening, extends from the front to the rear body pillar, and is welded to the vehicle's floor pan. It has a box-like construction (fig. 1–50) with three components: an inside rocker panel, outside rocker panel, and a stile plate (not shown) that covers it in each door opening.

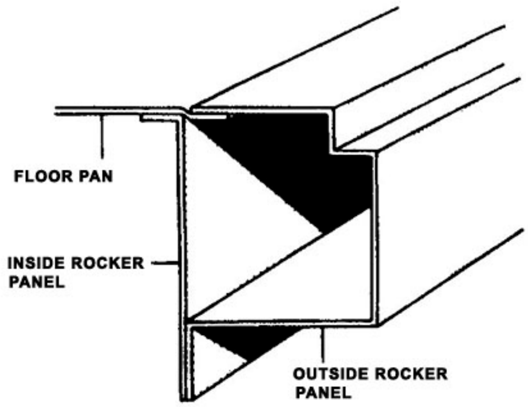


Figure 1–50. Rocker panel.

Straightening rocker panels involves cutting away the outside rocker panel to gain access to the inner panel. If the outer rocker panel receives damage and you cannot straighten it, perform the following to remove it:

1. Use a hacksaw, small rotary saw, or cutting torch for the work.
2. Loosen the points where it is welded to the inner rocker panel, floor pan, and center pillar post.
3. Loosen the welds at both ends.

NOTE: Do not cut or damage the inner panel while removing the outer rocker panel.

Once you have removed the outer rocker panel, continue with these steps:

1. Inspect the inner rocker panel.
2. If it *is not repairable*, replace it.
3. If repairable, loosen the spot welds to the floor pan with a sharp slim-tapered chisel or drill out each spot weld.

Make any necessary repairs to the remaining structure with the rocker panel removed.

If you need to replace the rocker panel, the replacement can be made from sheet metal (using the old one as a pattern) or acquired from the manufacturer. Once you have the replacement panel, hold it in place and make sure the panel fits like the original; then weld it into place.

Performing interim repairs

An interim repair is performed to enable a vehicle to be used until such time as it can be repaired completely. You may encounter situations when only interim repairs must be conducted. An example would be a specialized vehicle that is needed to perform a critical mission. You would perform the minimum repairs necessary to enable the vehicle to perform its mission. The actual performance of interim repairs can vary depending on the damage, the tools, and expertise available. The procedures covered in this unit may all be used to perform an interim repair. A common repair in a deployed environment is to replace badly damaged components with new ones that are left unpainted. You should try to provide adequate corrosion protection. It may be necessary to use aerosol products to protect any bare metal on damaged panels.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

606. Identifying collision damage

1. Briefly, state the sequence of events as they occur when a panel receives damage in a collision.

2. Briefly, describe each of the following damage conditions.

   a. Displaced area.

   b. Upsets.

   c. Stretches.

   d. Simple bend.

   e. Buckle.

3. What must you do before starting to remove any distortions a body panel has received in a collision?

4. What can result if you do not follow the repair sequence?

607. Metal bumping and shrinking

1. Why should you follow step-by-step procedures during metal bumping operations?

2. What should you do to prevent dust and grit from possibly sticking to the face of a bumping hammer during a bumping operation?

3. What can happen if you are not careful to bring down the raised metal first during a bumping operation?

4. What must you do to the knot-like dents raised by using a pick hammer?

5. Briefly explain how you can shrink a stretched area using the cold-shrinking process.

6. What size of torch tip do you use for hot shrinking?

7. Why is it necessary to quench the heated area when you perform hot shrinking?

8. What are the two recommended methods for pulling out dents?

608. Component repair

1. How can you align or reposition a fender?

2. Why is it better to remove a hood when you are repairing panel damage?

3. Describe how you can determine if a hood is aligned properly.

4. Why should you straighten a panel area prior to the measuring operation when replacing/fabricating a panel?

5. Why should you avoid using a cutting torch to cut out a replacement panel?

6. How can you minimize the distortion of a welded replacement panel?

7. What conditions warrant the replacement of a new outer panel on a door?

8. How can you correct minor misalignment on a door?

9. List two methods for checking the fit and alignment of a deck lid.

10. What do you use to determine the correct curvature of a center pillar?

11. What tools do you use to straighten a bowed-in center body pillar?

12. List three tools you can use in removing the outer rocker panel in order to access the inner rocker panel.

1–4. Auto Body Filling

In most instances, you will have to use body fillers after straightening and metal bumping operations. This is especially true if the damage is in an area where you cannot use dolly blocks or spoons. So, what do you use to fill the area—plastic or fiberglass? In this section, we will discuss two important areas: applying body fillers and fiberglass repair.

609. Plastic fillers

We stated you use body fillers after straightening and metal bumping operations, especially when working with steel parts. What is the purpose of fillers? No one can pull out dents in steel parts and return them to the exact appearance before the damage occurred. There are always going to be slight imperfections; therefore, fillers help to reduce surface imperfections. Using body filler is very much an art; while the technique is the same, all repairs are "unique." So making the repair imperfection as insignificant as possible is different each time. This "art" can be learned and applied by following two important steps: surface preparation and the plastic filler application.

Surface preparation

Surface preparation is very important. You need a clean, bright metal surface to ensure good adhesion between the filler and the metal you are repairing. To ensure a clean surface, remove all paint, grease, dirt, and any rust that may have accumulated. Additionally, clean the damaged area as well as the surrounding area with a grease and wax remover. You can create a clean, bright metal surface by scraping, sanding, filing, or disc grinding. You will find that disc grinding is ideal and is the quickest way to prepare the surface for applying the filler. Whatever method you choose, clean the surface about two inches beyond the damaged area. This ensures complete filling as well as good adhesion of the filler.

The disc sander is pneumatically or electrically powered. The disc itself is normally made of hard rubber that flexes very little. However, the more force you exert against the surface, the more the disc flexes. The round abrasive discs (very abrasive sand paper) come in various diameters; as a result, you need to know the actual size of the sander you will use before ordering any discs.

You can find the size in the operator's manual; however, if you do not have the manual, measure across the disc on the sander to see what size you have. The correct disc size is approximately $^{1}/_{4}$-inch larger than the diameter of the sander's disc. This "excess" allows the abrasive disc to roll around the outer edges of the sander and remain in contact with the metal surface after you raise the handle of the sander.

NOTE: The center of the abrasive disc normally has a perforated hole for the retainer stud fastener, which is used to secure both the abrasive disc and hard rubber disc to the sander's power shaft.

Like any other sand paper, the abrasive discs come in various grades of abrasiveness. The coarser discs grind away the metal faster and leave deep marks on the surface. Less abrasive discs grind away less metal and leave a much smoother surface. When using the sander, the correct angle to the metal surface for grinding is approximately 10–20° (fig. 1–51). In other words, when using the sander, $1^{1}/_{2}$–2 inches of the abrasive disc should contact the metal surface at all times (fig. 1–52).

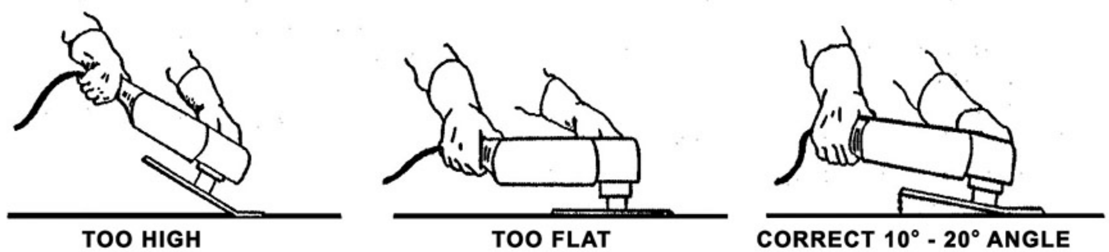


Figure 1–51. Disc sander grinding angle.

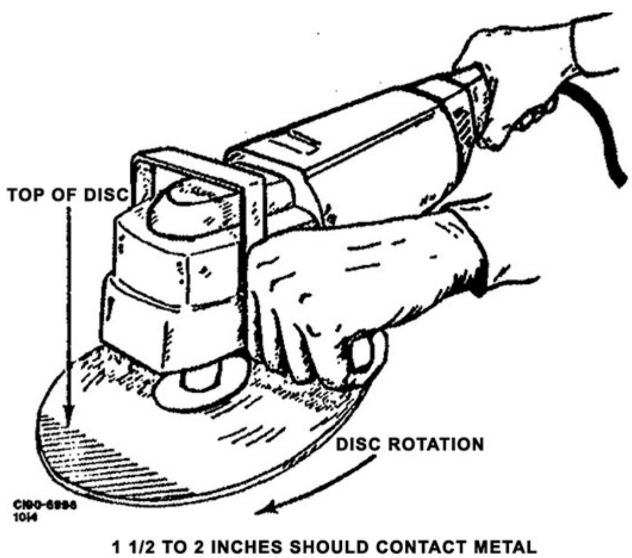


Figure 1–52. Disc sander operation.

NOTE: Always remove the sander's power source before installing or removing the abrasive disc. This prevents potential injury in case the ON switch or trigger is accidentally activated.

The disc normally rotates in one direction only. Remember to keep the face angle of the disc 10°–20° from the metal surface for the best grinding results. Move the sander back and forth across the metal surface in one direction—horizontal or vertical.

CAUTION: Never try to move the sander disc into a corner where two pieces of metal come together to form a single joint. Should the outer edge of the disc contact the corner, you could lose control of the sander. The result could be serious injury to yourself or someone standing nearby.

Replace the sander's entire rubber disc if the hard rubber disc starts coming apart or if there are dry-rot cracks. If you do not, small pieces of hard rubber can fly off in any direction during operation of the sander and cause serious injury.

NOTE: Always use appropriate personal protective equipment (PPE) when operating the sander. For example, wear goggles, hearing protection, and respirators during any grinding or grinding operation. The fine particles float in the air and can be inhaled. Wearing leather gloves when operating the sander is also advisable because the metal surface you are grinding can become very hot.

Filler application

The type of plastic filler you use depends on the sources available to your shop. Plastic fillers come in two parts: a resin base and a catalyst (hardener). Mixing the two parts immediately starts the curing process. The curing time can be adjusted by varying the amount of catalyst mixed with the resin. Always follow the manufacturer's instructions when mixing. We recommend mixing the components on a flat, clean, easy-to-handle, lightweight, and inexpensive object (an old piece of safety glass is ideal). The following are important when mixing the components:

- Make sure the object you use is clean and free of oil, grease, and dirt. If you do not, foreign material can adversely affect the chemical properties of the plastic.
- Do NOT use paper, cardboard, or wood to mix the filler components. These absorb some of the liquid of the filler.
- Mix only enough to fill the damaged area.

Make sure you apply enough filler to bring the body surface to the desired level or contour. You can use a hard rubber paddle (squeegee), putty knife, or other device that enables you to apply the filler smoothly. Consider the step-by-step procedure in the following table.

Step-by-Step Filler Application

Step	Procedure
1	Before applying filler, determine the number of applications necessary. Mix only the amount of filler material needed for each application. Trying to apply filler after it starts to "set up" usually results in caking or roll-up; additionally, it tends to pull loose from the metal.
2	Slide the filler applicator into the filler material Make sure you do not have too much on the applicator. If you pick up too much filler, some may drop off the applicator onto the ground. This not only wastes filler, but also creates another mess to clean up.
3	Spread the filler over the prepared metal surface using firm hand pressure. This eliminates air bubbles and ensures good contact with the metal.
4	Apply the filler in a single operation (if possible). This is best for applying filler material to a small area or to an area requiring a buildup of less than $^{1}/_{4}$ inch. For more than $^{1}/_{4}$-inch thickness, make two or more applications, allowing each to layer set up before adding the next.
5	After the drying or hardening time elapses, smooth the plastic filler. • Disc grinding is recommended because some plastic fillers dry hard enough to dull a body file. • Use a back-and-forth movement of the sander. • Be careful that you do not cut away more material than is necessary to restore the original contour of the part. • Experience with applying filler material helps you determine which abrasive discs provide the best results.
6	If needed, use a body file to remove excess filler or form body contours. The body file operates like a potato or cheese grater. You use it to remove excess filler and form contours of the body surface. Be careful not to cut into the surrounding metal because this dulls the tool rather quickly. Use light pressure during each stroke to avoid undercutting (removing too much filler). Once you achieve the correct contour, you are ready for final sanding in preparation for painting.

610. Fiberglass repair

Fiberglass is used in the construction of many vehicles for several reasons, including the following:

- It is easily formed into different shapes.
- It is immune to mildew and corrosion.
- It has good weather-resistant characteristics.
- Its strength-to-weight ratio is excellent.

Contrary to popular belief, fiberglass is as easy to work with as plastic filler. However, there are certain safety precautions you must take when working with it. You should *always use* the following PPE:

- A face shield.
- A respirator.
- Goggles.
- A rubber apron.
- Rubber gloves.

We will discuss other safety precautions as the lesson progresses. In the remainder of this lesson we will cover fiberglass characteristics, repairing metal surfaces, repairing fiberglass surfaces, and curing.

Characteristics of fiberglass

Four basic materials are combined for fiberglass repair work: fiberglass mat, resin, catalyst, and promoter (drying agent). To be successful when working with fiberglass, you must know what each item does when working with fiberglass, and how one acts on the other. The following table discusses each of these in more detail.

Fiberglass Components	
Component	**Description**
Fiberglass Mat	Fiberglass mat consist of sheets made from fiberglass threads. Use them to build up as well as span damaged areas.
Bonding Agent	The bonding agent is used in fiberglass repair along with the resin, catalyst, and the promoter.
Resin	Polyester-type resin is used to bond the mat to the assemblies when making repairs. It is manufactured from hydrocarbon chemicals and is liquid. You do not use resin alone in its original state for repair. It must have other chemical materials added so they will adhere and harden (cure). The addition of a chemical or agent known as a catalyst changes the resin from liquid to a solid. This change is called polymerization (meaning to set, harden, or cure).
Catalyst	Since the resin is liquid and has no strength, something must be added to harden it. The catalyst is the chemical agent that serves this function. Two catalysts are commonly used with polyester resin: 1. Methyl-ethyl ketone peroxide (MEKP). 2. Benzoyl peroxide (BZP). **NOTE:** *Always* add the catalyst last because the chemical reaction starts *immediately.* **CAUTION**: Always store the catalyst in a cool location. NEVER store catalyst in any airtight refrigerator or storage facility.
Promoter (drying agent)	Without the promoter, resin is an air inhibitor, which polymerizes or cures as a tacky surface. This is not ideal for proper finishing. A drying agent, which dries the surface for proper finishing, is added as part of the process. Usually either *cobalt octoate* or *cobalt naphthenate* is used as the promoter and is normally added by the manufacturer. If, for any reason you have to add promoter, observe the following WARNING.

WARNING: If you have to add the drying agent, cobalt (promoter) and catalyst are explosive! DO NOT MIX THEM TOGETHER. IF YOU DO, AN EXPLOSION WILL OCCUR! Always add them to the resin one at a time.

Repairing with fiberglass

Fiberglass can be used to repair a variety of problems. The two most common include repairing rusted metal areas and damaged (broken) fiberglass components. Depending on the extent of the damage, it may be more economical to replace the entire component or part of it. To proceed with fiberglass as a repair material, prepare the surface as previously discussed regarding plastic and begin mixing the filler. From this point, your process depends on whether you are repairing metal or fiberglass. We will start with metal repair.

Metal Repair Using Fiberglass	
Step	**Action You Take**
1	Prepare the metal surface as previously described.
2	Mix an epoxy resin. • Epoxy is used because polyester will not stick to metal satisfactorily. • ALWAYS follow the manufacturer's instructions when mixing. • Various factors determine how you should mix the materials under different conditions.
3	Cut several pieces of a fiberglass mat approximately 2 inches larger than the area you are going to repair.
4	Wipe a thin coat of mixed material on the prepared surface.
5	• Saturate the fiberglass mat, one piece of at a time, and apply to the damaged surface. • Use a rubber squeegee to work out all air bubbles that become trapped.
6	Repeat Step 5 until the filled area is flush or slightly higher than the surrounding contour.

When you repair a fiberglass surface, the procedures discussed previously still apply but with some variations. First, always use polyester resin on polyester-base fiberglass components to ensure a good bond. There are other methods you use when preparing the surface. The following procedures deal with a typical break in a $^{1}/_{4}$-inch-thick panel.

Repairing Fiberglass with Fiberglass	
Step	**Action You Take**
1	Grind or file the edges to remove all splintered material.
2	Bevel one-third of the material from both sides of the crack as well as both sides of the panel (i.e., inside and outside of the panel). **NOTE:** When the inner surface is not accessible, bevel one side one-half the total depth of the panel.
3	Clean the area you are going to repair with an oil-free solvent.
4	Apply the fiberglass repair material.
5	Sand the repaired area once the resin has cured. Repaired areas should resemble the shaded areas in figure 1–53. **NOTE:** The figure shows repairs done on both sides and when only one side is accessible.

Repairing Fiberglass with Fiberglass	
Step	**Action You Take**
	 **Figure 1–53. Repaired fiberglass surface.**

In all fiberglass repairs, there is the question of curing time for the resin. Different factors can affect the curing time of the resin mixture. Generally, you cure the part you repair at room temperature (70 degrees Fahrenheit [° F]). If the resin is slow to cure at this temperature, apply a small amount of heat (use a heat lamp) to help speed the curing. Humidity also affects the length of curing time. Consequently, allow for a longer curing time when you are in a very humid situation.

Safety precautions

Earlier in the lesson, we mentioned general safety precautions when working with fiberglass. Keep in mind that you need to be very careful when mixing resins or any other chemicals. In addition to the safety precautions mentioned previously, you need to be aware of the following:

- Wear a good respirator to prevent inhaling the fumes during mixing procedures.
- Never mix the catalyst and promoter together; such a mixture can cause an explosion.
- Always mix the promoter with the resin; then add the catalyst to the mixture.
- Protect your skin and wear a respirator at all times when working with chemicals.
- Identify, properly label, and place all chemicals in suitable containers.
- Be sure you have plenty of ventilation in the room where you are working. The sanding and scraping on fiberglass fabric laminates give off a fine dust. This can cause skin irritation, and inhaling an excessive amount of this dust can injure your skin, eyes, and respiratory tract. The bottom line: Protect yourself!

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

609. Plastic fillers

1. Before you order any abrasive discs, what should you do first?

2. At what angle should you maintain the face of the sander to the metal surface for grinding?

3. Why should you never move the sander disc into a corner where two pieces of metal come together to form a single joint?

4. What should you do if you notice dry-rot cracks on the sander's rubber disc?

5. When preparing a surface for filling, what safety equipment should you wear during grinding operations?

6. How can you adjust the curing time for plastic filler?

7. Why must the mixing surface for filler be completely clean and free of oil, grease, and dirt?

8. What tools can you use for applying body filler?

9. What would be the result if the filler starts "setting up" before application?

10. Describe the procedure for filling an area over $^{1}/_{4}$-inch deep.

11. If you use a body file, how can you avoid undercutting?

610. Fiberglass repair

1. List the PPE you should use when working with fiberglass.

2. What is the purpose of the fiberglass mat?

3. What happens when you add a catalyst to the resin?

4. Why should the catalyst be the last item added to the resin?

5. What is the reason for using a promoter?

6. What happens when you mix a catalyst and promoter together?

7. State how you should add a catalyst and promoter to a resin.

8. How do the surface preparation procedures for fiberglass and plastic filler differ?

9. Is it permissible to use polyester resin to repair metal surfaces?

10. Describe how to cut a fiberglass mat when making a repair.

11. What should you use a rubber squeegee for when making a fiberglass repair?

12. How should you bevel a fiberglass component that has both sides accessible?

13. How can you speed up the curing time of a fiberglass repair?

14. What will happen if you mix the catalyst and promoter together?

Answers to Self-Test Questions

601

1. Side members or side rails.
2. Center.
3. Frame horns.
4. Riveted or welded.
5. To allow clearance for the front wheels during sharper turns.
6. When a vehicle is used for the wrong purpose (overloading, running over curbs or parking area concrete stops, and repeatedly operating on very rough terrain—unpaved roads or no roads) or is involved in an accident.
7. Manufacturing process where sheet metal body parts are combined with stress-bearing elements to form the body and chassis as a single piece, as opposed to attaching body parts to a frame.
8. Lighter weight.
9. (1) a.

(2) b.
(3) d.
(4) a.
(5) b.

10. Kinks, bends, rips or tears on the side members; loose rivets, bolts, and body support brackets; cracks in the welded connections.
11. The plumb bob method.
12. Facilitate making measurements with greater ease and more accuracy.
13. Measurements should not vary more than $^{1}/_{8}$ inch at any point.

602

1. They help enhance the beauty and style of the automobile, while adding considerable strength and rigidity.
2. Low-crown, high-crown, combined high- and low-crown, reverse crown.
3. Usually springs back to its original shape.
4. No, high-crowns offer additional strength for resisting force.
5. (1) Formed reinforcements include flanges, grooves, ridges on the inside of the door panels and on floor pans.
   (2) Welded-on reinforcements are normally box sections or channels and occur as crossbars on the underside of the floor pan, roof rails under the hood or deck lid, and in many other places.
6. Front section.
7. Floor pan.
8. Trunk lid.

603

1. (1) Bumping.
   (2) Dinging.
   (3) Pick.
2. Bumping.
3. Top and bottom left drawings.
4. Dinging.
5. To pick out small dents in panels and other hard-to-get-at places where you cannot use a dolly block.

604

1. More.
2. Lightly, letting your grip slacken as the hammer descends.
3. Hammer-on-dolly method.
4. Hammer-off-dolly method.

605

1. It is a bar of steel that is forged flatter at one end than the other or flatter at both ends than the middle. Spoons are bent into a variety of shapes depending upon their use.
2. Straightening long, relatively smooth buckles where the distortion is comparatively light and spread out over a large area.
3. High-crowned bumping spoon.
4. (1) Dolly block.
   (2) Driving tool.
   (3) Pry tool.
5. When straightening and reshaping short-radius bends on narrow, flat surfaces.

606

1. Panel damage starts with a minor dent caused by colliding objects. Next, a larger area caves in while a ridge buckles at the extreme edge of the same cave-in. As the colliding object moves further across or deeper into the body panel, the buckled-up ridge travels ahead in much the same way a wave travels ahead of a boat. As the collision reaches full intensity, this high ridge remains kinked up (locked) and becomes the extreme outer rim of the damaged area. As the impact slows and stops, the damaged area springs back slightly but remains inflexible because of the locked ridge and inverted V-channels.
2. a. A *displaced area* is part of the damage only because it pushes out of position.
   b. An *upset* occurs when opposing forces apply pressure to an area of metal and cause it to yield. As the surface area reduces, the thickness increases proportionally.
   c. A *stretched* area is the exact opposite of an upset area. Tension, instead of pressure, causes stretching. This results in an increase in surface area.
   d. A *simple bend* is an area of metal that serves as a pivot for movement without breaking.
   e. A *buckle* is the result of a severe bend where the metal buckles or kinks up at the pivot point.
3. Determine the direction the damaging force came from and the point at which contact was made.
4. Stretched metal, cracks, breaks, or additional unnecessary work.

607

1. To prevent new lines of strain as well as stretching and bending of metal.
2. Clean the metal.
3. The metal stretches and bends at such sharp angles that further correction is very difficult.
4. Use a body file to file them level with the body surface.
5. Take a dolly with a groove in it and strike on the groove with a cross-peen hammer.
6. The same size torch tip you would use for welding metals of the same thickness.
7. To reduce the possibility of annealing the metal and to help shrink the metal.
8. Suction cups and stud spot welds.

608

1. By loosening the attaching bolts.
2. Because it is much easier to repair the damage if you remove the hood from the vehicle and place it in a holding device.
3. It opens and closes easily, presents a smooth contour in relation to the adjoining sections (front panel or front fenders), matches the contour of the cowl panel perfectly, and has a uniform gap along each side for its full length.
4. To provide a more accurate measurement and allow you to know the exact amount of panel to cut out.
5. Because a cutting torch tends to leave ragged edges and surrounding metal may be distorted by the heat.
6. By using the GMAW welding process and staggering the welds from one side to the other around the entire panel.
7. If the inner panel and construction are reparable or undamaged.
8. Move door hinges. Either the hinges or pillar posts have elongated holes that allow the hinges to be moved in, out, forward, or backwards.
9. (1) Rub chalk around the flange of the lid, close the lid, and then open the lid and check the weather stripping. The chalk leaves marks on the weather stripping and easily indicates any spots that do not fit.
   (2) Close the deck lid on strips of paper and then attempt to pull them out.
10. A template.
11. A hydraulic body jack with a rubber flex head and extension tubes.
12. (1) A hacksaw.
    (2) A small rotary saw.
    (3) A cutting torch.

609

1. Consult the operator’s manual that comes with the disc sander or measure across the disc to determine its size.
2. Approximately 10° to 20°.
3. You can lose control of the sander, seriously injuring yourself or someone standing nearby.
4. Replace the disc because small pieces of hard rubber can fly off in any direction during operation of the sander and cause serious injury.
5. Use goggles, hearing protection, and respirators during any grinding operation. Wearing leather gloves when operating the sander is also advisable because the metal surface you are grinding can become very hot.
6. By varying the amount of catalyst mixed with the resin.
7. Because they can adversely affect the chemical properties of the plastic.
8. A hard rubber paddle (squeegee), putty knife, or other device that enables you to apply the filler smoothly.
9. The filler would cake or roll up; additionally, it would tend to pull loose from the surface.
10. Make two or more applications, allowing each layer to set up before adding the next.
11. Use light pressure during each stroke.

610

1. Face shield, goggles, rubber apron, rubber gloves, and respirator.
2. To build up as well as span damaged areas.
3. The resin changes from a liquid to a solid—polymerization.
4. Because the chemical reaction starts immediately.
5. To serve as a drying agent; in other words, it prevents the resin surface from becoming tacky.
6. An explosion will occur.
7. Add only one at a time and never mix the two together.
8. The preparation procedure is the same.
9. No; polyester will not stick to metal satisfactorily. Epoxy resin is recommended for use.
10. The fiberglass mat should be cut approximately 2 inches larger than the damaged area.
11. Use a rubber squeegee to work out all air bubbles that become trapped.
12. Bevel one-third of the total depth on each side.
13. Through the use of a heat lamp to apply a small amount of heat.
14. You will cause an EXPLOSION.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

1. (601) The vehicle frame and body are combined together as a unit in a
   a. mono frame.
   b. unitized body.
   c. integral frame.
   d. three-rail body.

2. (601) What type of frame misalignment do you have if the cross members no longer form right angles with the side rails?
   a. Zig.
   b. Sag.
   c. Sway.
   d. Diamond.

3. (601) If you do *not* have specialized measuring equipment determining frame misalignment, what other method are you using if you transfer checkpoints to a level floor?
   a. String and pencil.
   b. Bubble level.
   c. Pitted level.
   d. Plumb bob.

4. (602) What auto body shape has the appearance of a curved surface?
   a. Crown.
   b. Round.
   c. Bend.
   d. Arc.

5. (602) What auto body curved type has lower door panels, hoods, and deck lids?
   a. High-crown.
   b. Low-crown.
   c. High bend.
   d. Low bend.

6. (602) The auto body curved surface around the taillights and headlights is *usually* a
   a. low bend.
   b. low-crown.
   c. high-crown.
   d. reverse crown.

7. (603) Which is normally the heaviest and largest auto body repair hammer?
   a. Bumping.
   b. Gouging.
   c. Dinging.
   d. Picking.

8. (603) If you need to repair a panel that is hard to get to, which auto body repair hammer do you use?
   a. Ball-peen.
   b. Bumping.
   c. Dinging.
   d. Pick.

9. (604) What auto body repair tool do you hold against the inside of the body panel as a backup tool when using a hammer?
   a. Dolly block.
   b. Impact block.
   c. Dinging hammer.
   d. Bumping hammer.

10. (604) What type of dolly block working face do you use if you want increased metal stretching and increased lift of the damaged metal surface?
    a. Contact crown.
    b. Impact crown.
    c. High-crown.
    d. Low-crown.

11. (605) When making auto body repairs with a bumping spoon, where do you place the spoon in relationship to the metal surface?
    a. On the other side of the metal surface from the hammer side.
    b. Between the metal surface and the hammer.
    c. To the right of the body panel damage.
    d. To the left of the body panel damage.

12. (605) Which spoon would you use as a pry tool for repairing body damage?
    a. Caulking.
    b. Bumping.
    c. Body.
    d. Low.

13. (606) What do you call the damage to the auto body panel where there is an increase in surface area?
    a. Bend.
    b. Stretch.
    c. Distortion.
    d. Displacement.

14. (606) When removing distortions from a damaged auto body metal surface, you should *start* with the
    a. first distortion to occur.
    b. last distortion to occur.
    c. center point of impact.
    d. deepest impact point.

15. (607) After you inspect and analyze the body damage, your next step in body and fender repair is to perform metal
    a. bumping.
    b. roughing.
    c. grinding.
    d. cutting.

16. (607) During your auto body repairs, it is important to carefully lower the raised metal first because it
    a. increases the chances of buckling.
    b. is the only surface you can get to first.
    c. reduces the chances of shrinking and large bends of the metal.
    d. reduces the chances of stretches and sharp bends of the metal.

17. (607) The auto body repair process where you release a stretched area with a cross-peen hammer and a specialized dolly is called
    a. automatic stretching.
    b. hand shrinking.
    c. cold stretching.
    d. cold shrinking.

18. (608) What two methods can you use to straighten a deck lid?
    a. Manually and hydraulically.
    b. Hydraulically and pneumatically.
    c. Manually and with a hydraulic wedge.
    d. Hydraulically and with a hammer and wood block.

19. (609) When you need to use plastic fillers, what two items will you mix?
    a. Plastic base and adhesion promoter.
    b. Resin base and a catalyst.
    c. Plastic powder and resin.
    d. Catalyst and plastic gel.

20. (610) If you mix a catalyst and a promoter together to repair fiberglass, the mixture will
    a. harden.
    b. explode.
    c. not react.
    d. evaporate.

Please read the unit menu for unit 2 and continue ➔

Student Notes

Unit 2. Automotive Glass, Plastics, Trim, Hardware, and Upholstery

THE FOLLOWING lessons will cover a wide range of miscellaneous components and repair methods. In this unit, we will discuss automotive glass, plastics trim, hardware, bumpers, upholstery, and towing attachments. Although it may seem like a lot of material to cover, the information needed to explain each area is relatively small.

2–1. Automotive Glass

Automotive glass serves many functions. Most importantly, it provides vehicle occupants with the ability to see while being protected from both the elements and forces the vehicle is subjected to during operation. Glass comes in many shapes, sizes, and types. In the following two lessons, we will discuss all aspects regarding automotive glass.

611. Glass types and repair equipment

As a vehicle technician, it is to your advantage to know the characteristics of the various types of glass you will encounter. In this lesson, we will discuss the composition of glass and the equipment you use when working with glass.

Glass characteristics

As you are probably well aware, glass is a hard and brittle material. In fact, the glass used in vehicles is almost as strong as some grades of cast iron. Glass is made by combining silicon (sand), alkali (potash or soda), and either lead or lime. Most automotive glass is lime glass; however, manufacturers may add other substances to provide additional desired properties.

Though it is not as durable as metal, glass has many desirable properties metal does not possess. For example, it is transparent and, for all practical purposes, it is not subject to corrosion. With very few exceptions, acids or other chemicals do not affect glass. (An exception to this is hydrofluoric acid used to etch glass.) Glass is an excellent electrical insulator because it does not conduct electricity. It is also a very poor conductor of heat but does expand with an increase in temperature. Because of this, you must allow for *expansion and contraction* where glass is subject to temperature changes.

As stated previously, glass is hard but brittle; therefore, you must be very careful when handling glass. When it breaks, it has a tendency to shatter. The shattered pieces range from microscopic to very large pieces; they also have needle points and razor edges.

Though glass is strong, its highly polished surface is easily scratched by small pieces of metal or other foreign material. To help avoid this from occurring, always try to lay glass you are working with on a surface protected by cloth, paper, or other soft material.

Types of glass

Manufacturers produce glass in many forms. This ranges from the finest optical lenses and exquisite crystal ware to glass paperweights. In your job, you will be handling and working with sheets of glass that resemble simple windowpanes. While all glass might appear to be alike, vehicle glass must withstand many more stresses than ordinary plate glass. We will now discuss a few types of glass you may encounter.

Plate glass

Although one of the most common forms of glass is window glass, it must be refined before being used in vehicles. Window glass must be ground and polished to eliminate any distortions, resulting in what is commonly known as "plate glass." However, plate glass has its own set of disadvantages that must be overcome. For example, it is easily broken and shatters when it breaks. You can imagine what would happen during a vehicle accident; for example, the driver and passengers would be showered with deadly glass splinters. Consequently, plate glass is not satisfactory for use in modern vehicles.

Safety glass

Safety glass was developed to address some plate glass problems. It breaks into small rounded pieces and does not shatter, nor does it produce sharp points and edges. For many years, safety glass was the standard in the automotive industry. Today, manufacturers seldom use this type of glass because it breaks more easily than newer types.

Tempered glass

Tempered glass is one of the newer types used in automobiles and trucks. The manufacturing process includes rapidly heating the glass and then exposing both sides to cooling jets of air. The benefit of this process, called tempering, is that it strengthens the glass and gives it much greater resistance to breaking and chipping. Tempered or "unbreakable" glass, as it is sometimes called, is often used in rear and side windows; however, it is *never* suitable for windshields. It is not truly unbreakable because even a light blow with a pointed object will sometimes break it. One disadvantage tempered glass possesses is that you cannot cut it. Instead, you must order windows with the exact size and shape for their respective locations on the vehicle in question.

Laminated glass

Laminated glass is another newer type used in automobiles and trucks, generally for windshields. Laminated means made up of layers. As a result, laminated glass is built like a sandwich with a sheet of tough, clear resin (plastic material) bonded between two sheets of glass. The two sheets of glass are highly polished on both sides before being bonded. This ensures a clear, undistorted view for the vehicle operator. Most manufacturers use polyvinyl butyral (PVB) as the resin in laminated glass.

Sometimes, manufacturers make laminated glass with a thick pane on one side and a thin one on the other. The thick pane always faces the outside of the vehicle. It is possible for one side of laminated glass to crack without the other side being affected. This condition results from misalignment or vibration. Recently, manufacturers increased the thickness of the resin and reduced the thickness of the glass. This not only strengthens the glass if impact occurs, but also decreases the weight of the glass.

Although laminated glass is very durable, it is not perfect. For example, the resin (plastic layer) may decompose or separate from the glass under certain conditions, such as very high temperatures. If this occurs, the glass loses its safety features and must be replaced. At times, separation may occur in the center or around the edges. This may cause optical illusions in the form of rainbows or colored spots when light strikes the glass from different angles. It sometimes looks as if there are wet spots on the glass. Deterioration of the resin may cause the glass to turn brown and interfere with vision. It may even allow the two pieces of glass to shift so objects appear double, farther away, or nearer than they really are. If this condition exists, replace the glass immediately.

As you may already know, when a hard object hits a windshield or a collision twists the windshield frame, the glass normally breaks. In the case of laminated glass, the bonded plastic holds the fragments and prevents injury to passengers. Because the plastic is tough and elastic, it allows the windshield to bend out of shape after breakage and still provide protection for the vehicle occupants.

Most commercial vehicles have curved one-piece windshields. These windshields are made by bending and matching the two sheets of plate glass and then laminating them together. The glass is set into a rubber channel to cushion and seal it against the body in the windshield opening. Tinting the glass reduces the amount of glare the vehicle operator has to endure. This reduces eyestrain during operation of the vehicle. Tinted glass is more expensive than clear glass, but it provides more safety features than clear glass. The windshield is subject to more stress and is more likely to suffer an impact than any other glass on any Air Force vehicle. The primary specification for vehicle windshields is that they remain intact after they break. The laminated glass in the vehicle windshield keeps it intact after it receives an impact and breaks. Replace windshields only with laminated glass. You can use laminated glass to replace other vehicle windows as well.

Even though manufacturers call this laminated safety glass, the name is often shortened to safety glass. Do not confuse *laminated safety glass* with the safety glass discussed in an earlier paragraph. You will probably be working with this glass more than any other kind.

Trade tools for cutting and fitting glass

No matter what task you encounter working with glass, it is important that you use the correct tool. Doing so will save you time and labor, and possibly help maintain your composure. We jokingly refer to this as “controlling your ‘temper,’” which is a play on words due to tempered glass. Anyone who works with glass will tell you how true this phrase is. You may not have all the tools we will discuss in your shop, but you will have other tools that serve as substitutes. The fact remains—you must be able to use the tools to “make the cut.”

Glazier’s rule

Use the glazier’s rule (fig. 2–1) for measuring glass. It is made from hardwood and is 60 inches long, 2 inches wide, and $^{1}/_{16}$ inch thick. The rule is marked off in eighths of an inch. It is designed with a lip on one end, permitting the rule to hook over the edge of the glass. This also eliminates the need for holding that end of the rule.

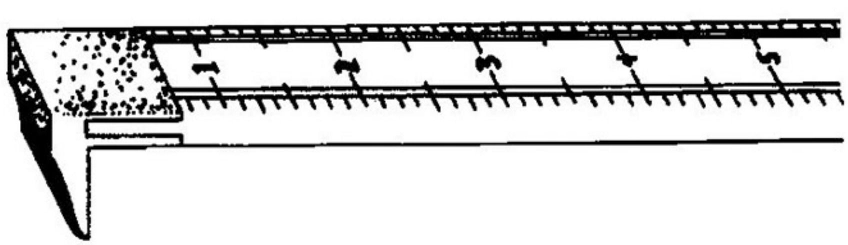


Figure 2–1. Glazier’s rule.

Glass vise

You use the glass vise (fig. 2–2) to remove old glass from channels, thus increasing the amount of glass you can salvage. The vise permits you to replace channels without bending or buckling them. Use the knobs, shown in the illustration, for clamping the glass in the vise. The upper inset in the illustration shows the grasping arms used to grasp and pull the channel from the glass. Also, note that the lever handle attached to the grasping arms is adjustable. This allows it to accommodate various sizes of glass panels or frames. The lower inset shows an anvil arrangement for straightening bent channels.

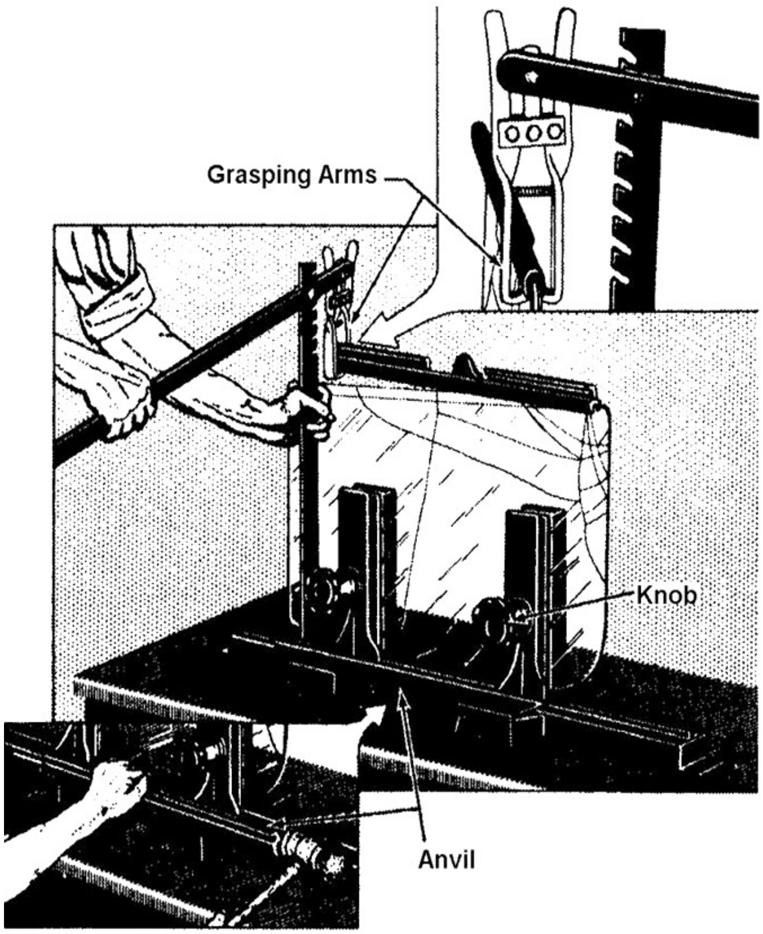
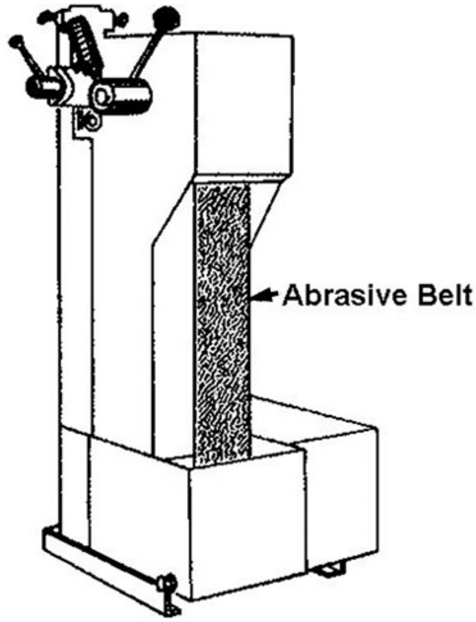


Figure 2–2. Glass vise.

Glass edging machines

Air Force vehicle maintenance shops have several machines for edging glass. All are driven by electric motors and allow you to perform edging from rough grinding to polishing.

Glass Edging Machines	
Type	**Description**
Wheel	The wheel-type edger normally comes with the different wheels, or grits, needed to complete a finishing job—roughing, smoothing, and polishing. The wheel mounts horizontally above the drive wheel and on the same shaft. It comes with a trough partially filled with abrasive powder (silicon carbide or aluminum oxide). A thin trickle of water flows onto this powder, forming a thin paste that drips onto the wheel surface to form a fast-cutting compound. Cutting compounds are available in different grits, ranging from coarse to fine. The 120-grit is satisfactory for grinding or polishing laminated safety glass.

Glass Edging Machines	
Type	**Description**
Belt	The belt-type edger (fig. 2–3) is probably the most common type. In this edger, the cutting is done by an abrasive belt. Either the machine comes with a spray nozzle to keep the belt wet or a belt that runs through a water vat. Belts are the continuous-loop type and are available in grits ranging from 40 to 400. The most common grits are 60–20 for roughing, 180–220 for smoothing, and 420 for polishing. This machine uses only one belt at a time, so to produce a highly proficient edge you will need to use all three belts.  **Figure 2–3. Belt-type edging machine.**

Small hand tools

You should be familiar with a number of small hand tools used for glass repair. These include pliers, pullers, glasscutters, channel drivers, chisels, and various others (presented in the table of Miscellaneous Glass Working Tools later in this lesson). You can obtain these in various styles and sizes, depending on the particular needs of certain automobile models and the task at hand.

Pliers and pullers

There are various types of glass-holding and -chipping pliers. Two representative examples are shown in figure 2–4. The important point to remember is to *never use them for anything but glass!* If the lips of the jaws become nicked or grooved in any way, there is a good chance you will damage the glass. If you can file the nicks or grooves smooth again, continue using them; however, if you cannot get rid of the nicks or grooves, replace the pliers with new ones. Chipping pliers are particularly useful for breaking off projecting pieces of glass from a pane prior to grinding. Notice that one of the jaws of the chipping pliers is hooked (fig. 2–4); this facilitates the chipping of glass. Use these pliers mainly for plate glass and single-pane glasswork.

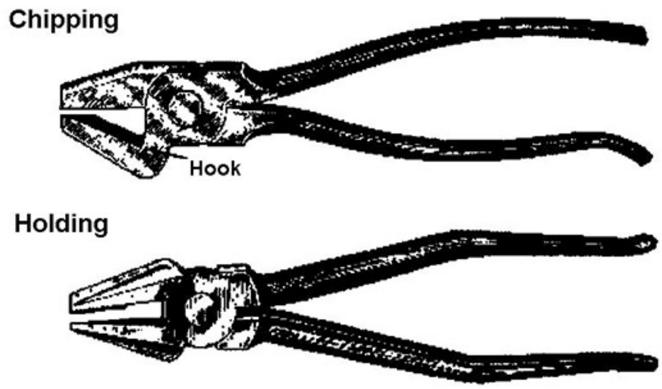


Figure 2–4. Holding and chipping pliers.

There are various types of vent-glass pullers, but the handiest type is a wide-jaw tool with a vise grip. You can use it to pull small vent glasses. The jaws are normally lined with cork to prevent damage to the glass. Remember, NEVER use vent pullers for anything except glass.

Figure 2–5 illustrates another type of puller known as a glass-and-channel puller. This tool is particularly useful in removing glass from the channels of quarter panels and door windows. Sliding clamps and thumbscrews enable this tool to accommodate various window and frame configurations. Also, note the long threaded handle and hand crank. These allow you to force the channels away from the glass.

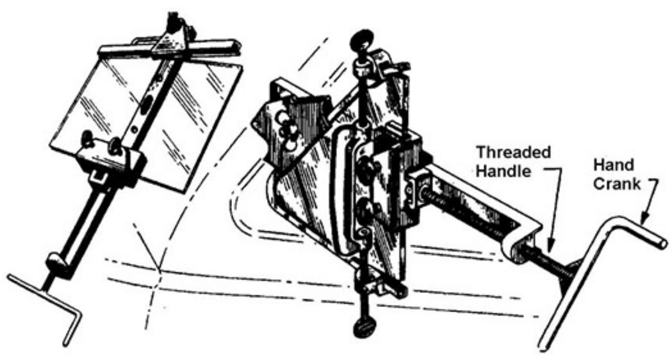


Figure 2–5. Glass and channel puller.

Glasscutters

Figure 2–6 shows some examples of wheel-type glasscutters. You use these for cutting along a line laid out on the glass. The glasscutter comes with a hardened steel wheel mounted on a pin in a metal handle. Make sure there are no nicks in the cutting wheel because wheel nicks will cause skips on the glass. If there are skips, the glass WILL NOT break straight as you attempt to break it. The break will veer either towards or away from the main portion of the glass.

Glasscutters come in a variety of styles: single wheel, multiple wheels, or diamond cutter. You can obtain them with or without the tapping knob shown on the multiple wheel cutters. You use the tapping knob to tap along the opposite side of the initial cut on the glass to crack it more. The self-oiling-type cutter is shown with an oil-soaked sponge, which acts as an oil reservoir for the cutting wheel. The steel-wheel type is easiest to use and is satisfactory for general cutting. Notice that all of the cutters in figure 2–6 have slots on the face of the cutter for breaking off the glass. The diamond cutter (not illustrated) differs from the wheel type in that the cutting is accomplished by a stationary diamond point, or stylus, instead of a rotating wheel.

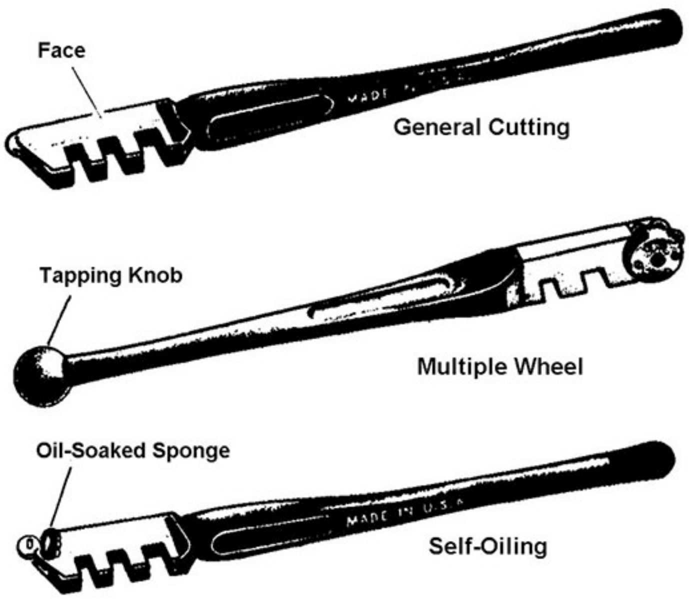


Figure 2–6. Glass cutters.

Channel driver and chisel

You use the channel driver (fig. 2–7) to install the channels on the glass. The driver is approximately 8 inches long and machined to fit the channel grooves. It has an offset head, which enables you to get under the flange of the channels and drive them on. In addition, you use it for straightening distorted or sprung channels.

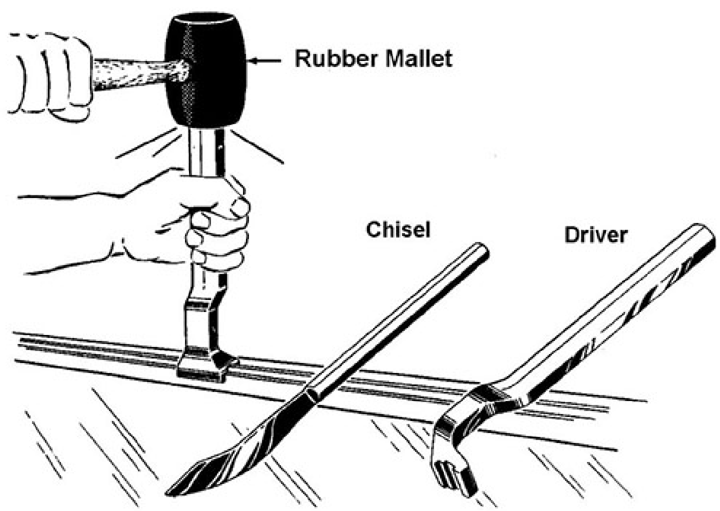


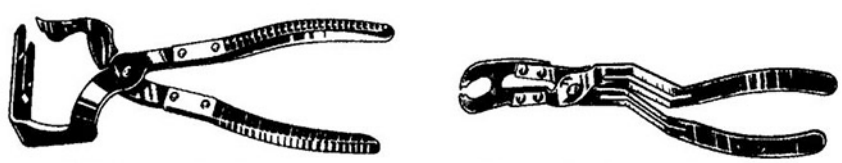
Figure 2–7. Channel driver and chisel.

You use the channel chisel, also shown in figure 2–7, to remove all broken pieces of glass and so forth from the channels. The chisel is approximately 16 inches long so that you can use it as a pry bar or strike it with a mallet.

Miscellaneous tools

Additional hand tools used in working with glass include the Phillips offset ratchet, rubber mallets, window seal installation kit, and handle-clip tools.

These are described in the following table:

Miscellaneous Glass Working Tools	
Tool	**Description**
Phillips offset ratchet	This tool operates more effectively than the fixed-offset screwdriver because you have greater flexibility when using the ratchet to remove screws in close quarters.
Rubber mallets	You use rubber mallets for setting the glass in the frame and channels. They are available in a number of different sizes. The mallet in figure 2–7 is used to strike a channel driver. Because of this mallet type's resiliency, you are less likely to break the glass or mar any part of the glass.
Window seal installation kit	This installation kit contains the tools necessary to properly install the seal around the rear window glass in sedans, trucks, and buses. You use the channel spreader to open the glass channel of the weather strip for installation of the glass into the proper position. The guides pilot the locking strip into the channel.
Handle clip tools	These tools vary widely in size, shape, and style to accommodate the different methods used to retain door and window handles. Nearly every manufacturer uses a different method to do this. Figure 2–8 illustrates two types of clip-removing tools. They are designed to force out, or disengage, the retaining spring clips used to hold the door handles to their respective mechanisms. Insert the jaws of these tools between the door or window handle and the upholstery protecting washer (escutcheon) or friction plate. In some cases, the handle must be in a specific position, such as straight down, to permit proper engagement of the pronged jaw of the tool with the retaining clip. Some vehicles use straight or tapered pins in place of clips to retain the door handles. You can remove a tapered pin by pushing or driving it out from the small end after depressing the spring-loaded rubber escutcheon and metal retaining ring that conceals the pin. You can remove straight pins in either direction. Other vehicles have set screws to retain the door handles. These mount on serrated (notched) shafts, making it possible to position the handles in the most desirable or convenient locations.  Clip Removing Tool Spring Clip Removing Tool **Figure 2–8. Handle clip tools.**

NOTE: Always wear safety glasses, goggles, or face shields when working with glass.

612. Glass finishing and cutting

Working with automotive glass requires patience, a steady hand, and following established safety practices to successfully repair or replace glass. In today's vehicles, you will probably replace more glass than you repair. In this lesson, we will first discuss how you cut glass. Then, we will look at how to replace glass in a vehicle.

Glass cutting

In nearly all cases, you will find it is best to use factory-cut glass. Why? It saves time and money. However, there will be times when you will have to cut flat panes of glass. This is particularly true for noncommercial vehicles. The following information should give you the necessary knowledge you need for cutting glass.

The complete cutting operation involves preparing the pattern, making the cut, cracking the cut, and cutting the plastic. Making and cracking the cut are the most difficult and critical procedures. They consist of setting up stresses in the glass to guide the crack and applying forces that cause the glass to break along the lines of these stresses. Any other stresses may cause the crack to travel in an undesirable direction away from the line.

One such stress occurs, because glass is a slow conductor of heat. Glass expands when you heat it and contracts when you cool it, even though the temperature change is slight. Stresses are set up by supporting the glass on an uneven surface or by applying any pressure to an edge or corner that is not supported.

The other two jobs, preparing the pattern and cutting the plastic, are less difficult but essential. First, let us discuss the making of patterns and then the remaining operations in order.

Pattern making

Before you can cut the glass, it is necessary to measure it or lay out a pattern. You may measure straightedge glass with a ruler. However, because most vehicle glass has curved corners, you need patterns. The broken glass makes an ideal pattern if the resin laminate holds the fragments together. If not, you can make your own pattern out of a $^{1}/_{8}$-inch-thick piece of cardboard. Ensure you use a sharp pencil to trace the exact edge of the glass. If you lean the pencil in or out you will make the pattern too large or too small; therefore, take your time and hold the pencil upright and as close to the exact edge as possible. The pattern must be an exact duplicate for the new glass to fit properly.

Any time you replace a glass, you can make a pattern to keep on file. Consider the following guidelines:

- Annotate on the pattern the vehicle model, style, and year.
- Try to store the pattern flat, not folded or rolled, and in a dry place.
- If possible, store the pattern near the cutting bench.

Use a wood- or steel-frame cutting bench with a flat wooden top. The top must be larger than the largest piece of glass you are going to cut. The cutting bench should be high enough for convenience. Cover the table with a cloth material soft enough to prevent scratching and slipping, yet hard enough to rigidly support the glass. Locate a table where there are no air drafts that could interfere with the cutting operation. Sudden temperature changes during cutting operations will almost certainly result in glass breakage. Never slide a piece of glass to the edge to pick it up. Instead, lift the glass straight up and lay it straight down. Otherwise, small glass chips on the table will scratch the pane.

Glass cutting

After you lay the glass out and are ready for cutting, dip the cutter wheel in turpentine or light oil. This provides lubrication to assist the cutting action. In addition, the lubricant acts to control the movement of the tiny glass splinters formed as the cutting wheel makes a groove along the surface of the glass. In other words, the lubricant has somewhat the same effect as the cutting oil used in making threads on metal stock.

- If you use a ruler to guide the glasscutter along the line you have marked, hold the face of the cutter against it so the wheel rolls straight in the direction of the cut.
- If you use a pattern, place it under the glass in a position where you will not end up wasting glass; keep your cutting actions as minimal as possible.

If you are working with laminated glass with a thick side and a thin side, you must cut the thick side first. Cut this glass so that as you mount it, the thick side (it has the trademark on it) will be on the outside of the vehicle.

1. Hold the cutter like you would hold a pencil.
2. Pull or push it along the line of the pattern.
3. Move the cutter smoothly with moderate but steady pressure, guiding it by hand as shown in figure 2–9.

NOTE: Use only enough pressure on the cutter to make a thin line cut. If you apply too much pressure on the cutter or drag the wheel, you will make a wide, frosty “snowy” cut. A “snowy” cut will not guide the crack as easily as a thin hairline cut.

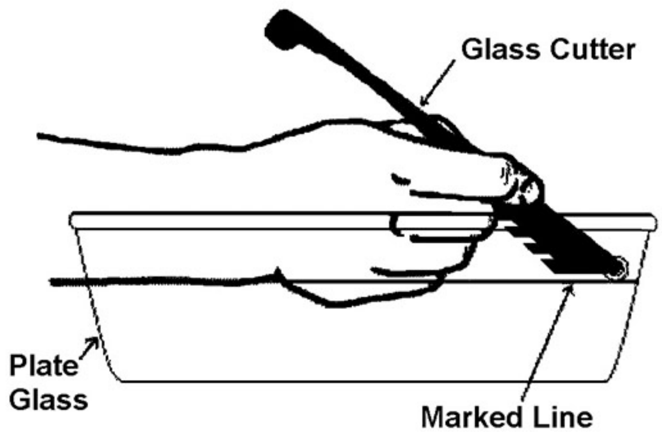


Figure 2–9. Cutting glass with a glasscutter.

It is critical that you make only one cut. Retracing the line you make on the glass will ruin the cutter wheel. You can identify a dull, stuck, or flat cutter wheel by the skips it leaves in the cut. Uneven pressure, too much pressure, or unsteady support of the glass can also cause skips. Too much pressure, insufficient or no lubrication, or a poor cutter wheel causes chipped cuts. Always start and finish the cut at the edge of the glass.

- Perform your cuts as straight as possible.
- If you must cut a sharp curve in the glass, remove as much waste glass as possible with straight cuts and finish the curve, later, on the glass edger.
- At a sharp corner, make two or more separate "relief" cuts.

Glass cracking

You must crack the glass immediately after you make a cut. If glass "rests" more than one or two minutes, the cut will "heal" or relieve itself of the internal stresses. Although its appearance does not change, the cut will no longer guide the crack. When you are ready to crack the glass, take the following steps:

Starting the crack

1. Move the glass to the edge of the table.
2. Carefully press on a corner (never in the middle) of the waste piece to initiate the crack.

Cracking the glass

1. If the waste strip of glass is less than one inch wide, use glass pliers to press the waste piece down and away from the cut.
2. Take particular care to "run" the crack completely.
3. Crack all cuts on one side of the safety glass and then repeat the process on the reverse side, exactly opposite.
4. You may make the cuts on both sides and then crack the cuts in one operation by bending the waste glass up and down to run the cracks together.
5. Remove the waste glass from the one edge before making the cut for the adjoining edge.

WARNING: Cuts must not cross each other. Doing so may result in an inaccurate break, or damage the piece beyond salvage, since the crack may jump between cuts.

Sometimes you may have difficulty in cracking cuts because the crack will not follow the cut. A poor cut, a cold draft on the glass, failure to make the cut on the reverse side directly opposite the first, or failure to run the crack soon enough after cutting may cause difficulty in cracking cuts.

Plastic cutting

After cutting both sides of the glass and cracking it, you must cut the plastic. You can cut the plastic with a razor blade, a plastic solvent, or butane torch.

Cutting Plastic	
Method	**What To Do**
Using a Blade	Follow this method at temperatures above 75° F. • Rest the glass on the edge of the bench with the waste piece overhanging. • Insert the blade in the cut and bend the waste piece down slightly. • Bending the waste piece too far will chip the glass.
Using a Solvent	There are liquid products on the market that are highly effective. Denatured alcohol is one you can use. After you cut and crack the glass, perform the following: • Apply denatured alcohol to the plastic by putting slight pressure to the waste piece and squirting the alcohol into the crack. • Wait 30 seconds to one minute for the plastic to dissolve before pulling the waste piece free.

Edge grinding

After glass has been cut, the edges are highly sharp. It cannot be installed in this condition because it will damage the channels. The edges need to be ground to a smooth finish before installation.

CAUTION: After glass is cut, the edges are dangerously sharp. As you handle the glass for edging, or any other time, wear gloves to protect your hands from chips and sharp edges.

A belt edger is generally used to smooth the edges of the glass and make it ready for installation. You will need to have belts handy for roughing, smoothing, or polishing the glass. Each belt contains different grit sizes. To finish the edge, take the following steps:

1. Hold the glass horizontally.
2. Press it smoothly and evenly across the belt, starting with one corner of the glass.
3. After one pass, pull the glass away from the belt and repeat the operation in the same direction.

CAUTION: Never move the glass back and forth because it may chip. Uneven pressure or chattering may also cause chipping.

4. After you grind the edge of the glass smooth and flat, carefully round all the corners.
5. Smooth all exposed edges, including those that slide in channels.

If the belt edger does not round the edges enough, carefully rock the glass. It is best to work all the way across the glass in a single pass. This gives a smoother and straighter finish. For final polishing, use a number 420- or 400-grit belt. As you finish the edges of glass, use particular care not to catch the corners of the glass on the belt.

After you finish the edges, wash the glass thoroughly with clean water at low pressure to remove the grinding compound or grit. You may scratch the glass if you allow this grit to remain.

Replacement and adjustment

As you remove safety glass, try to keep it intact. Avoid cutting yourself and preserve the old glass as a pattern. Methods of removing glass vary widely according to the construction of the door or window. Always consult the technical order when in doubt about specific procedures. Many Air Force heavy-duty vehicles have framed windshields and door glasses that include the channels. Ordinarily you remove both the frame and the glass from these vehicles, take them to the workbench, and then remove the frame from the glass with a glass vise. Reverse the procedure for replacement.

In the following paragraphs, we will first consider the replacement of the fixed glasses and side windows. Then, we will discuss curved windshields and rear windows.

Flat windshields

Unlike most side windows, flat windshields are nearly always stationary in their frames. The frame and window together may be hinged at the top and swing outwards at the bottom for opening. Alternatively, the window may slide horizontally inside the frame. Although the construction varies from model to model, the methods of sealing fixed glasses are very similar. A typical flat windshield mounting is shown in figure 2–10. Notice that the glass pane mounts in the rubber weather strip and is sealed with rubber cement. Construction differences normally dictate the variances in procedures for removing fixed windshield glasses. However, there are several options that apply to nearly all windshield installations, including the following:

- Cover the interior of the vehicle next to the garnish molding around the windshield before you start the task to prevent damage to the finish and upholstery.
- Apply masking tape next to the molding to hold the protective cover in place.
- Cover the hood to prevent damage to the paint finish.

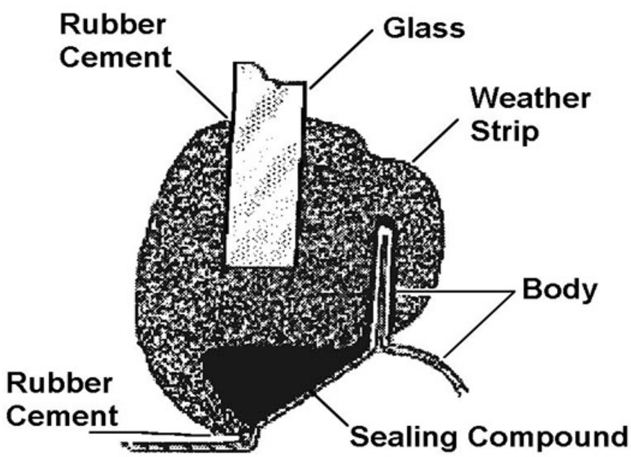


Figure 2–10. Flat windshield weather strip.

In some instances, the rearview mirror is attached to the inner molding itself. On a two-piece windshield, you may have to remove the inner center-division molding and push the glass and rubber weather strip toward the inside of the body.

After you remove moldings and trim from a one-piece, early model windshield, work from inside the vehicle.

1. Pry the rubber strip from the body flange with a screwdriver or specialized tool.
2. Use your hand and press firmly against the glass adjacent to the portion of the removed weather strip to force out the complete assembly.
3. Push at the top of the windshield starting at either corner, working your way across the top of the windshield, carefully applying even, steady pressure.

You can replace glass by reversing the removal procedure. The process is similar to that used for curved windshields, which will be explained later. Now, let us consider the side windows.

Side windows

Construction of side windows varies, depending on the vehicle make and model. The small vent windows (which are not installed on all vehicles) normally mount in integral metal channels. Door windows normally slide in separate channels on either side, mounting in a channel at the bottom; this facilitates cranking them up or down by means of a regulator arm hooked into the channel. The side channels are felt- or fabric-lined, extended over the top of the window frame. They are then held in place by clips that snap into holes in the doorframe. This allows the channels to be replaced when they are worn, and are each supported by the garnish molding.

As a result, you can remove the window after you remove the molding and channel. If the channel is not removable, perform the following:

1. Roll the glass halfway up.
2. Press the top edge out of the channel (supported by the garnish molding).
3. After the top edge of the glass is clear of the channel, turn the regulator handle until you expose the arm.
4. Unhook the window.

Some military-designed vehicles have the glass mounted inside a channel that moves with the glass inside another channel.

The installation of side windows can be divided into several different tasks. The glass damage determines the type of procedure necessary to complete the installation. You may have to do any one or a combination of the following:

- Install glass in channel and install assembly in body.
- Straighten, repair, or replace window channels.
- Repair or replace window-raising or -opening mechanisms.
- Adjust window regulators.
- Connect and adjust raising or opening mechanisms.

Integral window channels ordinarily need cleaning after you remove the broken glass. You can use the glass vise like the one shown in figure 2–2 to remove the channels. If your shop does not have a glass vise, use a 2-inch-wide piece of hardwood against the channel and tap with a hammer. Alternate from side to side as you tap the channel from the glass. You can clean the channel properly and straighten it if necessary by using the channel chisel (fig. 2–7) and the anvil attached to the glass vise (fig. 2–2). Replace any damaged channels. You can draw or clamp together the channels over the glass by using the vise. Another way to do this is to use a channel driver such as the one shown in figure 2–7. In either case, seat the glass in the channel with the trademark surface facing out.

Always force the channel onto the glass rather than the glass into the channel. Also, drive the channel straight down, starting at either corner and working towards the other corner.

- Seat the channel by striking moderate blows with a rubber mallet or tapping against the channel driver with the rubber mallet.
- The channel must be tight enough to prevent rattles but not so tight as to risk breaking the glass.

Always apply new window channel tape to the glass when replacing windows with integral channels. It contains rubber and it swells after you install it. You can obtain the tape in the size needed for a tight fit.

Use the following steps when applying the tape:

1. Lay the tape along the edge of the glass the length of the channel.
2. To apply the tape around a corner, pinch the excess together in pleats with pliers and cut it off smooth with a razor blade. Never leave a double thickness.
3. Let the tape dry for a one-hour period.
4. Apply a thin layer of silicone adhesive around the edges of the tape to keep it from coming in contact with moisture.

NOTE: Do not use duct tape; besides being the wrong material for the job, it deteriorates quickly in hotter/drier climates.

The procedure for installing the new glass with the channel is the reverse of the removal process we explained earlier.

Window-operating mechanisms

You will work with many types of window operating mechanisms, but most of them operate on the same principle. To connect a complete mechanism to the window, you must have some knowledge of its construction. Refer to figure 2–11 as we discuss the installation of the window-operating mechanism.

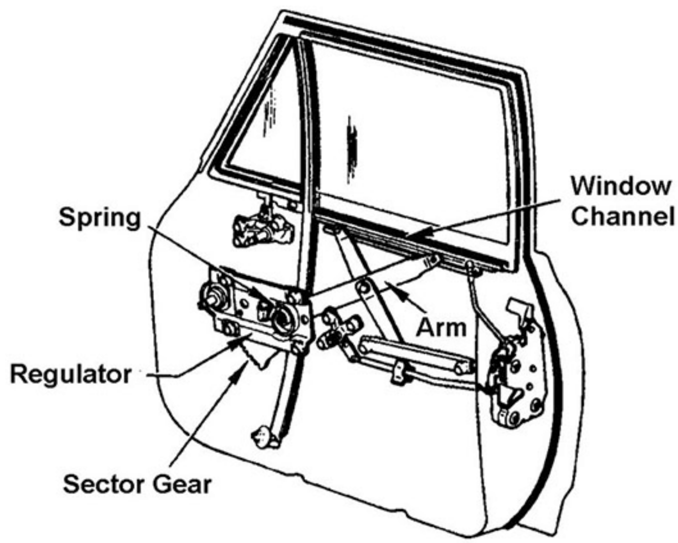


Figure 2–11. Window operating mechanism.

The first unit you connect is the section containing the regulator sector gear, the spring, and the arm. This unit fastens to the inside of the door panel by screw fasteners, rivets, or spot-welds. The arm moves the glass up or down. It is equipped with a grooved roller that fits in a slot on the window channel. The glass fastens to this slot. The shape of the slot is normally like an elongated keyhole so you can insert the roller and its grooves can engage the edge of the slot. Apply a small amount of general-purpose lubricant to the mechanism during assembly, paying particular attention to the sector gear and the slot in the lower channel.

Adjust the arms so they lift the glass completely up to the top and lower the glass to the proper level (normally flush with the bottom of the door window opening). You can make adjustments by increasing or decreasing the tension on the arm springs or, on some vehicles, by changing the position of the upper and lower window stops (bumpers).

In most cases, the regulator screw fasteners pass through elongated holes in the inner door panel. This arrangement permits you to adjust the regulator mechanism so the glass will fit properly in the channel and not bind as you raise or lower it.

The door glass bumpers (or stops) can be made of solid rubber; however, they can still wear out even though the rest of the vehicle is in good working condition. When this happens, replace the bumpers; otherwise, the glass could be damaged if it contacts the metal portions of the door interior. Normally, these stops are replaced easily once the door trim panel has been removed. As a result, always take time to check the stops whenever the trim panel is removed.

If you are adjusting the window-operating mechanism or removing the door glass, you have to remove the inner door panel. This panel will have either screw fasteners or clips holding the panel in place. If the panel has clips holding it in place, be careful when removing them and do not damage the panel or the clips. Slipping a wide flat-tip screwdriver or specialized tool between the panel and door and prying the panel away from the door will unfasten the clip from the door. Do not yank on either the screwdriver or the specialized tool; instead, apply steady firm pressure to unfasten the clip from the door. After you remove the inner door panel, remove the weather shield (paper or plastic cover) so you can see inside the door. Do not throw the weather shield away because you need to install it back on the door when you reassemble the door panel. At some point, you will need to reach inside the door and inspect the window and window-operating mechanism. Be extremely careful as you withdraw your hands and arms from inside the door as many sharp metal edges can cut you. Take the time to withdraw your hands and arms slowly to prevent them from catching on any of the sharp edges of the door opening to the window mechanism area.

Curved windshields and rear windows

Most of the Air Force commercial vehicle fleet (sedans, truck-tractors, stake-and-platform, and pickups) have fixed windshields with curved surfaces. Typical installations are shown in figure 2–12. Notice that in both cases the glass is set in rubber weather strip with garnish molding on the inside and reveal molding on the outside. The weather strip is sealed into the windshield opening as well as to the windshield glass.

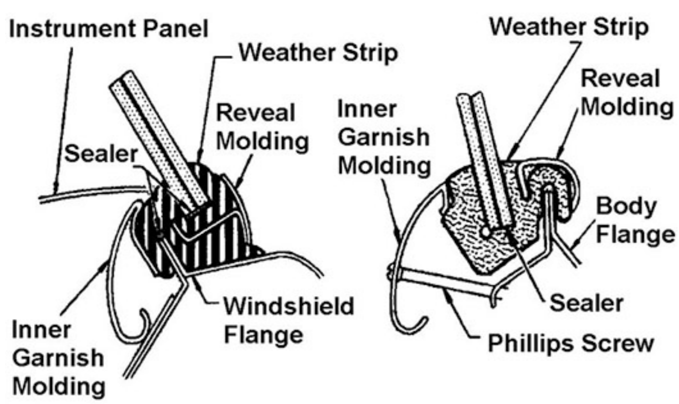


Figure 2–12. Curved windshields.

Removing curved glass is not much different from other fixed glasses, but two people must always work together for this task. Almost all curved glass is removed from the outside rather than the inside. Since most curved glass is factory cut, it is not likely that you will need to make patterns. While wraparound windshields vary in fastening methods, they are basically the same as other curved windshields.

Always try to determine the cause of the glass breakage as you replace a cracked windshield. A break originating from under the weather strip indicates the possibility of a pressure crack. If you trace the cause to a defect in the windshield opening, you must correct the defect before installing new glass.

For example, if a high spot or small obstruction somewhere around the opening caused the windshield to break, it will likely crack the replacement windshield. This is especially true if the strain on the glass is augmented by such conditions as wind pressures, extreme temperature changes, jolting of the vehicle, and so forth. Therefore, mark the location of the break on the weather strip and body. Although at this point you need to remove the windshield and file down any high spots or eliminate any obstructions, other preparations must first take place.

Preparations for windshield removal

Before removing the windshield, provide protection for the paint finish (both inside and outside the vehicle). You then remove the inside garnish molding and the outside reveal molding. Something that may cause difficulty in removing the outside windshield molding is hidden screws. These are sometimes hidden beneath sliding sections of molding. For such a case, all you need to do is carefully drive the movable section along the other molding until you expose the screws. A typical hidden screw installation is shown in figure 2–13. Notice that the screw is covered by the rubber channel and retains the reveal molding to the roof panel. You can locate hidden screws by sliding the blade of a putty knife between the molding and the rubber channel. To ease the movement of the putty knife, as well as the screwdriver you use for removal of the screws, coat these tools with rubber lubricant.

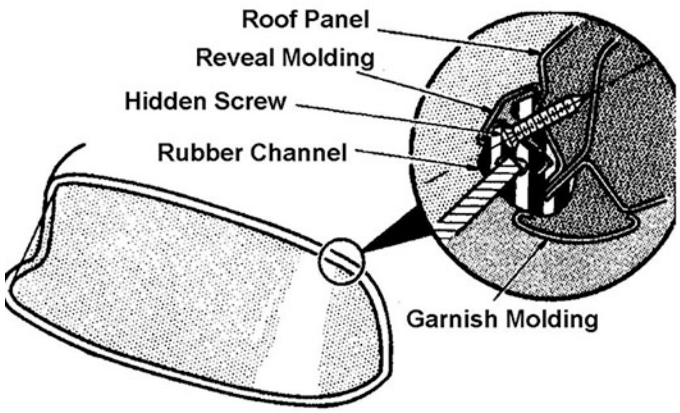


Figure 2–13. Hidden screw installation.

Depending on the make and model of the vehicle, you may have to remove various other items before you can take out the windshield. These may include the following:

- Sun visors and rearview mirror, in nearly all instances.
- The cowl air intake cover may need to be removed.
- Windshield wiper arm and blade assemblies.

Windshield removal

After you remove all of these items, apply pressure on the inside of the windshield and push the windshield and weather strip out of the opening. You will need an assistant on the outside of the windshield to keep it from falling as you push on the windshield from the inside. Lay the assembly on a padded bench or table to remove the weather strip. Some manufacturers recommend cutting the weather strip away for easier removal of the windshield. This, of course, requires you to install a new weather strip. You can reuse the old weather strip if it is not stretched or deteriorated.

As previously mentioned, windshields and rear windows on commercial vehicles come with curved surfaces. Curved surfaces are very hard to cut and form. This means it is more practical to obtain the windshield or rear window from a manufacturer of windshields or rear windows. To install these factory replacements, use almost the same procedure you would use for installing other fixed glass. For example, you force the glass into position in the rubber weather strip.

However, before you install new glass, inspect the contour of the pinch-weld flange for any defects and for the presence of old cement. If necessary, use a scraper to clean off the old cement.

Force the glass into position in the rubber weather strip, starting from the center and working toward the ends. Use a swab applicator and lightly coat the grooves with liquid soap so the rubber slips on more easily. To help prevent cracking the class, ensure the weather strip is free of wrinkles and is not swelled or stretched. Apply weather strip cement in a continuous bead to the flanges of the windshield opening. On one-piece windshields, two people should work together pressing the glass in at the center bottom and working around and up. After you press the glass into place within the frame, install the molding. For installing some windshields, you insert a stout cord into the pinch-weld cavity of the windshield channel. Pulling on the ends of the cord aids in lifting the lip of the weather strip channel over the pinch weld. Some manufacturers recommend using a sealing gun to squirt sealing compound between the glass and the weather strip after you position the windshield. The gun is similar to an oil squirt can except it injects liquid sealant instead of oil.

On some vehicles the rear window glasses, rear corner glasses, and windshields have a weather strip with a retainer seal insert (fig. 2–14). The insert is triangular and fits into the weather strip seal so it wedges the rubber against the glass and against the metal panel (or flange) at the window opening to provide a secure fit. You install this type of weather strip in the same manner as any other weather strip. Then cut the insert to the proper length and butt it into position by starting at the center of the insert and working toward each end.

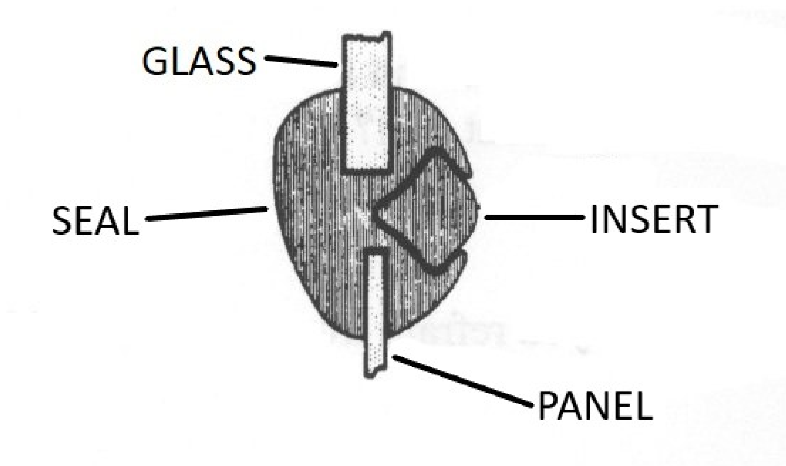


Figure 2–14. Seal insert installation.

Adhesive installations

On newer vehicles, many manufacturers use special adhesives to install windshields, rear windows, and other nonopening windows. The adhesive is strong, durable, weather resistant, and cost-effective. Removal of windows requires cutting of the adhesive. This can be accomplished using a variety of common and specialized tools.

The four basic methods used to remove adhesive bonded glass from a vehicle include wire, vibrating knife, cold knife, and hot knife. The following describes how to remove the glass adhesive using each method:

- Wire–One of the most basic methods. A piece of wire can be run through the seal in order to affix a handle to both ends. With one person each inside and out, pull the wire around the windshield while using a back and forth sawing motion.
- Vibrating knife–Can be electric or pneumatic. It uses a rapidly vibrating blade to cut through the adhesive.
- Cold knife–It uses a blade to cut the adhesive. This tool needs significant force to pull the blade through the adhesive. It is critical that the blade is clean and sharp.
- Hot knife–It works well with tough adhesives. The knife is heated to around 750° F which makes cutting easier.

Once the seal is cut, the window can be removed. The adhesive that remains on the vehicle body will have to be removed. The mating surfaces on the body and the new windshield should be thoroughly cleaned to promote good adhesion. Installation requires running a bead of adhesive around the window opening and carefully placing the window in its place. Ensure the window is properly positioned in the opening. Small blocks may need to be placed around the window to center it properly while the adhesive cures. Installation of this type may or may not have trim or molding around the window openings; this trim or molding should be installed before the adhesive begins to cure. Be sure to follow the instruction included with the adhesive you are using.

Windshield repair

In today’s operating environment, the ability to repair a windshield rather than replace it saves both money and time. As a vehicle management Airman, you will need to be able to determine whether to repair or replace a windshield. Although there are several repair methods available on the market, the most widely used is the resin injection system. Therefore, for our purposes, we will refer to this repair method. You must also always remember that the only repairable glass on a vehicle is the laminated type. In almost all cases, this is only the front windshield. The most important consideration in windshield repair is safety. Any damage or defect to the windshield that interferes with the driver’s view and/or ability to safely operate the vehicle must be repaired or the windshield must be replaced.

Types of breaks

The windshield is made of laminated glass. As you remember from the beginning of this lesson, laminated glass is two sections of glass with a plastic lamination between them. Most breaks are repairable due to this construction method. When an object strikes a windshield, it usually only damages the outer layer of glass. The space between the break may appear as a dark spot, indicating air is trapped between the layers of glass. The object of the repair is to remove the air and replace it with a resin down to the lamination. This in-turn bonds the glass and prevents splitting as well as aid with visual clarity. See figure 2–15 for the four types of breaks that commonly occur.

Figure 2–15. Types of breaks.

Of the four types, the bull’s eye and half-moon are the easiest to repair and can produce the best results.

The star and combination are the hardest and can be unpredictable, in the sense of creating an extended crack due to the pressure of the injected resin. The optical clarity will also depend on the following:

- Location–Where the break is on the windshield.
- Age–The older the break the harder it is to repair.
- Presence of foreign material–Wax, dirt, and so forth.

To achieve the best results for any of these types of breaks, the repair should be made as soon as possible after the damage is discovered.

Types of cracks

There are only two types of cracks in a windshield:

1. Branching cracks have more than one end.
2. Straight line cracks have only two ends.

Though not common, it is possible to repair some small cracks. Depending on the area of the crack, good results can be obtained with little or no notice of the repair. In other cases, a crack may seem to appear and disappear at certain angles. In either case, once a repair is accomplished, it will prevent the crack from splitting any further. Generally, a crack in a windshield requires it to be replaced. Any crack longer than 25 percent of the length or width of the window (may be less per local laws), extends to the opposite edge or through both layers of a laminated window, must be replaced.

Resin injector

There are a variety of windshield repair kits available, whether manually or power operated. The function they have in common is providing a means to create a vacuum and to inject resin into the break. We will briefly cover how a common manual-type kit would work. Always follow the instructions that come with your shop's kit.

The resin injector is the heart of the windshield repair system. It provides a means of creating a vacuum or pressure in the damaged area. The injector (fig. 2–16) is made of lightweight aluminum alloy and plastic and generally includes the following parts:

- Injection cup–This is where resin is injected; further, it is also used as a guide and bubble gauge when accomplishing repairs.
- Base–Mounts to the windshield and stabilizes the injector over the repair site.
- Handle and Rod–These are used to create vacuum or pressure in the injector.

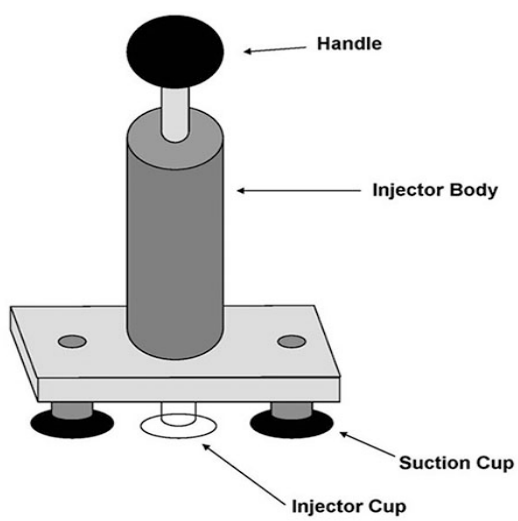


Figure 2–16. Resin injector.

The resin injector performs all of the processes needed to repair windshield damage using only one tool and the following three modes of repair:

Neutral

The neutral mode cancels the vacuum and pressure modes. It is used for tool set-up and to initiate the repair process.

Vacuum

The vacuum mode is accomplished by pulling the handle back. It then creates the vacuum that is used to remove air from the break. The time needed to complete the vacuum mode varies from two to 10 minutes.

Pressure

The pressure mode always follows the vacuum mode and is accomplished by pushing the handle forward, injecting the resin into the break. The time needed to complete the pressure mode varies from five to 10 minutes.

Drilling and curing the repair

As when conducting any repair, there are preparation and finishing steps. In windshield repair, the preparation step starts with drilling the break. To drill the break is to simply enlarge the injection site. This will allow for a more even distribution of the resin filler, resulting in a better repair. Although bull's-eye and half-moon breaks do not require drilling for repair, it is good practice to drill all repairs. To practice, get an old windshield and become acquainted with the feel of the drill against glass. Drill straight in and straight out (fig. 2–17), going in far enough to cover the round drill head but never to exceed the lamination between the glass layers. While practicing, you will want to drill down to the lamination to see how it feels when you drill in too far. This will help you in gauging future repairs.

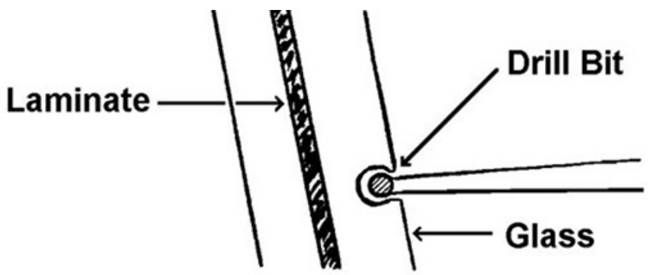


Figure 2–17. Drilling glass.

To complete any repair, you must cure the resin. This is accomplished with the curing agent supplied with the repair kit. The curing agent is a catalyst with the glass resin and speeds up the drying time through a chemical interaction. To initiate the curing process, you can use an ultraviolet light or reflect direct sunlight on the repair spot using an inspection mirror. Depending on your needs and situations, either source of light will work; using direct sunlight will cure the resin faster.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

611. Glass types and repair equipment

1. What materials are combined to make glass?

2. What allowances must be made where glass is subject to considerable changes in temperature?

3. State one way to avoid scratching the surface when working with glass.

4. What is the reason for grinding and polishing window glass?

5. Describe the manufacturing process for tempered glass.

6. Why must you order tempered glass for vehicles?

7. What type of glass do you use for windshields?

8. What type of resin do manufacturers use in laminated glass?

9. What one factor can cause the resin in laminated glass to decompose?

10. What device allows you to remove window channels without bending or buckling them?

11. What do you use to edging, such as rough grinding to polishing the glass?

12. Name five small hand tools you use in glass repair.

13. What tool do you use for removing broken pieces of glass from channels?

14. How is the Phillips offset ratchet used and what makes it effective for its purpose?

15. What allows you to position a door handle in the most desirable or convenient location?

612. Glass finishing and cutting

1. What are the two most difficult and critical procedures for cutting glass?

2. When can you use the old broken glass as a pattern for cutting glass?

3. As you trace a pattern, why is it important not to lean the pencil?

4. What size should the top of your cutting bench be?

5. Why should you locate the cutting bench away from any drafts of air?

6. What lubricants can you dip the cutter wheel in before making any cuts to the glass?

7. When preparing to cut a laminated glass with a thick side and a thin side, which side should you cut first?

8. Why should you refrain from making a wide, frosty cut on glass?

9. Why should you not wait more than one or two minutes after you make the cut to crack the glass?

10. After making the cut on glass, explain how to start the crack?

11. Why should you *not* move the glass back and forth when edge grinding?

12. Briefly state the procedure for replacing a framed glass on a heavy-duty vehicle.

13. Why should you cover the vehicle's hood before removing a windshield?

14. If the door window slides in separate window channels, how are the channels secured?

15. What would you use to remove glass from integral window channels?

16. How tight must you install integral channels to the window glass?

17. How can you determine whether a door window-operating mechanism is adjusted properly?

18. How can you adjust a typical window mechanism to raise and lower the glass to its correct level or position?

19. What can you use to unfasten the door panel clips from the door?

20. What precaution should you take when you are inspecting the door window mechanism inside the door?

21. How many people are required when removing curved glass from a vehicle?

22. What can cause a new windshield to break in the same area as the old glass you recently replaced?

23. What is the reason some vehicle windshields use a retainer seal insert in the weather strip?

24. Which type of automotive glass can be repaired?

25. How many modes does the resin injector function in and what are their names?

2–2. Automotive Plastics

Another area of automotive maintenance that falls within your responsibility is plastic. More and more vehicle bodies, and especially trim parts, are constructed of various types of plastics. A good grasp of some repair principles involved is essential to becoming a skilled technician. To help you in this endeavor, we will cover how to identify the composition of plastic vehicle parts and the concepts of plastic repair.

613. Automotive plastics

Modern vehicles are equipped with literally hundreds of plastic parts. To aid in identifying all of these parts, the Society of Automotive Engineers (SAE) developed *SAE Recommended Practice J1344: Marking of Plastic Parts,* to establish an industry standard.

Marking

SAE Recommended Practice J1344: Marking of Plastic Parts provides a system for marking plastic parts with identifying symbols designating the general compound from which each part was fabricated. The purpose of this system is to help you determine the best materials and procedures to repair and repaint plastic vehicle parts. The SAE system for designating the general type of automotive plastic parts is based on standard symbols for terms relating to plastics published by the International Organization for Standardization (ISO). There are so many different types and shapes of parts are manufactured, this recommended practice does not prescribe the size, location, and/or method of marking. Unfortunately, because it is only recommended, manufacturers do not have to comply with it.

A part manufacturer who conforms to the SAE recommended standard follows or observes certain objectives. While you do not need to know all of the standards, the ones that directly impact you include the following:

- Identify the material from which the part is made so you can use suitable repair and paint procedures.
- Whenever practical, locate the marking where it can be seen while the part is assembled in/on the vehicle.
- Place the marking on an outside surface of the part in an unobtrusive location (as far as the owner/operator is concerned).
- Design the marking to remain legible during the entire life of the part.
- Use multiple markings on large or complex shaped plastic parts.

The *SAE Recommended Practice J1344: Marking of Plastic Parts* for vehicles specifies a series of alpha characters (letters), 3.0 mm high, placed inside a “football-like” shaped circle molded onto the component part.

Types of plastic

Thermoplastics, thermosetting plastics, and composite plastics are the three categories of plastic vehicle parts described in the following table:

Plastic Types	
Type	**Description**
Thermoplastics	These compounds soften when heated and harden as they cool. You can do this repeatedly with the same soften/harden result. These can be repaired through a process called plastic welding (discussed later).
Thermosetting Plastics	As the name may suggest, thermosetting compounds set permanently. Once they are in their final form, they cannot be softened by heat. In addition, they cannot be welded.

Plastic Types	
Type	**Description**
Composites	These are special plastics, which blend properties of the other two types and other ingredients to get the desired special results. An example of this type is sheet-molded compounds (SMC), which has gained some favor as an external body panel. In fact, complete vehicles are being produced with exterior body panels made largely of this substance.

Unmarked plastics

As we remarked earlier, if the part in question is not clearly marked, you are faced with the trial-and-error method to determine the type of material used to manufacture it. You may be asking why composition is important. We will answer this by saying the world does not exist in black and white; instead, it contains many colors. Similarly, plastics are not only one type or the other; instead, there are many different types (especially composites). This makes it difficult to determine the appropriate type when you are trying to make a repair. If you cannot find an ISO marking, you can group plastic parts into flexibility categories. One way might be to divide plastics as follows:

- Rigid.
- Semi-rigid.
- Flexible.

The type of material plays a factor in the materials/procedures you use to do the repair. By grouping them into categories, you can make a better decision about what materials to choose for the repair. Call this the flexibility test. For example, companies manufacture adhesive-type plastic repair product lines with two or more flexibility ratings. To get the best repair results, you must choose the correct compound based on its flexibility rating and how you have rated the panel needing repair. No matter the number of flexibility ratings in an adhesive product, always choose the one most closely related to the material being repaired.

Another method that can be used to identify plastic types is the float test. You simply cut off a small sliver of the plastic in question and drop it into a container of water. If it floats, it is thermoplastic; if it sinks, it is thermosetting plastic or composite.

There is no doubt the automotive plastics industry is growing and dynamic. New substances are appearing every year. We have barely scratched the surface of this manufacturing process. With the information we have presented, hopefully you have gained a fair understanding of plastic identification. One thing you should take with you from this lesson is that learning is a lifelong endeavor. There is no doubt you will be a better technician if you keep up with the changes taking place in all facets of manufacturing and repair; plastic is no exception.

614. Plastic repair

As you go about your job, you find that plastics can be repaired through one of two methods: the “welding” and the “adhesive” processes. There are no hard and fast rules when it comes to repairing plastics. However, you must be sure of the plastic’s type and apply the best applicable repair. In this lesson, we will look at the characteristics of both repair methods as well as the repair of composite plastics.

Welded plastic repairs

Yes, plastics can be welded! At least the process and concept are very similar to the metal welding process. You will read more about metal welding in subsequent units. The reason for associating plastic welding with metal welding is that both substances (the base material and the filler material) are fused with each other; that is, they become one. What types of plastics can be welded? You can safely say thermoplastics can be repaired by welding, although it is not always a given.

Thermosetting and composite plastic should be repaired using different methods discussed later in this lesson. To weld or not to weld is your call as the technician on the spot. If the plastic is not easily identified, remember that simple float test previously discussed in this unit. However, always remember, that if there is any doubt, your best bet will be to ask your supervisor or other more experienced technicians.

Now we have reached the point where it is time to talk about how you actually do welding on plastic.

"Welded" Plastic Repair	
Process	**Description/Discussion**
Hot Air Plastic Welding	This method uses an electrical unit that generates heated air at high temperatures. The unit forces a stream of heated air at a rate of about 3 pounds per square inch (psi) down a special "torch" head to the weld site. You may have to adjust this rate to accommodate the thickness of the material. The unit may also have the following three types of tips: 1. Tacking tip–Shaped to tack weld broken sections of plastic together. 2. Round tip–Used to make short welds, repair small holes, and weld hard-to-reach places and sharp corners. 3. Speed tip–Holds, feeds, and preheats the plastic welding rod into the weld area and is used for long and straight welds.
Airless Plastic Welding	This method uses an electric-heating element to melt a smaller diameter rod (much like an electrical soldering gun) with no external air supply. Use of a smaller rod helps eliminate panel warping and excess rod buildup.
Filler Material	With either type, you use a filler material, which comes in the form of a long rod. There is a large selection of rods and they are made of many different materials. The best way to match up the proper rod material with the material being repaired is to match the ISO symbol. If you cannot determine the ISO symbol, you will have to determine the correct rod to use by performing a preliminary test. We will call it the "melt test." The basic concept of this test is to try several of the most sensible choices of rod and melt them into a hidden portion of the repair panel. The rod that adheres much better than the others is the one that most closely matches the properties of the material being repaired. Obviously, you should use this one.

Just as with any other automotive task, once you have decided to weld a panel, your next step is proper preparation and procedures. The following applies to both hot air and airless plastic-welding procedures.

1. Remove residue (road dirt, silicone compounds, etc.) by washing the locality well with soap and water first. Then wash with a plastic cleaner. Do not use solvents, thinners, or reducers for cleaning.
2. Prepare the damaged area (crack, break, or tear) by cutting a channel in the shape of a "V." The use of a single or double "V" joint (fig. 2–18) is dictated by the material's thickness and ability to get to the backside of the repair area.
3. Bevel the part being repaired $^{1}/_{4}$ inch on each side of the damaged area.
4. Tack weld the break or tape the break line with aluminum tape to prevent movement of the area during welding.
5. Select the welding rod best suited for the plastic being repaired and the type of damage.
6. Make the weld. The weld should penetrate 75 percent of the base material (single "V"), or the second weld should fuse with the first weld (double "V").

7. Allow weld to cure and bond for at least 30 minutes.
8. Grind and sand the weld to achieve the proper contour and apply a flexible filler and topcoat.

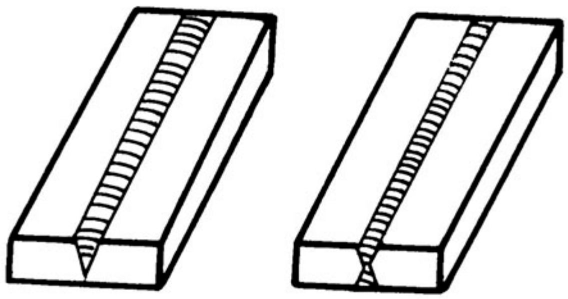


Figure 2–18. Single and double "V" butt joints.

Adhesive repairs

At this point in your career, you should be familiar with using adhesives to repair items. The two basic adhesive categories used in plastic repair include one-part and two-part adhesives.

One-part adhesive repair

Cyanoacrylate (CA), sometimes known as a "super glue," is one-part repair adhesive. It is a fast-curing adhesive that can be used to repair rigid and flexible plastics. It can also act as filler or to tack parts together before applying the final repair material. It is an invaluable tool for the repair of plastics and sets up very quickly. Although it is one-part adhesive, an activating agent can be added to improve the bonding process. There are no hard and fast rules in the use of a CA other than it does not work as well on some plastics. The rule of thumb, as with any chemical compound, is to use products from reliable suppliers and always follow the manufacturer guidelines for their use.

Two-part adhesive repairs

Most adhesive repairs are made with a two-component adhesive product. While there are many such products on the market, they typically consist of a resin base of polyester, epoxy, or urethane. They also use a hardener or catalyst as the second component. There are many manufacturers and their products come with varying flexibility ratings. There are *no preferred products*, so choose the one most like the material to be repaired.

The best recommendation is to choose one manufacturer's system and stick with it. Doing so will give you consistent results and allow you to concentrate efforts on the repair. In keeping with this "system" approach, find the manufacturer's product that produces the best repairs at the least cost and effort to you. *Do not* mix individual components from different manufacturers. When we say, "use one manufacturer's system," this also includes preparation materials.

WARNING: **Use the correct adhesive!** When working with adhesive repairs, use the manufacturer categories to decide on a repair product and procedure. The vehicle manufacturer's repair manual is the most accurate source of information. The service manual will recommend products and procedures for the exact type of plastic in the part.

You might be tempted to use thinners or reducers to clean the area you are repairing. *Do not do it!* The chemicals in these substances can damage the area (depending on the material) enough to make it impossible to repair. Regardless of manufacturer, the following are common preparation steps for all repairs:

1. Initially, clean the material with soap and water and then with a plastic cleaner.
2. Ensure both the part and repair materials are at room temperature for proper curing and adhesion.

3. Thoroughly mix adhesive materials and in the proper proportions as needed.
4. Apply material within the time limits established by the manufacturer.
5. Follow curing times established by the manufacturer.
6. If heat is recommended during the curing process, ensure the heat source is regulated.
7. Properly support the part being repaired to ensure no movement occurs during the curing process.
8. Follow the product procedures for guidelines on when to reinforce a repair.

Some plastics repairs require the use of an adhesion promoter. A following simple test will tell if this is the case.

1. Lightly sand a hidden spot on the piece with a high-speed sander and at least 36-grit sandpaper.
2. If the material gives off dust (most plastics will), then it can be repaired with standard plastic adhesives.
3. If the material melts or smears, you need to use an adhesion promoter.

Composite plastic repair

As stated at the beginning of this lesson, composite plastics are a combination of plastics with other materials. In other words, the plastic is being reinforced. Due to the reinforcement method, composites require a different approach when conducting repairs. There are many different types of composite plastics; however, for our purposes we will concentrate solely on reinforced plastic repair materials and methods.

Adhesives

Many materials used in reinforced plastic repair are two-part adhesives. This simply means that there is a base material and a hardener that must be mixed for the adhesive to cure. The manufacturer also has an established work life or open time, which is the time that the adhesive can be disturbed during a curing process and still be able to maintain a good bond. Temperature and humidity can affect the work life/open time; therefore, be aware of your work-area environment. Always remember the manufacturer's recommended work life/open time after mixing an adhesive.

Fillers and glass cloth

Two types of fillers, cosmetic and structural, are specifically formulated for reinforced plastic repair.

1. Cosmetic filler is typically a two-part epoxy or polyester type with a hardener. It is used to cover up minor imperfections.
2. Structural filler is typically a two-part filler used to fill larger gaps in a panel.

Curing time and heat temperature are critical in application of these fillers. If the product is not properly heated to a full cure, shrinkage will occur with time. If the product does not contain heat-curing ranges, a good rule of thumb is to heat the filler at a temperature higher than the highest temperature that the vehicle will be subjected to while on the road. For example, a black vehicle sitting in the sun will attain temperatures of about 170° F. However, always check for manufacturer's cure times and recommended heat ranges. Generally, most products with heat-curing requirements will range from 200° F to 250° F for about 20 to 40 minutes.

Another invaluable repair material is the glass cloth. This is essentially fiberglass cloth. There are several types available; however, only a few are adequate for reinforced plastic repair. These include the unidirectional cloth, woven cloth, and nylon screening. These types of cloth have no random layers of fiberglass strands, making them ideal for repairing large damaged areas due to the fact that the fibers will not stick out at odd angles. The random layers of roving fiberglass cloth make it a poor choice in composite plastic repair. Instead, they are used in conjunction with structural adhesive in the two-sided repair method.

Single-sided repair

Damage that does not penetrate or break the rear side of the panel can be repaired by using the single-sided repair procedure. The object of this repair is to bevel deep into the panels, on all sides of the break, to expose the fibers in the panel. The exposed fibers of the beveled area aid in bonding the adhesive to the panel. After the damaged area is prepared, you will use the two-part structural filler to fill in the damaged area. After the proper curing time, sand the filler to match the contour of the original panel. Sand to a finished quality and then paint.

Double-sided repair

Damage that passes all the way through the panel will be repaired using the double-sided repair procedure. The key to this repair is the use of a backing strip or a backing patch, depending on the damage type, as structural support for the panel. This not only restores the integrity of the reinforced panel, but it also provides the foundation needed to form the exterior surface. You will apply the beveled-edge concept to this repair as well; try to maintain a 30-degree angle on all edges. After the damaged area is prepared, you will use layers of activated resin-soaked glass cloth to form a patch over the inner and outer areas. Once the patch is properly shaped and cured, you will apply the structural filler until the damaged area is filled. After the proper curing time, sand the filler to match the contour of the original panel. Sand to a finished quality; then paint.

Repairing plastic will be a trial-and-error process. After a few years of experience, you will be able to better determine what type of plastics you are dealing with and what repair methods work best. Always remember to enlist the aid of your supervisor, trainer, and other qualified personnel to help you determine the best way to make a repair.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

613. Automotive plastics

1. What organization has developed a recommended standard for identifying plastic parts, and what is the standard’s title?

2. List four objectives a part manufacturer who conforms to the SAE recommended standards should follow.

3. How does the SAE recommend plastic parts should be marked?

4. What are the three categories of plastics?

5. Which plastic category can be softened with heat repeatedly?

6. Which plastic category cannot be softened with heat once in its final form?

7. If you cannot find an ISO marking, how could you group plastic parts?

8. How might you divide plastics?

614. Plastic repair

1. Generally speaking, what types of plastics can be welded?

2. Describe the two types of electrically-based plastic welding equipment.

3. What is the best way to match up the proper plastic filler rod material with the material being repaired?

4. How are most “adhesive” plastic repairs made?

5. What substances provide the resin base in two-component adhesives?

6. Why should you refrain from using reducers and thinners to clean (prepare) a repair area?

7. How should you initially prepare a plastic panel for adhesive repair?

8. What two fillers are specifically formulated for reinforced plastic repair?

9. Name the three types of glass cloth that can be used for reinforced plastic repair.

10. Which reinforced plastic repair procedure uses the backing strip or patch?

2–3. Trim, Hardware, and Bumpers

Manufacturers use trim and hardware parts on both the inside and outside of vehicle bodies. These include molding, upholstered pads, bumpers, door handles, window regulators, locks, latches, hinges, clips, and chrome strips. In this and the following lessons, we will look at how you replace or repair many of these items. We will specifically cover the following:

- Hard and soft vehicle trim replacement.
- Door lock mechanism and hinge replacement.
- Bumper replacement and repairs.

615. Vehicle trim

When a vehicle suffers major damage to the roof and sides, you must remove and replace the interior trim. To do this, it is essential for you to understand how these assemblies attach to the vehicle body. Because there are so many designs and removal and installation methods, the information we will present is general in nature. For vehicle-specific procedures, refer to the applicable technical order for the vehicle you are repairing.

Vehicle trim covers items such as trim panels, weather seals, headlining, moldings, and bumpers. Most interior trim is considered soft trim because it is mainly upholstered items. The interior construction and the methods of attaching the linings and moldings vary somewhat on the different vehicle makes and models. For this reason, always consult the applicable technical order. In contrast, moldings (found both inside and outside the body) and bumpers are classified as hard trim.

Door trim and hardware

Figure 2–19 shows a typical front door assembly. Whenever you repair the outer door panel and adjust or replace the inner hardware, you normally remove the inner door coverings. These include the trim panel, door lock knob, window handle, and arm rest. Remember, your job is easier if you select the correct tool for a specific task.

Removing Trim Panels	
Part	**What To Do**
Window Handle	This requires special clip-removing tools. Because there are a wide variety of these tools to fit the many clip designs, consult the appropriate technical order.
Door Lock Knob	The door lock knob screws onto the door lock link rod (not shown in figure 2–19). Simply unscrew it from the link rod.
Arm Rest	Unscrew the attaching bolts or screws.
Trim Panel	The trim panel is secured to the inner panel by retaining screws, concealed retaining clips, or plastic trim retainers (view B, fig. 2–19). **NOTE:** Be careful; do not damage the trim panel when you remove retainers. 1. Loosen the trim retaining clips by prying with a thin-blade screwdriver or specialized tool. 2. Behind the trim panel is a sheet of waterproof material (plastic or heavy paper) covering the opening to the door's interior. 3. Remove this covering carefully and handle it gently. 4. Reinstall it to deflect water and prevent wetting the reverse side of the trim panel. **NOTE:** Not reinstalling this waterproofing can cause water-leaking problems later. Always reuse the waterproof barrier or replace it if damaged. Do the same for any insulation between the trim panel and the inner panel. The insulation is important for blocking road noise while the vehicle is in operation. Installation is largely the reverse of removal.

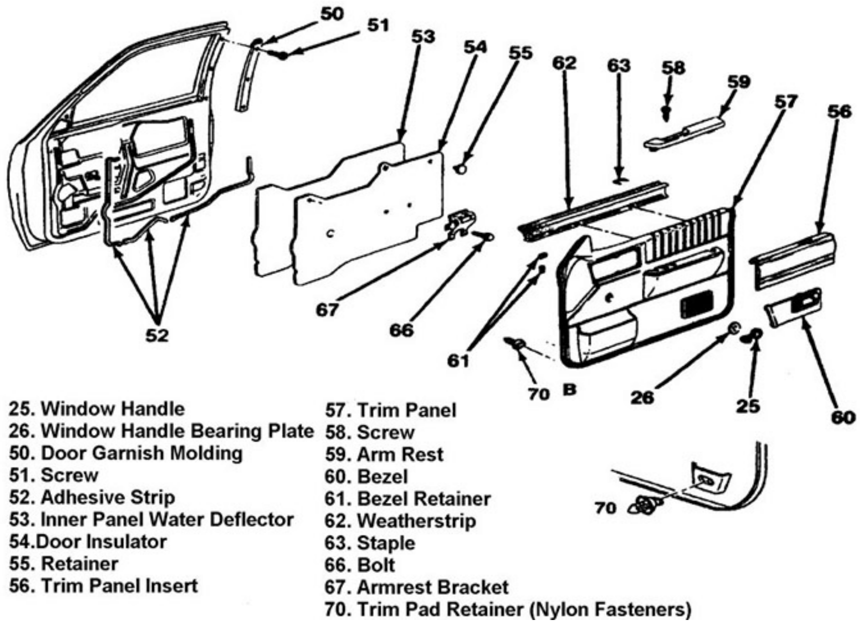
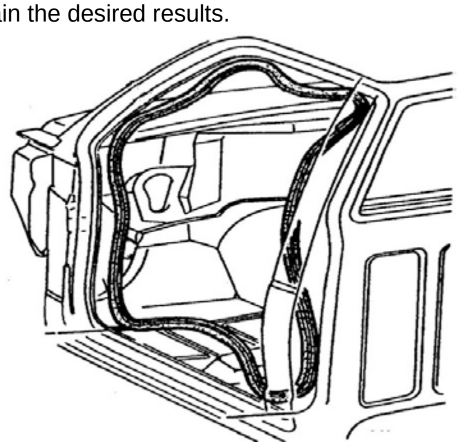


Figure 2–19. Door trim and hardware.

Weather seals

Weather seals come in many forms. The weather seals you will work with are for the door opening and the door glass. Weather seal can come manufactured for a specific purpose, such as a door opening, or it can come in rolls of various lengths and of a universal design for its required use.

Weather Seals	
Type	**Description**
Door Opening	This seals out air (cold or hot), dust, and moisture. Door opening seals are made of soft sponge rubber covered with a tough outer skin, which does not reduce the sealing effect. The weather seal maintains a tight seal between the door and the door opening of the body (fig. 2–20). It seals the sides, top, and bottom of the door assembly. On most vehicles, it is fastened to the door, door opening, deck lid opening, or door glass opening with fasteners, rubber cement, or a combination of both. When you install a door weather seal, the ends normally cement together along the bottom of the door or door opening, depending on the application. While this prevents moisture from leaking into the interior, it allows moisture to drain out. Door weather seals require very little maintenance. In cold weather, the rubber hardens and loses some resiliency, causing the door to become loose in the door opening, creating noise or rattles. You can rejuvenate the rubber by applying a good rubber softener solution or silicone compound. If the rubber is dry, it may take several applications to obtain the desired results.  **Figure 2–20. Door weather seal.**

<table>
<tr><th colspan="2">Weather Seals</th></tr>
<tr><th>Type</th><th>Description</th></tr>
<tr><td>Door Glass</td><td>
These seals are usually specially constructed for the application. A door glass seal is normally a hard rubber strip with a special softer rubber face that butts against the door glass surface. The hard section acts as a buffer between the metal of the door and the door glass, keeping foreign material from collecting in the door. The soft section acts as a wiper when the glass is wet.
The seal (fig. 2–21) is attached by special retaining clips. These may be imbedded into the rubber to make the seal a one-piece design or the retainers may be separate.
You will most likely replace these weather seals after they become weather damaged through years of use. Replace them as follows:

Remove the door trim panel.
Drop the glass from its track to remove and replace the inner and outer door glass seals.
Remove the old seals from the door by removing their securing clips.
Install the new seals by reattaching the securing clips.
Reuse old serviceable clips if necessary and applicable.

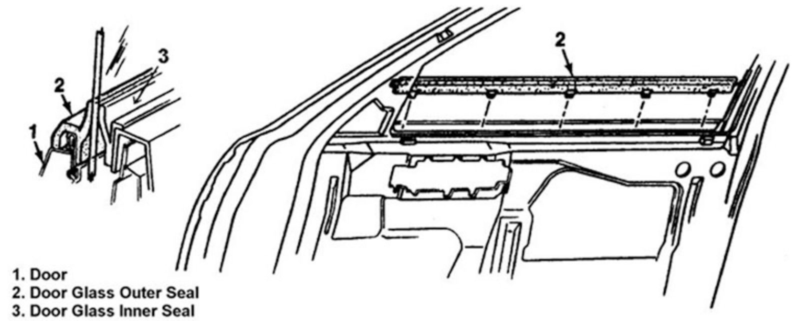
NOTE: Embedded clips require you to remove the seal as a unit.


Figure 2–21. Door glass seals.
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Headliners

Normally, the only time you need to remove and replace a headliner is when you are doing metal work on the roof panel. If the headliner material tears, consider replacing the complete headliner. Before removing the headliner, always refer to the applicable technical order; it can guide you in removing the headliner without damaging it or related parts. Before removing the headliner, you must remove the garnish molding around the upper door openings and windows (front and rear), sun visors, coat hooks, and shoulder seat belt anchor.

Dash pads

The panel that covers the instrument panel; heating, ventilation and air-conditioning (HVAC) components; and other components in front of the passenger compartment is referred to as the dash or dash pad. Some older vehicles and heavy equipment have metal dashes with a vinyl-covered pad on them to protect occupants from the hard metal in a crash. This type of dash pad is easy to repair or recover with new vinyl. It is a simple nuts and bolts procedure to remove the pad and replace the worn padding and vinyl. On newer vehicles, this panel is generally plastic that may be textured and dyed or may be covered with vinyl. The modern dash assemblies are much more involved, yet there are commercially available repair kits you can use to repair minor cracks. However, as long as they are serviceable, they are often not repaired. If it becomes necessary to remove or replace the dash, refer to the applicable technical order for the proper procedures. It may be necessary to remove other interior trim or other dash components first. One instance where you may need to remove the dash is to replace a vehicle's HVAC system components.

CAUTION: If dealing with airbag systems, ensure you follow manufacturer's procedures during disarming, removal, and installation of airbag components. Failure to do so could result in accidental air bag discharge and serious injury.

Moldings

There are many different kinds of molding in automotive applications; as a result, it is impossible for us to cover every application. However, we will discuss body side moldings and rocker panel moldings, two of the more common types. In addition to these two, we will very briefly touch on some other types of molding.

Body side moldings

The body side moldings (fig. 2–22) usually attach by an adhesive backing on the molding. These moldings are often made of extruded plastic with "two-way" (sometimes called double-sided) tape. To install or replace the optional body side molding, follow the steps in the following table.

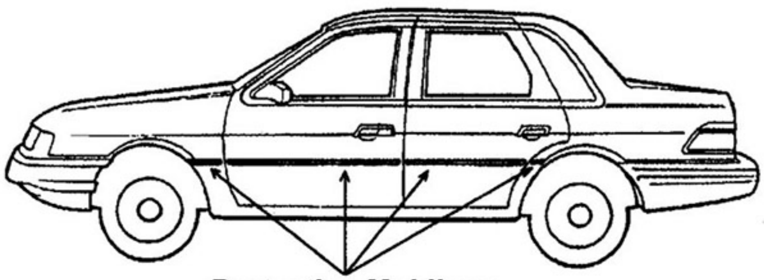


Figure 2–22. Exterior body side protection moldings.

Removing Body Side Molding	
Step	**Action**
1	Before replacing a body side molding, completely clean the sheet-metal surface area around the old molding. Use isopropyl alcohol and a clean soft cloth.
2	Mark the old molding's location at the top and each end with masking tape. Do not heat the molding or sheet metal surface; this only increases the adhesion. Cold temperatures (32°F and below) allow for easier removal of molding.
3	Using a nylon wedge, start at the rear of the body panel. • Wedge the nylon tool between the molding and the panel. • At the same time, pull the molding away from the panel with steady tension. Remove and replace one molding at a time.
4	Once a few inches of molding are free, grip the molding with both hands and pull it slowly toward the front of vehicle. Be careful not to damage the paint or sheet metal surface.
5	Not all of the tape will come off with the molding. The residue left on the sheet metal (white or gray acrylic tape) is easily removed by gently stretching it. • Grip the tape at one end, lift, and pull away slowly about $^1/_2$ inch at a time. • Then grip it and pull again. Remove small pieces by rolling your thumb across the sheet metal surface.
6	When all the tape is removed, wipe the area with isopropyl alcohol and a clean soft cloth. This will help to ensure all tape residue and road dirt is removed. A clean surface is required to apply the new molding. Repair any damage you may have caused to the sheet metal surface as you removed the molding. This will protect against sheet metal corrosion. A scratch left untreated begins corroding immediately.

Although the new molding is ready to be applied, temperature is an additional factor to be considered before proceeding.

Avoid installing body side moldings on a vehicle unless the sheet metal surface temperature is above 80 ° F and the molding is at 70 ° F (minimum). This does not mean that you have to make a precise check of the metal or molding temperature, but neither should be cold to the touch prior to installation. You should not try to install a new molding immediately after bringing a vehicle into the shop from very cold outside conditions. Always allow the vehicle some warm-up time to reach ambient temperature. Why? While colder temperatures allow for easier molding removal, they have the opposite effect on adhesion. Simply put, molding applied to cold sheet metal does not stick well! Once you have allowed the vehicle to reach ambient temperature, you are ready to install the new molding. To do that, use these procedures.

Installing New Body Side Molding	
Step	**Action**
1	Position yourself toward the front of the panel you are working on. • Pull back the tape protective liner approximately 3–4 inches. • Do not touch or contaminate the tape surface.
2	Line up the new molding with the marks you made using the masking tape at the rear of the panel (see Removal, step 2). Press gently forward, toward you, on the panel. Remove the tape's protective liner as you proceed forward. **NOTE:** Be sure the part is lined up correctly; once the tape sticks, the molding cannot be adjusted without damaging the tape backing. This procedure is usually a one-time deal. As such, it has to be done right the first time or you may have to start over with a new molding (which is costly).
3	Remove the masking tape you used to mark the position of the old molding. Wipe the area under it with isopropyl alcohol to remove tape residue. Do not use too much alcohol at this point. Excess alcohol can run down the sheet metal and work its way under the molding tape. If this happens, the molding tape in the affected area will not stick to the sheet metal panel.
4	Press the molding on with a hand roller. Use a *minimum* of 20 psi of pressure to ensure positive tape adhesion.

Rocker panel moldings

Rocker panel moldings (fig. 2–23) are another type of molding you will work with. Different manufacturers use different means of attaching the molding to the panel.

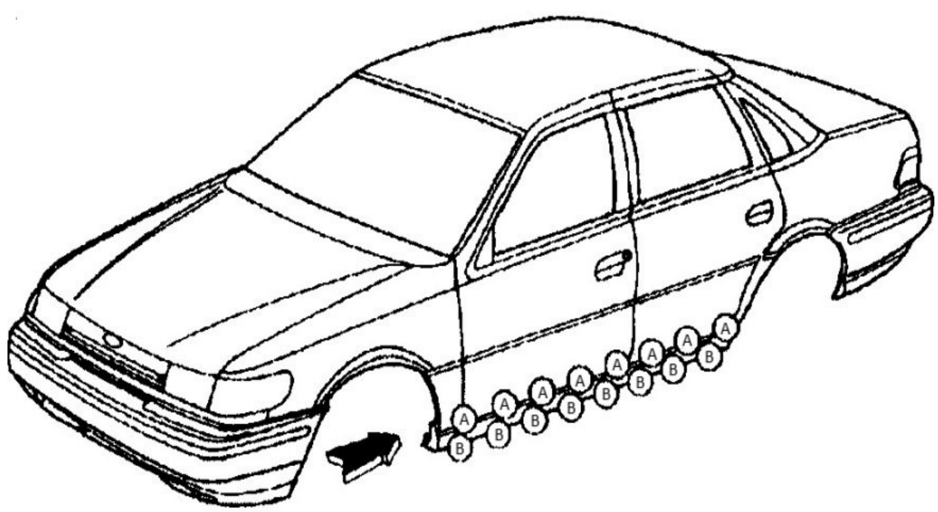


Figure 2–23. Rocker panel molding.

Figure 2–24, View A, shows the molding retainer is secured to the vehicle with pop rivets. A sharp bend in the molding locks into the molding retainer. The molding retainer can be replaced by drilling out the pop rivets and re-riveting a replacement back into the existing rivet holes. In figure 2–24, View B, the molding is secured to the underside of the rocker panel with an expanding screw. In figure 2–24, View C, you can see that a standard sheet metal screw secures the front section at the wheel well. Replacing this type of molding is simply a matter of removing the proper screws and reinstalling the replacement molding.

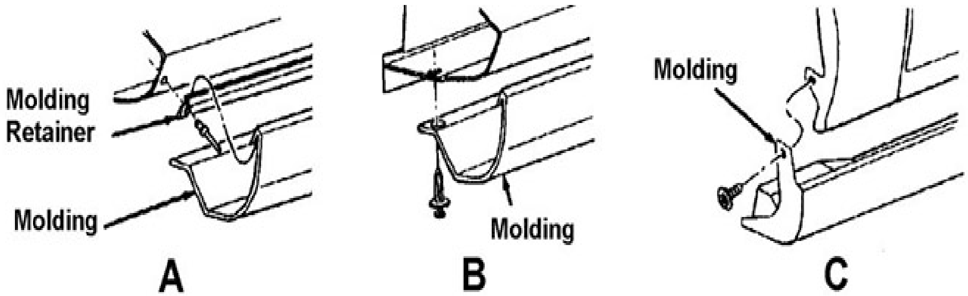


Figure 2–24. Rocker panel molding detail.

Other types of molding

Body side and rocker panel moldings are not the only moldings you will work with; there are many others. Some moldings are purely decorative and appear as trim (body side and rocker panel molding), whereas others are functional; for example, the reveal molding around a windshield that helps protect the rubber seal. Some moldings come in sections; when damaged, you replace only the damaged section. These moldings are made of various materials: metal, plastic, or other synthetic materials. Both of the types of molding we discussed earlier meet this description perfectly. Moldings are held in place by fasteners like those in figure 2–25. There is a large variety of fasteners for attaching moldings as well as many specialized tools for removing moldings. Experience dictates which ones work best for you.

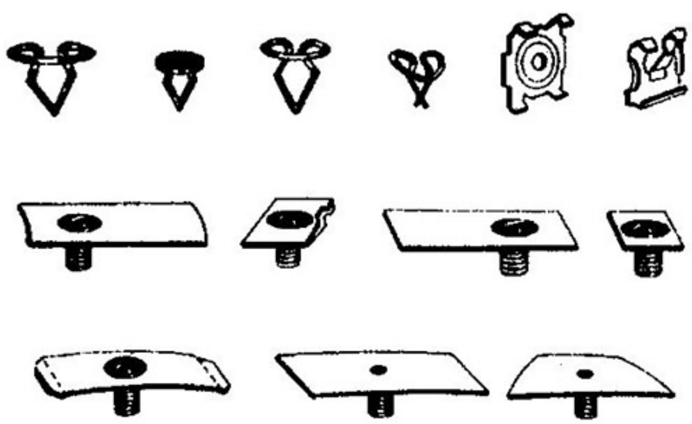


Figure 2–25. Trim fasteners.

616. Lock mechanisms and hinges

Vehicle door locks and hinge mechanisms are normally very dependable items; however, there will be times when you will have to repair or replace these items. In this lesson, we will cover the basics of both lock mechanisms and hinges. Like some other discussions, these are general principles that apply to all locks and hinges; for specific vehicle guidance consult the specific vehicle technical order.

Locks

Door locks normally require little maintenance other than applying a general-purpose lubricant to keep the lock mechanism in good working order. However, after many years of service, or if the locks have not been properly lubricated during scheduled maintenance, the lock may fail. Figures 2–26 and 2–27 illustrate the various components of a typical door lock mechanism. Refer to these figures as we describe how to replace a typical lock mechanism. The procedure we describe is an example only; the procedures will vary from vehicle to vehicle. To replace the lock mechanism, follow the procedure described in the table.

Replacing a Lock Mechanism	
Step	**What To Do**
1	Remove the door trim panel.
2	Disconnect the lock cylinder rod from the lock cylinder.
3	Disconnect the inside lock handle rod.
4	Disconnect the inside door handle rod.
5	Disconnect the outside handle rod.
6	Remove the lock screws.
7	Remove the lock mechanism.

NOTE: At this point, it is appropriate to stress a simple check to do **whenever** you have a vehicle door disassembled: ***check the drain holes at the bottom of the door***. Sometimes these become clogged with leaves, trash, or undercoating material. By ensuring these drain holes are open, water cannot collect and start the corrosion process. Making this check saves you many hours of corrosion repair work later.

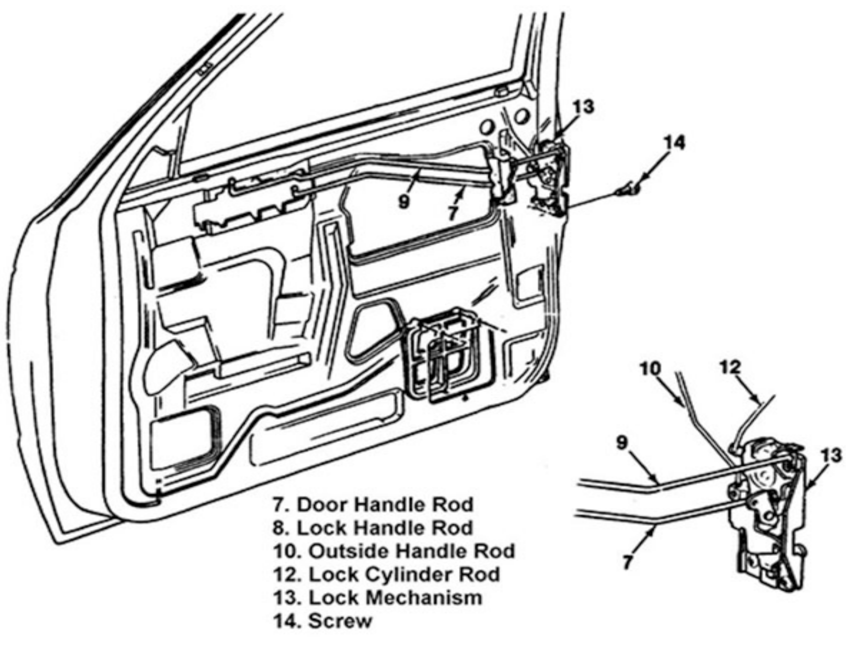


Figure 2–26. Typical door lock mechanism (lock half).

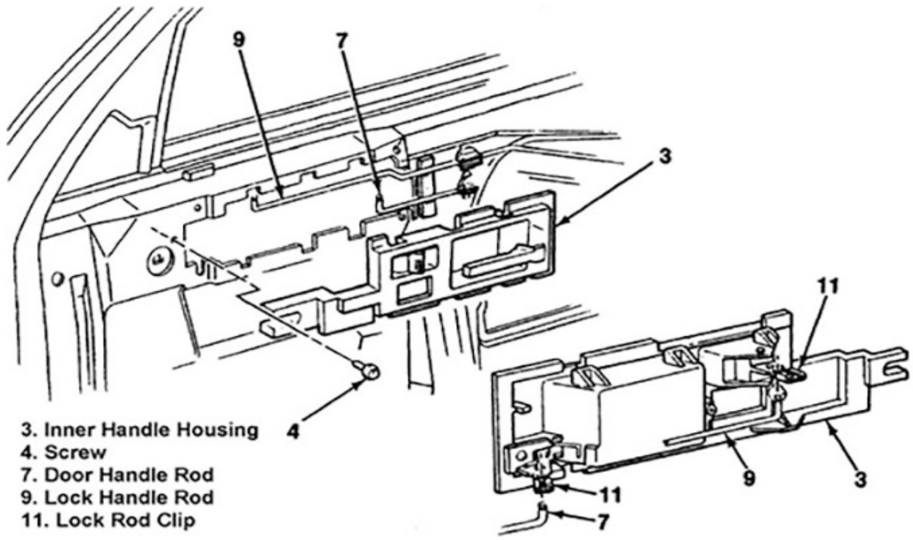


Figure 2–27. Typical door lock mechanism (handle half).

As you make your repairs, try not to bend the linkages that connect the lock to the various other components. The securing clips for the lock rods vary with the vehicle manufacturer and type of connection. Figure 2–28 is a detailed illustration of the door handle rod and the lock handle rod connection at the inner handle housing (fig. 2–27). The lock screws (fig. 2–26, item #14) are usually tapered-head, Phillips (cross-tip), or Torx head bolts. When screwed fully in, these are flush with the door surface. Why flush? Well, a bolt head protruding between the door and the door opening would not allow free movement of the door as it tries to slide past the opening when you close it.

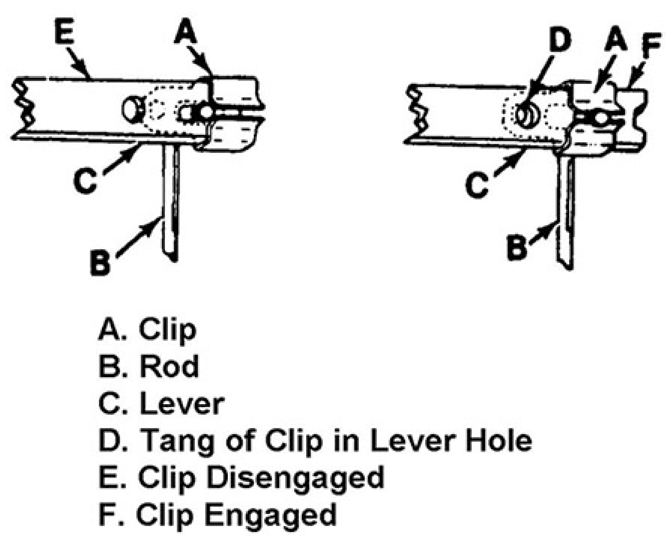


Figure 2–28. Lock rod clip.

NOTE: You may have to loosen a few other inner door components to remove the lock mechanism through the opening in the inner panel of the door. Be careful, as the edges of the door's inner panel are often very sharp! As a result, when removing or replacing a lock assembly, it is a good idea to wear a long sleeved shirt with the sleeves pulled down or wear light gauntleted gloves.

To replace the lock assembly or install a new lock assembly in the door, follow the steps listed in the following table.

Installing a Lock Assembly	
Step	**What To Do**
1	Place the new lock inside the door assembly.
2	Connect the outside door handle rod. This helps reassembly by holding the lock roughly in position for the next step.
3	Insert and tighten the lock screws in the lock assembly. Consult the appropriate vehicle technical order for tightening specs.
4	Connect the lock cylinder rod to the lock cylinder.
5	Connect the inside lock handle rod.
6	Connect the inside door handle rod.
7	Install the door trim panel.

Hinges

Hinges are a relatively simple subject in the automotive arena. However, you will find that repairing, replacing, and adjusting them can and often is a major part of your workweek. At the risk of sounding repetitive, it is impossible to provide information on all the possible ways to replace door hinges. There are just too many different models to cover them all. Use the technical order for the complete procedures. The information we will present highlights the general procedures for replacing front door hinges. In this discussion, we focus on two types: bolted-on and welded-on hinges. One thing you should do, regardless of the type of hinge, is mark or scribe the location of the old hinge. This simple step will save you time later during door adjustment.

Bolted-on type

As we discuss the hinge replacement process, refer to figure 2–29, an exploded view of a bolted-on door construction. Like many procedures, there are some preliminaries before you actually get to replace the hinge. The bolted-on hinge is no exception. Your first and, some say, most important step is to find something to help hold the weight of the door as you remove it from the vehicle. If available, use the special equipment designed for this purpose. If not, you can use a common hydraulic floor jack with a block of wood as a buffer between the door and the metal jack. For this method, raise the jack under the center of the bottom surface of the door. Keep the wooden block between the bottom of the door (and lightly resting on the bottom of the door) and the jack-lifting surface. Once you have the door supported, you can start the hinge removal process.

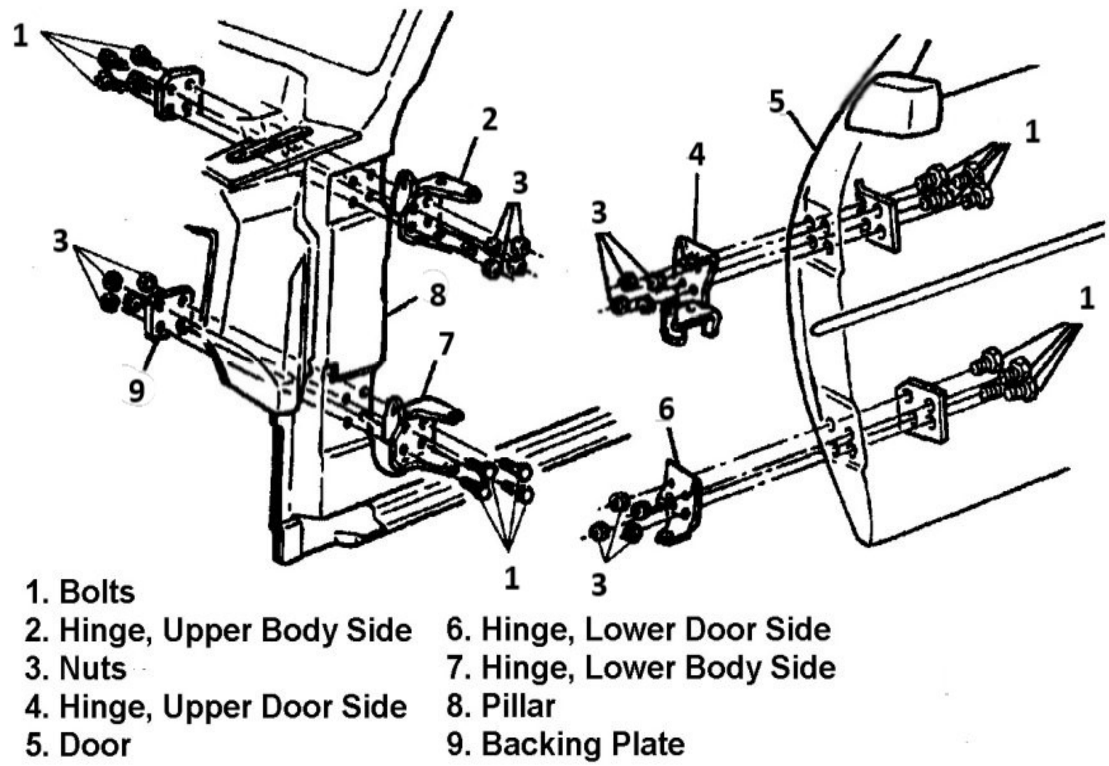


Figure 2–29. Bolted-on door construction.

The following table provides a description of how to remove the bolted-on type hinge.

Bolted-On Hinge Removal		
Step	**What To Do**	
1	First remove the bolts on the door side of the lower hinge. **NOTE:** The upper hinge bolts and the lower hinge will still support the door. Generally you will not have to worry about the weight of the door until you have the bolts of the upper hinge almost out because the door stays balanced on the upper and lower hinges.	
2	Remove the bolts on the door side of the upper hinge. **NOTE:** Be ready to steady the door on the jack. Have a co-worker ready to assist you in moving the door from the jack to the floor.	
3	Remove the hinges from the body pillar. **NOTE:** The complexity of the job depends on whether the bolts are “innies” or “outies”—yes, you read it correctly. When the heads of the hinge attaching bolts are on the outside of the pillar, you are dealing with “outies.” You are dealing with “innies” when the hinge bolts are screwed through the body pillar from the vehicle interior into the hinge.	
	Outie	If you are dealing with outies, you can jump for joy. Removing this hinge is relatively simple, as shown in the following two steps: 1. Mark the position of the old hinge. 2. Remove the bolts holding it to the pillar. **NOTE:** By marking the position of the hinge, it will aid you when installing the new hinge. It gives you a reference point in relation to the position of the old hinge and saves time.
	Innie	If the attaching bolts are innies, then the task can be a bit more difficult. With innies, you’ll have to perform the following: 1. Remove any trim, access panels, or other interior components that preclude access. **NOTE:** On some vehicles, this means moving/removing the dash or the glove compartment. Often though, you have some room to maneuver under the dash.

Bolted-On Hinge Removal		
Step	**What To Do**	
		2. Next, remove the hinges with a ratchet, socket, universal, or swivel joint, and a long extension. Experience helps in this situation. Once you have done it a few times, the process goes much faster.

CAUTION: Be careful of electrical connections during removal. This includes power window connections, door speaker connections, air bag wiring, or other components. The technical order will list any safety considerations regarding door hinge removal.

Remember: **When power equipment is involved, always disconnect the battery.**

Replacing bolt-on hinges is much the reverse of removal. The difficult part is getting the new hinges back in their proper place. You should have marked their positions on the body pillar AND the door before removing the old ones. When you have the door in place, snug the bolts enough to carry the weight of the door. Do not permanently tighten the hinges into position. After you have the hinges mounted and the door back on the hinges, you may have to loosen bolts to finely adjust the door to the opening.

Some technical orders list recommended tolerance measurements around the closed door opening. However, the operational stress and strain demands placed on an Air Force vehicle sometimes make it extremely difficult for you to quickly meet these tolerances. In any case, the door should operate properly with a natural look and have no leaks. Water leaks are a major consideration when reinstalling hinges and doors. Test your work before releasing the vehicle.

Welded-on type

Welded-on type hinges add another layer of complexity to the task of replacing door hinges. As you would expect, there are many different applications of welded hinges on many differing vehicle models. Again, we will only discuss the high points.

CAUTION: Always disconnect the vehicle battery and air bag systems *before* welding on any part of a vehicle body.

Like bolted-on hinges, you have to hold the weight of the door when it is released from the vehicle's pillar. You also need a co-worker available for the moment when the door comes loose. He or she can help you maintain balance and move the door to a safe place.

In the welded-on type, you remove the door by removing the hinge pins rather than removing bolts. Remove the hinge pin in the lower hinge first. After the door has been removed from the hinge halves, you can begin the work of removing the hinge halves from the door and the pillar. Follow on figure 2–30 as we cover the remaining steps in the process.

Removing Welded-On Hinges	
Step	**What To Do**
1	Scribe or otherwise mark the position of the old hinges on the body pillar and the door. (Both halves may be welded)
2	Center punch each of the circular welds on the original hinge halves. **NOTE:** Usually, there are as few as three, most of the time four, and as many as five welds per hinge half. It is critical you punch the *center* of the weld to ensure *only* the weld is removed.
3	Drill a $^{1}/_{8}$-inch pilot hole through each of the circular welds. Ensure to drill only deep enough to penetrate the width of the hinge base.

Removing Welded-On Hinges	
Step	**What To Do**
4	Using the $^1/_8$-inch hole as pilot, drill a larger hole through each of the circular welds on the hinge base. Use a drill of the same width of the circular weld—roughly $^1/_2$ inch.
5	To separate them from each other, drive a chisel between the hinge and the pillar or door (depending on which hinge half you are removing).

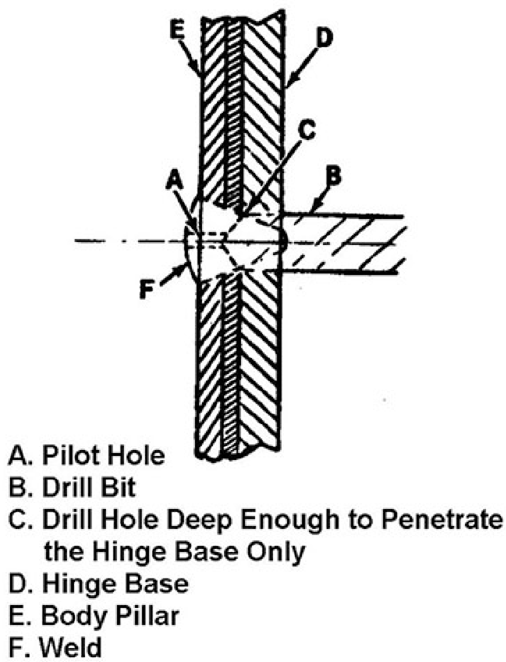


Figure 2–30. Drilling out welded-on hinges.

Again, you may need to move/remove several items prior to or during these procedures. For example, you may have to move/remove the dash or the glove compartment to get at an upper hinge. On some models, you may have to remove the electronic control module (ECM) from its mountings. Remember to take all precautions mentioned in the technical order, especially those pertaining to the ECM, which could be damaged by static electricity.

The replacement hinges are usually the bolt-on variety. In the following example, the hinges possess some form of tapped (threaded) backing plate, which you insert behind the hinge pillar. The hinge bolts and, hence the hinges, are then secured to this backing plate. When you are ready to begin installing the new hinges, perform the steps in the following table.

Replacing Welded-On Hinges	
Step	**What To Do**
1	Position the bolt-on replacement hinges, one at a time, within the scribe marks.
2	Be sure to center punch each bolt hole location on the body hinge pillar and the door.
3	Drill a hinge-attaching hole in three steps (three different bit sizes) to ensure you get the hinge mounted in the proper position. The initial hole must be well centered or the job can begin to become progressively difficult to complete. Drilling holes to $^1/_2$ inch will allow for adjustment later.
4	Finish the surface with a file or equivalent. Corrosion protect the mating surfaces with a medium-bodied sealer.
5	Align the hinge and backing plate with the holes in the hinge, pillar, and door.

Replacing Welded-On Hinges	
Step	**What To Do**
6	Place the bolts through the hinge, pillar, and/or door. Secure them to the backing plate.
7	Snug the bolts only and adjust the door to the door opening.

If you have done everything just right, you should be able to adjust the door by loosening the appropriate hinge bolts for upward, downward, or forward, rearward movement. Do not forget to tighten them down when you get the door into its final, adjusted position. The technical order will give torque specifications if required.

Bushings

Now that we have been through all that hard work, let us talk about a simpler method of accomplishing hinge surgery. Some vehicle models incorporate door hinges equipped with replaceable hinge pins and bushings. You can save much of the labor involved in hinge replacement by checking to see if the vehicle you are working on uses hinge bushings. If so, bushing kits are available from some vehicle manufacturers. These speed repairs and reduce parts costs because they are cheaper than replacing the entire hinge.

Since most vehicle door hinge problems center around the hinge pin and the bushings surrounding it, replacing the hinge bushings is preferable to replacing the entire hinge. This is precisely the reason bushings are used—they are replaceable. Bushings are made of a softer material than the surrounding hinge halves and hinge pins. They take up the space between hinge pins and the hinge halves and keep them firmly fastened with little movement (other than rotational) between the pins and the halves. After lots of use they wear, and the joint between the hinge halves becomes sloppy. If enough wear occurs, the door eventually comes to the point where it will not shut properly or water leaks develop.

You can check the state of the hinge pins and bushings by opening the door about half way and lifting on the rear portion of the door. If the door hinges have any play, it is most likely generated because of the slop (play or looseness) between the pins, bushings, and hinge halves. The solution is replacing the bushings.

617. Bumpers

Sometimes bumpers are considered as both hardware and trim because of their styling and chrome. However, they are very functional because they protect the grill, radiator, frame, fenders, deck lid, and rear panels.

Bumper construction

Manufacturers construct bumpers and brackets from a strong and flexible steel alloy. This feature allows these assemblies to spring back, to a certain extent, in the event of a minor collision. Some bumpers are constructed of two- or three-piece sections; if one portion is damaged, you can replace it. You can sometimes repair damaged bumpers by straightening them in a hydraulic press designed for this purpose. However, chrome-plated bumpers can be defaced (damage the chrome plating) in the repair process.

Sometimes you can straighten a chrome-plated bumper, remove the old chrome, and apply new chrome. However, if there is too much straightening to accomplish, it is often advisable to replace the assembly.

NOTE: Do not attempt to weld on a bumper assembly unless the welding rod is of a similar metal.

Bumpers are also constructed with a flexible plastic outer shell, or trim with either heavy steel or aluminum inner bumpers, or plastic honeycomb or foam-filled interiors. These bumpers have less overall weight and help produce a more fuel-efficient vehicle. They are also better able to withstand minor impact without damage. The outer trim, or “fascia” (as it is sometimes called), is attached to the steel backing in a variety of ways. Attachment methods may even vary on the same applications. On some models, for example, the bumper has a wrap-around feature, which allows it to attach to fenders or quarter panels. In most instances, replacing the fascia is a relatively simple task. Simply remove the plastic “push-in” fasteners, rivets, or bolts that secure the fascia to its underpinnings.

Energy-absorbing bumpers

Older vehicles have bumpers mounted directly to the frame horns. Replacing them is a simple nuts-and-bolts operation. However, the demand for safer cars with less collision damage from low-speed accidents led to the development of energy-absorbing bumpers. This bumper is designed to withstand the shock of low-speed front- or rear-end collisions. As the name implies, these designs involve using an energy-absorbing unit installed between the bumper and the frame (fig. 2–31). Notice how the piston ram attaches to the bumper and the cylinder attaches to the frame.

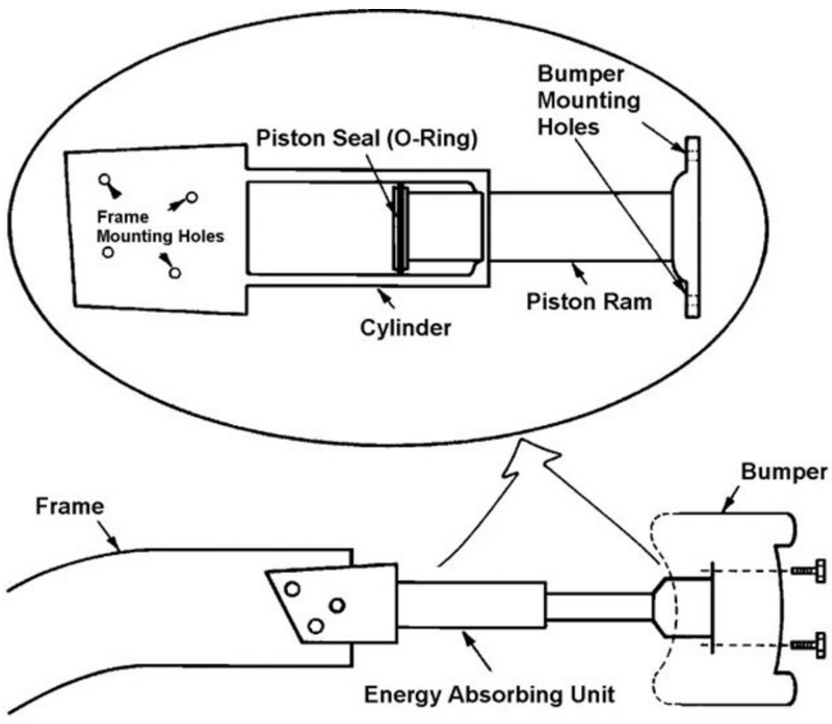


Figure 2–31. Energy-absorbing bumper.

During a low-speed collision, the energy-absorbing bumper’s piston ram retracts into the gas-filled chamber of the cylinder, cushioning the impact and decreasing the amount of damage and personal injury. As the gas compresses, the piston ram retracts inside the gas-filled chamber, increasing the pressure. When the bumper is no longer in contact with the colliding object, the excess pressure on the gas in the chamber and the slight spring tension extend the piston ram back to its original position. The piston seal prevents any of the pressurized gas from escaping.

Other energy-absorbing designs employ a coil spring and fluid-filled reservoir or rubber blocks to absorb the impact of a minor collision.

Maintenance on energy-absorbing bumpers consists mainly of testing and replacement of a defective unit. Follow technical order procedures for testing a unit because the procedures vary for different makes and models. Replacement is a matter of removing the securing bolts (plus any refinish operations necessary). Before performing any maintenance, determine the type of energy-absorbing unit you are working on and follow all technical order safety precautions carefully.

WARNING: When a vehicle equipped with a gas-filled energy-absorbing bumper has been involved in a front- or rear-end collision, no matter how minor, **BEWARE!** The absorbing unit may be jammed in the compressed position. A slight jar may cause the bumper to spring back to its original position.

Further, the gas-filled units contain a pressurized chamber that could explode if you apply too much heat to it. Therefore, *never weld on or near the gas-filled unit*. If you throw the unit away, relieve the pressure according to technical order directions.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

615. Vehicle trim

1. What attaching hardware is used to secure an armrest to the door panel?

2. How are trim panels typically secured to a door inner panel?

3. How are trim retaining clips removed?

4. Why is it very important the waterproof barrier and/or insulation material behind a door trim panel be reinstalled after disassembly?

5. When installing a door-opening weather seal, where are the ends joined? Why?

6. What are the two sections of a door-glass weather seal? What is the function of each?

7. What is the effect of heating body side molding during removal? Is it a recommended removal procedure?

8. If residue acrylic tape remains on the vehicle body after removing a body side molding, how do you remove the residue tape? How do you remove small pieces?

9. What should you use to clean tape residue and road dirt from a vehicle body before installing a new body side molding?

616. Lock mechanisms and hinges

1. What conditions may cause door lock replacement?

2. Why is it a good idea to have long sleeves pulled down or light gauntleted gloves on when replacing the door lock assembly?

3. Why do you connect the outside door handle rod before inserting and tightening the lock screws in the lock assembly?

4. What are two types of vehicle door hinges?

5. What is the first thing you need to do in door hinge replacement?

6. Why do you begin removing bolted-on door hinges on the door side of the lower hinge?

7. What should you do to the pillar before removing bolted-on hinges? Why?

8. When installing a vehicle door, why should you initially snug the bolts enough to carry the weight of the door, yet without permanently tightening hinge bolts?

9. On welded-on hinge applications, how is the door removed?

10. When removing a hinge-half weld, why is it critical you punch the center of the weld?

11. What tool is used to separate the hinge from the pillar after drilling larger holes through each of the circular welds on the welded-on hinge base?

12. How can you reduce much of the labor involved in vehicle hinge replacement?

13. Where do most vehicle door hinge problems occur?

14. How do you check vehicle hinge pins and bushings for wear?

617. Bumpers

1. What type of material do manufacturers use in the construction of bumpers?

2. What is another term used for the plastic outer shell or trim attached to a steel backing?

3. What is the purpose of the energy-absorbing bumper?

4. What is the first step in the repair procedure for an energy-absorbing bumper?

5. Explain why you must use caution when a vehicle with an energy-absorbing bumper is involved in a minor front- or rear-end collision.

6. What must you do before discarding a gas-filled unit?

2–4. Automotive Upholstery

Upholstery is the art of covering and padding seating surfaces. It is true that seats probably receive more severe treatment than any other part of a vehicle. At any given time, you are likely to find a vehicle in the shop requiring upholstery repairs. To ensure these repairs are made correctly, you must be familiar with the different types of upholstery and the procedures used to accomplish inspections in a timely and professional manner.

618. Upholstery types and repair

The two types of upholstery include flexible and rigid. An example of flexible upholstery is the use of springs in the foundation of the seat you cover; it gives when you sit on it. Rigid upholstery would have a solid seat foundation you covered with padding.

Flexible upholstery

There are varieties of flexible seat foundations you can use in upholstery. Some have regular springs, others have no-sag springs, and some have rubber webbing stretched from front to back and side to side. This type of upholstery allows part of the foundation of the seat to give together with the cushion and is also more comfortable to sit on.

Rigid upholstery

Although this type of seat is strong and durable, it is not the most comfortable. An example of rigid upholstery is a metal or wood seat framework and attaching only minimal padding and a seat cover. This type of rigid upholstery relies on the foundation to give it strength as well as to provide anchoring surfaces for attaching the cover.

Seat frames

Regardless of whether the upholstery is flexible or rigid, there must at least be a structure to attach both the padding and seat cover. Seat frames come in many variations. They range from very basic nonadjustable frames, such as the passenger seats in a school bus, to fully adjustable seats found in modern vehicles. Newer adjustable seats can recline, tilt front and back, as well as raise and lower. Nearly all front seats have a horizontal (front to back) adjustment and most can recline. Adjustment can be manual or power. Rear seats are usually nonadjustable.

Manually adjustable seats

Manually adjustable seats use simple locking track mechanisms, springs, and latches to facilitate adjustment. Manual adjustments are fairly easy to repair due to this simplicity and seldom require replacement.

Power adjustable seats

Power seat adjustments are considerably more complex, relying upon electric motors, gear drives, and flexible drive cables. It is far more common to replace power seat components; however, proper lubrication and adjustment of power seats can reduce the number of failures. Consult the applicable service manual for any maintenance procedures.

Removal and installation

Removal and installation of seats is generally a nuts-and-bolts operation. You may have to adjust the seats to facilitate removal of attachment hardware. Some seats may use shims or spacers located between the seat frame and floor pan. Ensure you install the shims or spacers in the correct position when reinstalling seat frames. Failure to do so may cause adjustment malfunctions or adversely affect driver-seating position.

Springs and cushions

Most modern vehicle seats use flexible upholstery; therefore, they have springs attached to the seat frame. As always, there are variations in what different manufacturers use. One of the more common types of springs is made from heavy-gauge wire that has been formed into continuous S-shaped springs. They are arranged in rows and span from the front to the rear of the seat frame. There may be a fabric layer between the springs and the cushion. The seat cushions are made from foam with various densities (firmness) and may be used in sheets or molded for the application. The molded-type foam is more common on newer contoured vehicle seats, whereas sheets may be used on more flat-shaped seats. Contoured seat cushions must be ordered for the specific vehicle you are working on.

Seat cover

The seat cover is just that, the cover for the seat, including the cushion, springs, and frame. It is the surface your body touches and is the seat component most susceptible to wear. The seat cover can be made from a nearly infinite number of textiles or leather types. On Air Force vehicles, you will typically see cloth and vinyl materials. Seat covers often require repairs, especially on vehicles that the operator is repeatedly entering and exiting, such as flight-line vehicles and Security Forces vehicles.

Inspecting seats

As the vehicles age, seats receive wear from the different personnel who operate the vehicle. As time goes by, they become torn and weather cracked and suffer spring breakage. You are responsible for inspecting the seat thoroughly to determine whether it needs to be repaired or reupholstered. To make this determination, examine the seat upholstery for holes, tears, worn areas, and deterioration. If a vehicle has flexible upholstery, inspect the springs for breakage. Although the springs are under the seat cover, you can locate broken springs by inspecting the seat for firmness or check for uneven areas when you sit in the seat. Also, inspect the seat framework for stability, broken members, loose joints, or other obvious defects. This may require you to remove the seat, which is not too hard. Remember, the ultimate goal of upholstery is a professionally finished product. If you do not have matching material to repair the seat cover, it may be necessary to fabricate or purchase a complete new seat cover.

Upholstery repair

Any damage to the framework normally requires you to remove the seat cover. If you must do any welding to the framework, remove the padding for safety reasons. If a spring comes loose, reattach it to its proper location. Some upholsterers use upholstery clips (hog rings) for securing springs in place, while others use heavy wire. In either case, use your own judgment as to what works best. Once you repair the framework and springs, you are ready to begin recovering the seat.

Today's Air Force vehicles use numerous types of seats and each requires a different sewing technique. The most acceptable method is using the old seat covering only as a guide for a sewing pattern. Everyone who uses Air Force vehicles will see and feel the work you perform as an upholsterer. Therefore, good workmanship is essential. Loose and wrinkled seat covers, besides having a poor appearance, will wear prematurely. To prevent these problems, you must take extreme care during fabrication.

Fabricating the seat cover

Do not use the old seat cover as a pattern in cutting a new cover. It normally stretches out of shape and is a poor cutting pattern (however, you may use it as a sewing guide). It is always better to measure for the new seat cover and make it to the size you need. Upon taking the exact measurements for the cover, add a $^{1}/_{2}$-inch seam allowance to all sides. Make sure you cut the fabric pattern in the same direction as the seat you are covering.

Construct your patterns out of heavy paper, wood, metal, or plastic, and, as you make them, allow for seams. Include on the pattern all points of alignment for assembly of the material, and positions for the installation of hardware and accessories.

Patterns must have accurate dimensions because you duplicate each part made from it. If you make an error in the pattern, all duplicates will contain this error. As you lie out patterns or cut materials, make allowances for seams and carefully place the pattern on the material to eliminate all possible waste in cutting. The easiest patterns to lie out are those using squares or rectangles. Lay out patterns with curves or irregular shapes with a compass, irregular drawing curves, or squared paper. You can obtain patterns for seat covers from original working drawings, blueprints, or, as a last resort, the old seat cover.

A blueprint contains the actual dimensions, lines, curves, and angles necessary to show the seat cover on paper. If you know how to read and understand blueprints, you can construct a seat cover pattern without the actual seat cover. To do this, place the blueprint idea on paper and it becomes the guide for producing the seat cover. In addition, the blueprint contains information on the type of material you will use and the size and tolerance of the seat cover.

Most drawings consist of three basic views: front, top, and side. If necessary, an additional view is furnished. This is either a detail or a sectional view. The detail view enlarges a portion of the drawing, whereas the sectional view shows a cutaway section of the object. These drawings make construction work easier.

You should cut the gusset (the part you sew between two panels or attach to one panel) 1 inch wider than the thickness of the cushion. A panel is the part of the seat cover covering the padding of the seat. Cut the gusset long enough to reach all the way around the panel. For good appearance, install welt cord, sometimes known as beading, to dress up the cushion and give it a better appearance. Cut the strips of fabric for your welt cord $^{1}/_{2}$ inch to $1^{3}/_{4}$ inches wide and long enough to go around the top and bottom panels of the cushion.

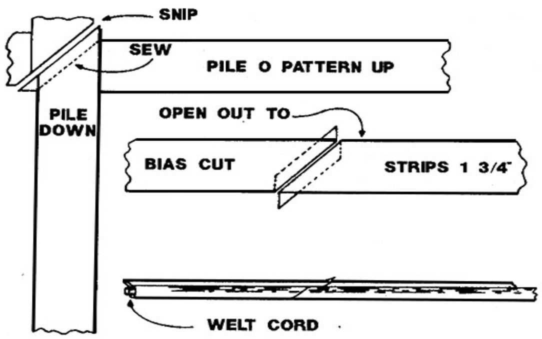


Figure 2–32. Welt splice.

Assembling the seat cover

If you use welt cord, measure and cut the cord accurately. Join these strips together to make a long, one-piece welt cord. The best method for sewing this strip is shown in figure 2–32. Sewing at a 45° angle (as shown) eliminates, as much as possible, the lump caused by folds in the material.

NOTE: On thin cover materials, a plain seam (straight across) is satisfactory if not using a welt cord. You can use scrap pieces of cover material.

Fold the strip of cut welt material over the welt cord (heavy cord) so you encase the cord in the strip. Sew the welt cord with a plain seam by using a sewing machine with a welt-foot attachment. Sew the welt cord to the cushion panel and gusset starting at the center rear, leaving an overlap of at least 1 inch (fig. 2–33). If you encounter difficulty in making square corners, snip the welt at the seam to relieve the material when sewing the welt around a sharp corner. If you stuff the cushion with foam, start sewing 4 inches from the corner on the backside, allowing enough opening to insert the foam rubber. If the seat does not contain any springs, you simply sew and fasten the seat cover to the seat frame.

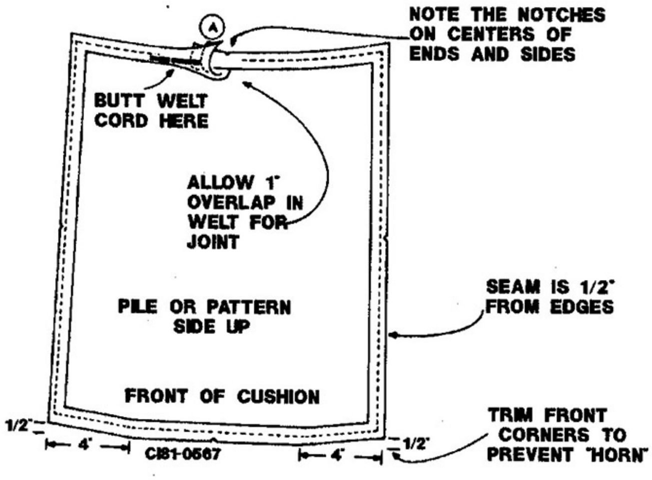


Figure 2–33. Sewing welt to cushion panel.

A large number of vehicle seat covers contain bolster tie down wires for extra strength and support, as illustrated on figure 2–34. If possible, try to sew the covers to include this feature. Make sure you transfer the bolster wires from the old cover to the new one. This will provide a good support for installing the hog rings on the cover.

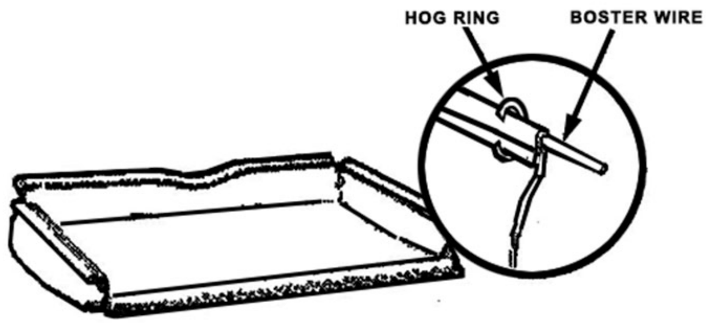


Figure 2–34. Hog ring and bolster wire installation.

Replacing the cover

At this point, you are ready to install the new cover. This is accomplished by positioning the new cover over the seat and attaching it to the seat frame. The placement of the hog rings is shown in figure 2–35. Some manufacturers recommend you use a certain number of hog rings for attaching the new seat cover. They recommend this to avoid too much stress or too little stress in areas.

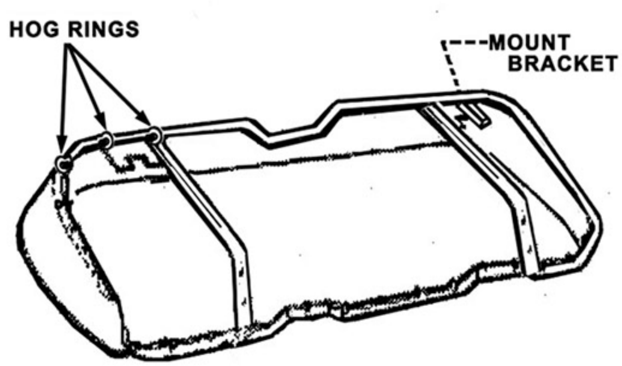


Figure 2–35. Seat cover attachment.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

618. Upholstery types and repair

1. Name the two types of upholstery.

2. State the characteristics of each type of upholstery.

3. Describe the common seat spring.

4. What upholstery component is the most susceptible to wear?

5. What should you look for when inspecting upholstery?

6. What type of damage may cause a seat to lose its firmness?

7. How much do you add to the measurement for seam allowance?

8. Why is bolster wire used on a larger number of vehicle seat covers?

2–5. Towing Attachments

The last miscellaneous item we will cover in this unit is towing attachments. Air Force vehicles have two main types of towing attachments. They are the fifth wheel and King Pin, and pintle hook and lunette towing assemblies. Items towed by Air Force vehicles have the potential to be exceptionally expensive, dangerous, or both. Effectively maintaining the towing apparatus in good working order is critical to mission accomplishment.

619. Towing attachments

Towing attachments on Air Force assets receive a lot of wear and tear, and as a vehicle management Airman, you will need to know how to inspect and repair these components. In this lesson, we will discuss the construction, maintenance, and limited repair procedures for each assembly type.

Fifth wheel and King Pin

A fifth wheel is not actually a “wheel” in the conventional sense of the word. Rather, it is a heavy-duty towing component that is attached to the vehicle. The term “wheel” comes from the fact that the assembly, in conjunction with the King Pin, enables the towed trailer to swivel when making turns.

This improves handling characteristics of extremely long tractor-trailer vehicles. You will not typically see these attachments on regular vehicles; however, they can be installed in full-size pickups, depending on the towing requirements.
They are commonly found on trucks that haul over the road semi-trailers. They are designed to accommodate heavier loads by positioning the trailer weight over the truck axles instead of the bumper or rear of a vehicle frame. Fifth wheel construction may vary in design from model to model, so it is important to follow the operator's manual when working on these components. Figure 2–36 shows the typical fifth wheel construction.

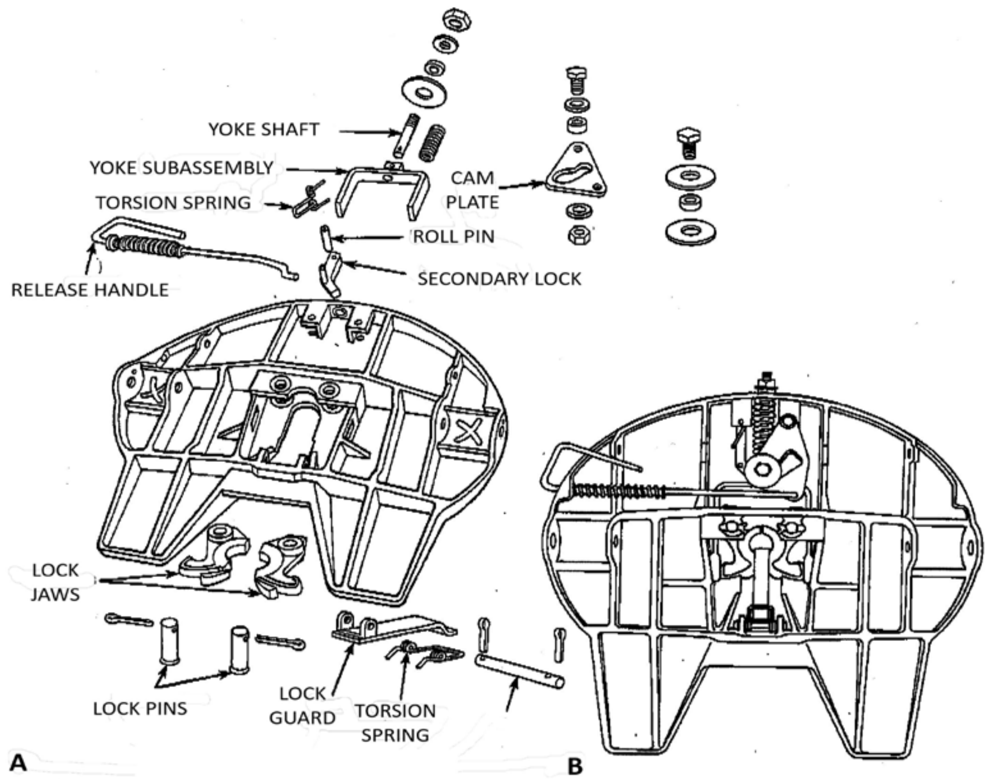


Figure 2–36. Typical fifth wheel.

Fifth wheel inspection & maintenance

Fifth wheel assemblies on Air Force vehicles are inspected annually by vehicle maintenance using the following inspection criteria:

- Completely steam clean all components and remove all dirt and grease.
- Check for cracks in the fifth wheel assembly, mounting brackets, and mounting parts.
- Confirm that the lube plates are in place and firmly attached.
- Ensure free operation of the secondary lock spring (if equipped).
- Check for loose nuts and bolts in the fifth wheel assembly.
- Ensure that all springs are securely fastened and working properly.
- Ensure the fifth wheel assembly rocks freely on the holding brackets.
- Ensure that the locking mechanism is working properly. Use a manufacturers lock tester or a pry bar to lock and unlock the assembly.
- Check the sliding mechanism for freedom of movement and make sure the locking plungers work properly (if equipped).

After conducting an inspection, if you find any cracks, broken parts, or worn springs, you must replace the defective components. Conduct any repair action in accordance with the manufacturer's directions. It is also very important to properly lubricate the fifth wheel. The following are some of the key areas that must be lubricated.

- Top plate–Use grease fittings (fig. 2–37, Location B) and direct application to spread the wheel grease all over the fifth wheel mating surface. Do not exceed $^1/_8$ inch, except in the indented "grease pocket" areas.
- Support bracket trunnions–Use the available grease fittings (fig. 2–37, Locations A & C) to lubricate these areas.
- Jaw Surface–Directly apply a light coat of wheel grease to these areas (fig. 2–38, Locations D & E). Too much can interfere with fifth wheel operation.

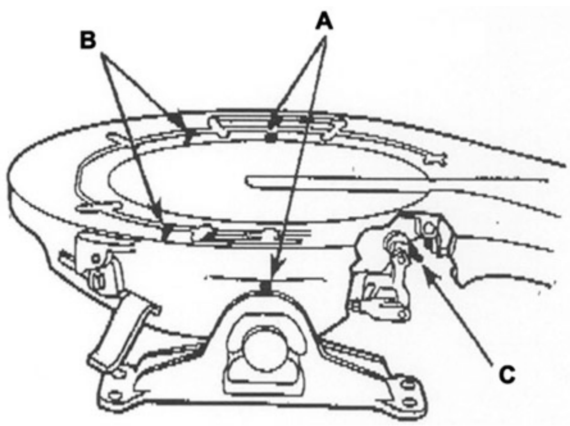


Figure 2–37. Fifth wheel lubrication points.

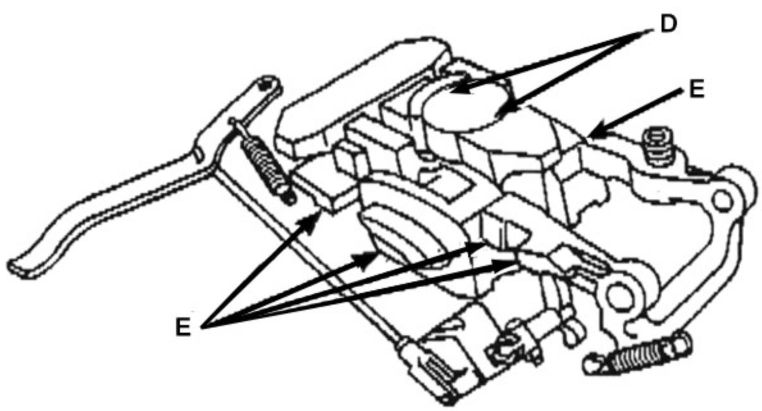


Figure 2–38. Locking mechanism lubrication points.

King Pin inspection & maintenance

The King Pin is the main component in the upper coupler assembly (fig. 2–39) on a semi-trailer. Inspection and maintenance of this component is just as important as its mating component, the fifth wheel. It has the same annual inspection requirement as the fifth wheel component. The King Pin can come in two diameters (2 and 3.5 inches). You must be sure of which diameters you are dealing with in order to properly conduct an inspection. The following are the areas you will need to inspect:

- Coupler plate flatness–Use a 48-inch straight edge to check for flatness in all directions. Replace the plate if flatness exceeds the specifications as shown in figure 2–39.

- King Pin straightness–Using a T square or a King Pin gauge (fig. 2–40), check for a bent King Pin. If the King Pin varies even one degree from square in any direction the King Pin should be replaced.
- King Pin length–Using a King Pin gauge (fig. 2–40) check the length that the King Pin protrudes from the coupler plate. If pin length is not adequate, or if it is too long, replace the assembly.
- King Pin wear–Using a King Pin gauge (fig. 2–40) you can determine whether the King Pin is worn. Simply, if the pin can slide into the appropriate diameter slot, it is worn. You can also use a micrometer to accomplish this inspection; a worn pin will measure $^{1}/_{8}$ inch or more over the assigned diameter of the pin.
- King Pin mounting–Grab the King Pin and try to move it back and forth. If it moves, the pin needs to be remounted.

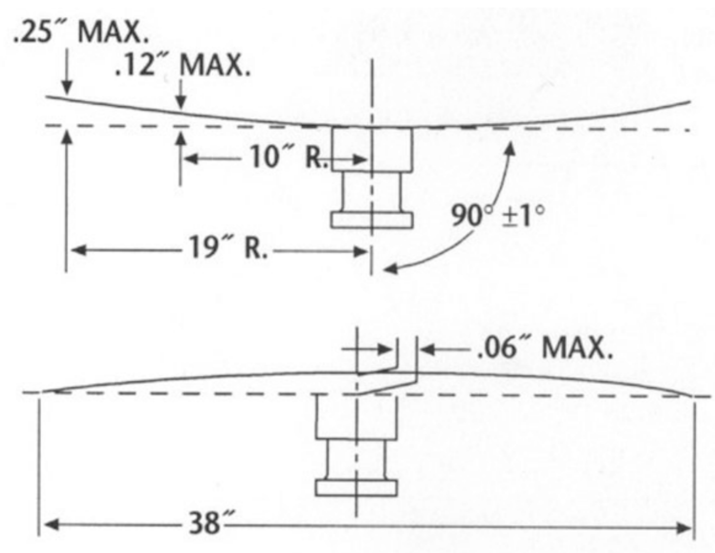


Figure 2–39. Coupler plate wear specifications.

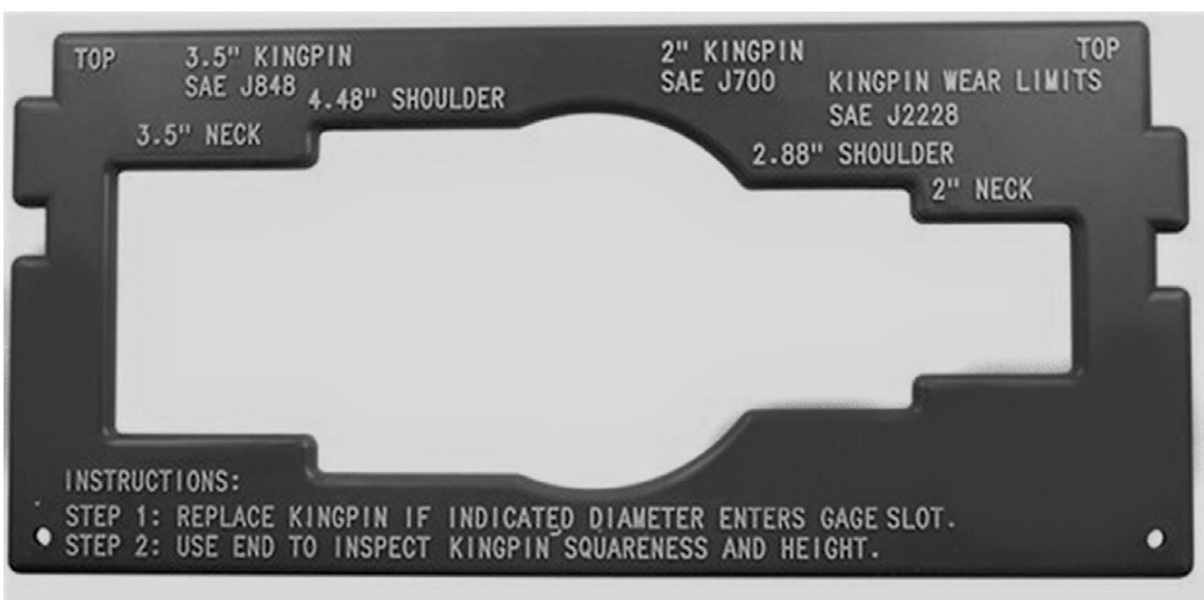


Figure 2–40. King Pin gauge.

If any damage is found during the inspection, you must replace the defective parts. When it comes to King Pin replacement it is best to follow the manufacturer's service manual. It is best to have the most qualified welder accomplish this task. The criticality of this rather small part cannot be overstated. Depending on local policies and conditions, this work is a potential candidate for contract maintenance.

Pintle hook and lunette

In wartime, we must be able to interoperate with our allies. The pintle hook and lunette towing attachment are based on a design approved by all North Atlantic Treaty Organization (NATO) countries, facilitating logistics cooperation between NATO allies. For example, service members may be tasked to reposition large guns or deliver ammunition to personnel from a friendly NATO military service. This will not be a problem because of the standardized pintle hook and lunette towing attachments described in TO 36–1–121, *Standardization of Lunette and Pintle Hook Type I, Class 1 and Class 2 Towing Attachments*.

Pintle hook

The pintle hook (fig. 2–41) is attached to the rear of the towing vehicle. There are three different standard pintle hook assemblies. The one *most commonly installed on small Air Force vehicles* is model MS51335. This pintle hook assembly is rated at 18,000 pounds of drawbar pull capacity.

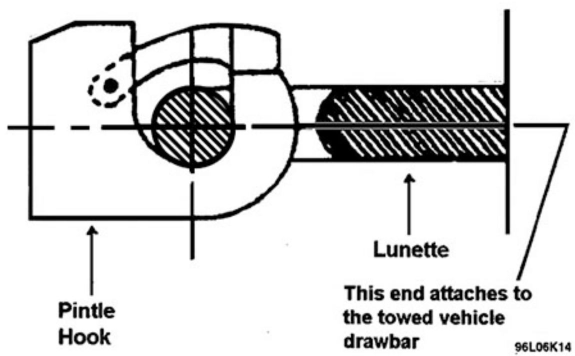


Figure 2–41. Pintle hook.

Lunette

The lunette, also called an eye (fig. 2–42), is a circular device and is always a part of the towed vehicle's drawbar. The lunette seldom requires maintenance and, under normal conditions, is virtually indestructible. However, as a minimum, a good visual inspection should be performed at the following times:

- During scheduled maintenance.
- After being involved in a major vehicle accident.

TO 36–1–121 lists some stringent tolerances for the size of the eye. These ensure the lunette meets the NATO standard. You can use them as a reference to determine if there is any excessive wear of the eye.

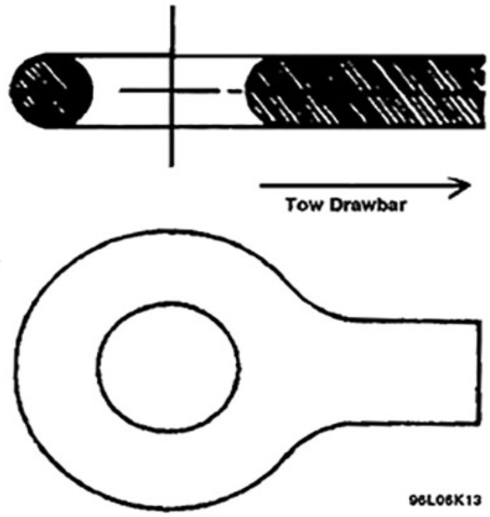


Figure 2–42. Lunette.

Operating characteristics

The following table discusses the various operating characteristics of the pintle-and-lunette assembly.

Pintle-and-Lunette Assembly Operating Characteristics	
Characteristic	**Description**
Articulation	The pintle-and-lunette assembly is designed to allow maximum possible articulation between the towing and towed vehicle. • *Vertically*, there should be a minimum of 45º of motion on either side of the center position. • *Horizontally* (tow and towed vehicle at an angle when turning), there should be a minimum of 60º of motion on either side of center. During an inspection, anything that may significantly reduce these values must be resolved.
Mounting security	For most applications, the bolts used in securing the pintle hook to the towing vehicle are hardened grade 5 bolts. If you have to replace any of these bolts, the replacement must also be grade 5. The securing nuts *must* be self-locking. A self-locking nut has a plastic insert on or near the interior threaded surface. When the nut is threaded onto the bolt, the bolt threads cut their own path through the plastic. The result is a closer contact of the thread surface area than with just the normal bolt-to-nut surface contact. This causes a very effective locking of the nut-and-bolt combination. If you remove the nut, the locking effect is greatly reduced and the nut should not be reused. You do not need to use a torque wrench when you are simply checking for pintle mounting security. The look-and-feel method is recommended for performing scheduled inspections. However, when you are installing a pintle hook, use a torque wrench and torque the securing nuts to between 90 and 100 foot/pounds (ft/lbs). If the pintle hook was installed aftermarket (that is, you or your shop installed it), it is good policy to make sure the assembly's mounting security and design is sufficient to tow anything within the rated tow capacity of the vehicle. **NOTE:** Always reference applicable technical orders, including TO 36-1-121, *Standardization of Lunette and Pintle Hook Type I, Class 1 and Class 2 Towing Attachments,* to ensure use of proper hardware and adherence to installation procedures.

Pintle-and-Lunette Assembly Operating Characteristics	
Characteristic	**Description**
Rotation	Pintles that are designed to rotate should be capable of doing just that. Rotation aids the towing process during off road operation where the two vehicles move into different planes. When inspecting the pintle-and-lunette assembly, ensure that the pintle rotates properly (there is no binding).
Locking pin	Cotter pins are used for locking the pintle hook jaw in the closed (and, for the MS51335, both open and closed) position. Perform the following to properly install the cotter pin: • Pry open the end of the pin just enough to cause you to compress it for installation. This provides enough spring tension to hold the pin in place. • Ensure the pin is inserted fully and the head is contacting the hook's upper jaw. • The shaft of the pin should be complete and have no broken halves. Ensure the cotter pin is secured to the pintle hook with approximately 8 inches of small chain (or wire rope if chain cannot be obtained). Keep the pin installed in the pintle hook, not hanging down by the chain or wire rope. Security of this pin is very important. This is of special concern on Air Force flight lines where running aircraft engines could ingest it and cause what is known as foreign object damage (FOD), requiring the damaged engines be replaced.
Latch mechanism	Lateral (sideways) movement and jaw opening free travel of the pintle hook latch increases through normal wear and tear. • When sideways movement is *more than* $^1/_4$ inch from the center of the hook to the furthest sideways movement, replace the hook. • When the jaw opening free travel with the jaw in the locked position *exceeds* $^1/_4$ inch, replace the hook. A repair kit is available to replace the worn hinge pins, which create both of these situations.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

619. Towing attachments

1. On what type of vehicle will you most commonly see a fifth wheel towing attachment?

2. How often does vehicle maintenance inspect fifth wheel components?

3. What is an acceptable amount of grease that you can put on a fifth wheel mating surface?

4. What tool(s) can be used to check the straightness of a King Pin?

5. What tool(s) can be used to measure the diameter of a King Pin?

6. What organization approved the design of the pintle hook and lunette towing attachment?

7. How many types of pintle hook assemblies are there, and which model is the one most commonly installed on small Air Force vehicles?

8. Which component of a pintle hook and lunette towing attachment requires little maintenance?

9. What are the requirements for securing a pintle hook in most applications?

10. Describe how to properly install a locking (cotter) pin in a pintle hook.

11. Why must the locking pin always remain securely installed in the pintle hook?

12. What two conditions require a pintle hook to be replaced?

Answers to Self-Test Questions

611

1. Silicon (sand), alkali (potash or soda), and either lead or lime.
2. For its expansion and contraction.
3. Always lay glass on surfaces protected by cloth, paper, or other soft material.
4. To eliminate any distortions.
5. Rapidly heating the glass and then exposing both sides to cooling jets of air.
6. It cannot be cut and the windows must be the exact size and shape for their specific locations on the vehicle in question.
7. Laminated glass.
8. PVB.
9. Very high temperatures.
10. Glass vise.
11. Glass edging machines.
12. Any five of the following:
    (1) Pliers.
    (2) Pullers.
    (3) Glasscutters.
    (4) Channel driver.
    (5) Chisel.
    (6) Rubber mallet.

(7) Handle-clip tools.
(8) Phillips offset ratchet.
(9) Window seal installation kit.

13. Chisel.
14. Removing screws in close quarters; because it has greater flexibility than the fixed-offset screwdriver.
15. Serrated (notched) shaft with set screws.

612

1. Making and cracking the cut in the glass.
2. If the resin laminate holds all fragments together.
3. Because leaning the pencil could possibly make the new pattern larger or smaller than the original. The pattern must be an exact duplicate for the new glass to fit properly.
4. Larger than the largest piece of glass you are going to cut.
5. Sudden temperature changes during cutting operations will almost certainly result in glass breakage.
6. Turpentine or light oil.
7. The thick side.
8. Because a frosty cut will not guide the crack as easily as a hairline cut.
9. The cut (glass) will heal or relieve itself of the internal stresses.
10. Move the glass to the edge of the table and carefully press on a corner (never in the middle) of the waste piece to initiate the crack.
11. The glass may chip.
12. Remove the frame and glass from the vehicle, take it to the workbench, and then remove the glass from the frame by using the glass vise. Reverse the procedures for replacement.
13. To prevent damage to the paint finish.
14. Clips on the window channels snap into holes in the doorframe.
15. Use a glass vise or 2-inch-wide piece of hardwood against the channel and tap with hammer. Alternate from side to side as you tap the channel from the glass.
16. Tight enough to prevent rattles but not so tight to risk breaking the glass.
17. By checking to see the mechanism will lift the glass completely to the top and lower it to the proper level (normally flush with the bottom of the door window opening).
18. By increasing or decreasing the tension on the arm springs. On some vehicles, adjustments can be made by changing the position of the upper and lower window stops (bumpers). In most cases, the regulator screw fasteners pass through elongated holes in the inner door panel, permitting you to adjust the regulator mechanism.
19. A wide flat-tip screwdriver or specialized tool.
20. When you withdraw your hands and arms from the door opening to the window mechanism, take your time and be careful to not catch them on the sharp edges of the door opening.
21. Two.
22. A defect in the windshield opening such as a high or small obstruction.
23. To it wedges the rubber against the glass and against the metal panel (or flange) at the window opening to provide a secure fit.
24. Laminated glass.
25. Three, including neutral, vacuum, and pressure.

613

1. The Society of Automotive Engineers; SAE Recommended Practice J1344: Marking of Plastic Parts.
2. Any four of the following:
   (1) Identify the material from which the part is made so you can use suitable repair and paint procedures.

(2) Whenever practical, locate the marking where it can be seen while the part is assembled in/on the vehicle.

(3) Place the marking on an outside surface of the part in an unobtrusive location (as far as the owner/operator is concerned).

(4) Design the marking to remain legible during the entire life of the part.

(5) Use multiple markings on large or complex-shaped plastic parts.

3. A series of alpha characters (letters), 3.0 mm high, placed inside a “football-like” shaped circle molded into the component part.
4. Thermoplastics, thermosetting plastics, and composite plastics.
5. Thermoplastics.
6. Thermosetting plastics.
7. Into flexibility categories.
8. Rigid, semi-rigid, and flexible.

614

1. Thermoplastics.
2. (1) An electrical unit that generates heated air at high temperatures and forces a small stream of this heated air down a special “torch” head to the weld site at a rate of about 3 psi.

   (2) An electrical heating unit using a heated tip in much the same fashion as an electrical soldering gun.
3. Match up the ISO symbol to the plastic being welded.
4. With a two-component adhesive product.
5. Polyester, epoxy, or urethane.
6. The chemicals in these substances can damage the area enough to make it impossible to repair.
7. With soap and water and then with a plastic cleaner.
8. Cosmetic and structural.
9. Unidirectional cloth, woven cloth, and nylon screening.
10. Double-sided repair.

615

1. Bolts and screws.
2. Retaining screws, concealed retaining clips, or plastic trim retainers secure the trim panel to the inner panel.
3. Prying with a thin-blade screwdriver or specialized tool.
4. The waterproof barrier deflects water and prevents wetting the reverse side of the panel. Not installing this waterproofing can cause water-leaking problems later. Further, insulation material is important to blocking road noise while the vehicle is in operation.
5. Along the bottom of the door or door opening; prevents moisture from leaking into the vehicle’s interior but allows moisture to drain out.
6. A door glass seal is normally a hard rubber strip with a special softer rubber face that butts against the door glass surface. The hard section acts as a buffer between the metal of the door and the door glass, keeping foreign material from collecting in the door. The soft section acts as a wiper when the glass is wet.
7. Heating increases the adhesion (to the body). No, cold temperatures actually allow for easier molding removal.
8. The residue white or gray acrylic tape is most easily removed by gently stretching it. Grip the tape at one end, lift, and pull away slowly about $^{1}/_{2}$ inch at a time. Then grip it and pull again. Small pieces can be removed by rolling your thumb across the sheet metal surface.
9. Isopropyl alcohol and a clean soft cloth.

616

1. Many years of service or the locks not being properly lubricated during scheduled maintenance.
2. The edges of the door’s inner panel are often very sharp.

3. This will help with reassembly by holding the lock roughly in position to accomplish the next step (Inserting and tightening the lock screws in the lock assembly).
4. Bolted-on and welded-on types.
5. Find something to hold the weight of the door as you remove it from the vehicle. Special equipment designed for this purpose may be available. If not, use a common hydraulic floor jack with a block of wood used as a buffer between the door and the metal jack.
6. Because the door will stay balanced on the upper and lower hinges until you have the bolts of the upper hinge almost out.
7. Mark the position of the hinge; it will help with installation of the new hinge and will save time.
8. After you have the hinges mounted and the door back on the hinges, you may have to loosen the bolts to finely adjust the door to the opening.
9. By removing hinge pins rather than removing bolts.
10. To ensure only the weld is removed.
11. A chisel.
12. By checking to see if the vehicle you are working on uses hinge bushings. If so, you may be able to install the bushings instead of complete hinge assemblies.
13. Around the hinge pin and the bushings that surround it.
14. By opening the door about half way and lifting on the rear portion of the door. If the door hinges have any play, it is most likely because of the slop (play or looseness) between the pins, bushings, and hinge halves.

617

1. A strong and flexible steel alloy.
2. Fascia.
3. To withstand the shock of low-speed front- or rear-end collisions; it cushions the impact and decreases the amount of damage or personal injury.
4. Identify the absorbing unit you are working on.
5. The bumper may be jammed in the compressed position and any movement could cause it to spring back.
6. Relieve the pressure according to technical order instructions.

618

1. Rigid and flexible.
2. (1) Some flexible seat foundations have regular springs, others have no-sag springs, and some have rubber webbing stretched from front to back and side to side. This type of upholstery allows part of the foundation of the seat to give together with the cushion and is more comfortable to sit on.
   (2) While not the most comfortable, rigid seating is strong and durable, relying on the foundation to give it strength as well as to provide anchoring surfaces for attaching the cover. An example is metal or wood framework with minimal padding and seat to cover it.
3. Heavy-gauge wire that has been formed into a continuous S-shaped spring.
4. The seat cover.
5. Holes, tears, worn areas, and deterioration.
6. Broken seat spring.
7. Add $^{1}/_{2}$ inch.
8. For extra strength and support.

619

1. Trucks that haul over the road semi-trailers.
2. Annually.
3. Not to exceed $^{1}/_{8}$ inch on the mating surface except in the intended “grease pocket” areas.
4. T-square or King Pin gauge.
5. King Pin gauge or a micrometer.

6. NATO.
7. Three, MS51335.
8. The lunette.
9. Use grade 5 bolts, use self-locking type nuts, torque nuts to 90 to 100 ft/lbs. torque.
10. Pry open the end of the pin just enough to cause you to compress it for installation. This will provide enough spring tension to hold the pin in place. Ensure the pin is inserted fully and the head is contacting the hook's upper jaw. The shaft of the pin should be complete and have no broken halves.
11. To prevent it from being ingested into running aircraft engines an Air Force flight line, creating FOD, and requiring engines to be replaced.
12. Lateral (sideways) movement and jaw opening free travel exceeding $^{1}/_{4}$ inch movement.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to AFCDA.

21. (611) When glass is subject to temperature changes, allowances must be made for
    a. its tendency to shatter at temperatures above 150° F.
    b. its tendency to crack at temperatures above 150° F.
    c. the impact of oncoming ambient air.
    d. expansion and contraction.

22. (611) What type of automotive glass can be used for replacement of side and rear windows, but *never* for windshields?
    a. Laminated.
    b. Tempered.
    c. Safety.
    d. Plate.

23. (611) The plastic layer inside the windshield allows the windshield to bend out of shape after breakage and still provide protection for the
    a. dash board.
    b. steering wheel.
    c. vehicle occupants.
    d. seat covers and carpeting.

24. (612) After you complete edging, wash the new glass thoroughly with clean water at low pressure to
    a. check for chips.
    b. temper the glass.
    c. rinse finger smudges off the glass.
    d. remove the grinding compound or grit.

25. (613) The *Society of Automotive Engineers (SAE) Recommended Practice J*1344*: Marking of Plastic Parts* for automotive vehicles specifies a series of
    a. letters, 3.0 millimeters (mm) high, placed inside a football-shaped circle, which is molded into the component part.
    b. numbers, 5.0 mm high, placed inside a football-shaped circle, which is stamped onto the component part.
    c. letters, 5.0 mm high, placed inside a perfect circle, which is stamped onto the component part.
    d. numbers, 3.0 mm high, placed inside a perfect circle, which is molded into the component part.

26. (614) Which is the *best* way to match up the proper plastic welding rod material with the material being repaired?
    a. Match the International Organization for Standardization (ISO) symbol.
    b. Sand the material to see if it melts or smears.
    c. Try several of the most sensible choices.
    d. Perform a melt test.

27. (614) During plastic welding, what percentage of the base material should the weld penetrate if using a single-V weld?
    a. 25 percent.
    b. 50 percent.
    c. 75 percent.
    d. 100 percent.

28. (614) Which composite plastic filler is used for repairing large gaps?
    a. One part.
    b. Two part.
    c. Cosmetic.
    d. Structural.

29. (615) What should you apply to the weather seal rubber to rejuvenate it during cold months?
    a. Rubber hardener solution.
    b. Rubber softener solution.
    c. Soap and water.
    d. Light oil.

30. (616) Before installing a new door with welded hinges, you should corrosion protect the
    a. bolts only with a thin coat of primer.
    b. mating surfaces with a medium-bodied sealer.
    c. hinge pillar and door with a thin coat of primer.
    d. backing plate with a fast-drying acrylic enamel.

31. (616) What item can save much of the labor involved in hinge replacement?
    a. Sockets.
    b. Springs.
    c. Cushion.
    d. Bushings.

32. (617) If your vehicle has a gas-filled absorbing-bumper unit, what actually attaches to the bumper and retracts when the bumper collides with an object?
    a. Piston ram.
    b. Spring bolt.
    c. Cushion pad.
    d. Retracting rod.

33. (617) You should *never* weld on or near a gas-filled bumper energy-absorbing unit because the unit could
    a. move into the retracting position.
    b. decrease the gas pressure.
    c. warp the bumper.
    d. explode.

34. (618) What type of vehicle upholstery has only minimal padding and a seat cover?
    a. Rigid.
    b. Flexible.
    c. Traditional.
    d. Ergonomic.

35. (618) Before you do any welding on the framework of a vehicle seat, you *must first* remove the
    a. the door panel.
    b. the headliner.
    c. floorboard.
    d. padding.

36. (619) When applying grease into the fifth wheel mating surface, the maximum thickness to apply is
    a. $^{1}/_{8}$ inch
    b. $^{1}/_{4}$ inch.
    c. $^{1}/_{2}$ inch.
    d. $^{3}/_{4}$ inch.

37. (619) To properly install a pintle-and-lunette assembly on most applications, with the MS51335 model pintle hook, you *must* use
    a. grade 3 bolts.
    b. grade 4 bolts.
    c. castellated nuts.
    d. self-locking nuts.

38. (619) What is the maximum amount of lateral movement from center and jaw opening free travel of a pintle hook latch mechanism?
    a. $^{1}/_{16}$ inch.
    b. $^{1}/_{8}$ inch.
    c. $^{1}/_{4}$ inch.
    d. $^{3}/_{8}$ inch.

Please read the unit menu for unit 2 and continue ➔

Unit 3. Oxyacetylene Torch and Plasma Cutter

WELDING is an important skill to master as a vehicle technician. With the advent of newer metal technology, welding has become an extremely high-tech process. However, the basics of the welding remain the same. In this unit, we will discuss metals, oxyacetylene torch, fusion welding, nonfusion welding, and the plasma cutter. We will also discuss heat exchangers, including radiators and oil coolers; further, we will consider how it may be possible to repair them using soldering, a technique related to welding.

3–1. Oxyacetylene Welding

Oxyacetylene welding has disappeared from most vehicle body repair processes. However, it is still one of the most useful tools in a shop for cleaning, heating, and cutting metal. Its usefulness has made oxyacetylene welding a mainstay in any vehicle maintenance shop, Air Force or civilian. Due to deployment taskings, you could be forward deployed to an area that may not have more advanced welding systems on site. However, you can almost guarantee that the oxyacetylene torch will be available. Therefore, you must have a comprehension of the oxyacetylene basics. Before we move onto the welding aspect, we will identify the metal you will be working with, providing you with a working knowledge.

620. Metals

Very few metals are usable in their natural states; as a result, most natural metals have to be refined. Various refined metal manufacturers do this by one of two methods to make the metals workable: removing undesirable elements or adding elements that make the metals workable. You must be knowledgeable of these properties before we can move on to our discussion of elements involved in welding.

Mechanical properties and relationships

External forces that cause internal reactions in a metal are known as mechanical properties. These mechanical properties are directly related to each other. A change in one property normally causes a change in one or more of the other properties. For example, increasing the hardness of a metal ordinarily increases its brittleness and normally decreases its toughness. Having said that, let us briefly discuss the different properties of metals.

Mechanical Properties and Relationships of Metals	
Property	**Description**
Hardness	Hardness is the resistance a substance offers to deformation or penetration. You can normally control the hardness of a metal by heat treatment—heating the metal until it appears red and then dipping it into water, cooling it rapidly.
Tensile Strength	Tensile strength, stated in psi of a cross-section area, is the resistance a substance offers to being pulled apart (stretched) by a slowly applied load. Tensile strength increases or decreases as the hardness increases or decreases.
Brittleness	Brittleness is the tendency of a material to fracture or break with little or no deformation, bending, or twisting. This is generally *not* a desirable mechanical property. Normally, the harder the metal, the more brittle.
Shear Strength	Shear strength is the resistance to an action, similar to the cutting action of a pair of scissors. A shear action is a force that tends to cause the particles of a body to slide over each other. The shear strength is approximately 60 % of the tensile strength. You can control shear strength in the same manner as tensile strength; that is, by varying the hardness of the metal.
Ductility	Ductility is the ability of a metal to be stretched without fracturing or rupturing. Metals that are comparatively soft are normally ductile.
Toughness	Toughness is the ability of a material to absorb sudden shock without breaking. Ordinarily, the harder the material, the less tough.
Wear Resistance	Wear resistance is the ability of a material to resist the cutting or abrasive action resulting from a sliding motion between two surfaces under pressure. A hard material usually has good wear resistance.
Stress	Stress is the internal reaction of a material to an externally applied force.
Strain	Strain is the change in the length within a material subjected to stress.

Metal identification and characteristics

To be a successful welder, you must be able to recognize different metals and alloys, especially carbon-content steels and cast iron. There are a number of methods to determine the composition of metals. These methods are very important because you will have to choose the proper welding method to match each type of metal. Four methods for this lesson used to determine metal composition include appearance, spark test, flame test, and the chip test. The following table provides a description of each one.

Metal Identification Methods	
Method	**Description**
Appearance	This is generally the first method in metal identification. You examine features such as color and the appearance of the machined and nonmachined surfaces.
Spark Test	For this test, you hold a piece of metal against a grinding wheel. • Ferrous metals (those attracted to a magnet) will spark. • In contrast, nonferrous materials (those not attracted to a magnet) normally *do not* spark. In spark testing, you get fair results in determining the amount of carbon and alloying elements in steel. The shape and the pattern of the spark stream vary with carbon content and with the alloy. Spark testing has its limitations since several steels have similar spark streams. The best way to identify unknown steel is to compare its spark stream with the spark stream of a known sample of steel.
Flame Test	The flame test also has its limitations, but you can use it in certain situations (e.g., to determine whether a metal is aluminum alloy or magnesium alloy).To make this test, cut a small piece from the metal and heat it with an oxyacetylene torch. • Aluminum alloy will melt and form a ball of molten metal. • Magnesium alloy will ignite, burn with a brilliant white light, give off white smoke, and leave a white ash.

Metal Identification Methods	
Method	**Description**
Chip Test	This test involves chipping small pieces off the metal with a cold chisel. The characteristics of the chips are important in this test. Listed are some examples of the metals you'll see most often: • Wrought iron is cut easily with a chisel and leaves a smooth, continuous cut. • Malleable cast iron chips and breaks off into small pieces.

Numerical identification codes

The terms *steel* and *aluminum* are general in meaning. There are many different types of steel and aluminum, which vary greatly in their chemical composition and physical properties. This is true of all metals. Every piece of metal is manufactured to meet certain specifications. It is not possible to mark all of this information on each individual piece of metal; therefore, a specification number is used. It is to your advantage to have the specification number marked on each piece of metal on the metal racks in your shop. If this is not possible, either tag or color-code them.

The numerical index system for classification of metals and their alloys has been generally adopted by industry for use on drawings and specifications. In this system, the class to which the metal belongs, the predominating alloying agent, and the average carbon content in points are indicated. Numbering systems exist for each type of metal; for instance, steel, aluminum, magnesium, etc. Since you will most commonly encounter and work with steel, we will limit our discussion to the standard designation system for steel. Information on other metals can be found in TO 34W4–1–5, *Welding Theory and Application*.

Standard designation system for steel

With only a few exceptions, plain steels and steel alloys are identified by a four digit numbering system. The table below describes what each number in a steel designation represents. It should be noted that this numbering scheme does not apply to stainless steels.

Deciphering Standard Steel Numbers	
Digit	**What It Represents**
1	Designates the kind of metal.
2	Typically indicates the approximate percentage of the major alloying agent of simple alloy steels. In some metals, this digit indicates a secondary alloying element.
3 & 4	Always indicate the approximate carbon content in hundredths of 1 %.

For example, a number of 1025 indicates carbon steel with no alloying agent and approximately 0.25 percent carbon content. In contrast, the number 2340 indicates nickel steel with approximately 3 percent nickel and 0.40 percent carbon content. Now that you know what the numbers represent, here is the table for SAE numbering.

Steel and Steel Alloy Numbering	
Series	**Alloy Content**
1000	Carbon steels
2000	Nickel steels
3000	Nickel-chromium steels
4000	Molybdenum steels
5000	Chromium steels
6000	Chromium-vanadium steels
7000	Tungsten steels

Steel and Steel Alloy Numbering	
Series	**Alloy Content**
8000	Chrome-nickel-molybdenum steels
9000	Silicon-manganese steels

621. Oxyacetylene equipment

As stated previously, Air Force vehicle maintenance shops make extensive use of oxyacetylene welding equipment. One of the key benefits is its portability.

Oxyacetylene equipment (fig. 3–1) consists of the following:

- An acetylene cylinder.
- An oxygen cylinder.
- Regulators.
- Hoses.

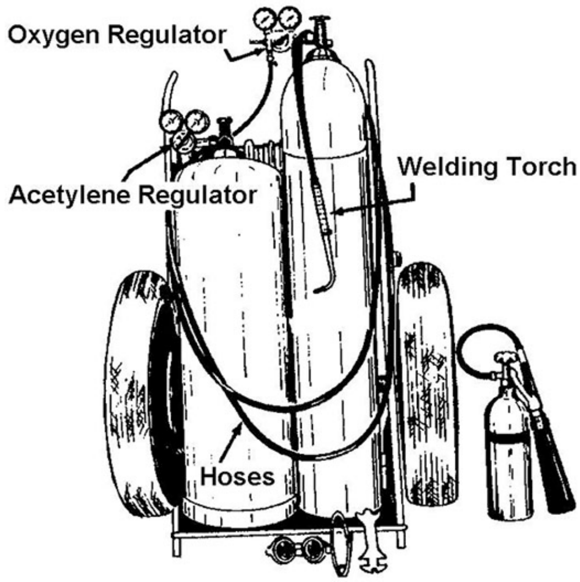


Figure 3–1. Oxyacetylene equipment.

In addition to these items, various safety items are part of the equipment. Another important component that is not listed is the torch tips used in oxyacetylene welding. We will discuss these later in this lesson.

Acetylene cylinder

The acetylene cylinder is made of welded or brazed steel and is designed to store acetylene under pressures up to 250 psi. The cylinder is filled with a porous substance (calcium silicate or wood pulp) that occupies 75–80 percent of the cylinder space. "Porous" describes a substance permeable by fluids or air (a substance through which fluids or air may pass). Manufacturers add acetone to this porous substance to 40 percent of its liquid volume and then pump acetylene into the cylinder up to 250 psi. Why use acetone? It absorbs many times its own weight of acetylene. As it absorbs the acetylene, the acetone stabilizes it under pressure. Without acetone to stabilize it, the free acetylene becomes self-explosive at a pressure of 29.4 psi.

CAUTION: The cylinder is equipped with a cylinder valve and a protective (safety) cap. **ALWAYS** install the safety cap before moving the cylinder.

If you do not install the safety cap, you could accidentally drop the cylinder and break off the valve. If this happens, you will have a large amount of acetylene filling the air around you. One tiny little spark could ignite the acetylene in the air and engulf you and the surrounding area in one large flame.

As a safety factor, the acetylene cylinder valve fitting has left-hand threads to prevent connecting the oxygen regulator to the acetylene cylinder. Another safety factor is the fuse plugs that release the acetylene if the cylinder is overheated. These plugs melt between 210 and 220 °F and are small enough to keep the gas from burning back inside the cylinder. All acetylene cylinders are yellow and must be stored upright to prevent the escape of the acetone.

Oxygen cylinder

This cylinder is painted green and made of seamless steel. It contains oxygen at a pressure of up to 2,200 psi and is equipped with a safety cap to protect the valve. As mentioned previously, *always install the protective cap when moving the cylinder by itself*, regardless of the fluid type. The enormous amount of pressure in an oxygen cylinder makes it a potential missile should the cylinder valve break off. The cylinder valve has a bursting disc for releasing excess pressure if the cylinder is subjected to heat. The cylinder valve fitting has right-hand threads to prevent confusing it with an acetylene connection with its left-handed threads.

Acetylene and oxygen cylinder safety precautions

Here are some safety precautions you must observe when working with and around oxygen and acetylene cylinders:

- Always refer to acetylene as acetylene and oxygen as oxygen, not gas and air.
- Do not drop either cylinder.
- Keep oxygen away from oil, grease, and other flammable materials because these items will ignite violently in the presence of oxygen.
- Never use acetylene from cylinders without reducing the pressure through a suitable pressure-reducing regulator. Never use acetylene at working pressure in excess of 15 psi from the regulator.
- Use soapy water to check all fitting joints for leaks.
- Do not substitute oxygen for compressed air when using pneumatic tools. Do not use oxygen to blow out pipes or to dust clothing or objects.
- Never use a hammer, pliers, vice-grips, or a pipe wrench to loosen or tighten fitting connections because these tools can damage the soft metal connections. Always use the correct size wrench to remove or install regulators and hoses.
- Place the acetylene and oxygen cylinders in a cart designed for them or place the cylinders up against a wall and use a strap or chain to secure them from falling over.

Keep in mind, these are just a few of the many rules you should follow when handling these cylinders. In all cases, be sure to follow the safety rules established in your local shop.

Regulators

These mechanical devices reduce the high cylinder pressure of acetylene or oxygen to pressures you can use for welding, cutting, and heating metals. Regulators also keep a steady pressure at the torch even though cylinder pressure is decreasing as you use the oxyacetylene equipment. They are of either the single-stage or two type. Their operation is similar except the two-stage variety steps down the pressure in two stages instead of one. In addition, two-stage regulators require fewer adjustments.

The first stage automatically delivers acetylene or oxygen to the second stage at a predetermined pressure preset at the factory. An adjusting screw for the second stage makes it possible for the operator to select the necessary acetylene and oxygen pressure easily, quickly, and separately for an appropriate (working) oxyacetylene flame.

A two-stage regulator (fig. 3–2) comes with two pressure gauges.

1. The high-pressure gauge indicates the pressure inside the cylinder.
2. The delivery cylinder pressure gauge indicates the pressure you have set for the torch.

CAUTION: As previously emphasized, never operate the oxyacetylene equipment with more than 15 psi acetylene. You normally operate the oxyacetylene equipment with no more than 45 psi oxygen. Before you open the cylinder valves, make sure the regulator adjusting screws are backed off all the way. This prevents full cylinder pressure from suddenly hitting the inside of the regulator. Should this happen, the regulator could explode or suffer interior damage.

If you need to change cylinders, quickly crack open and close the cylinder valve once before installing the regulator on the cylinder valve fitting. This blows away any dirt or other debris in the valve opening. If you do not do this, dirt could enter the interior of the regulator and cause it to malfunction.

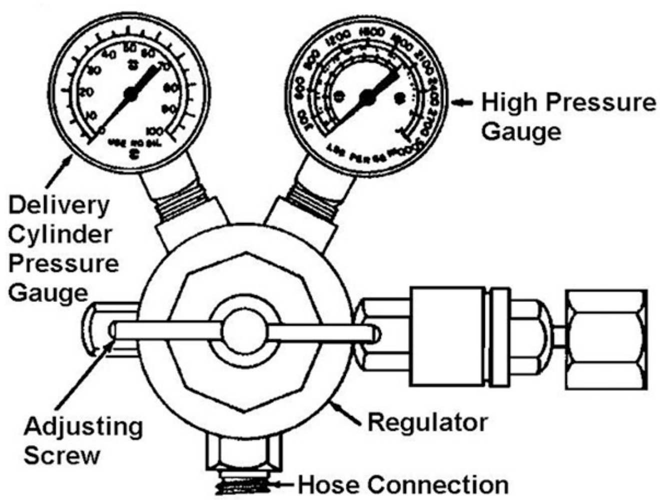


Figure 3–2. Regulator.

Hoses

The hoses, previously shown in figure 3–1, carry acetylene or oxygen at working pressure from the regulators to the welding torch.

NOTE: The *oxygen hose* is always green or black and has right-hand threads. Conversely, the *acetylene hose* is always red or maroon and has left-hand threads. This design is meant to prevent the two from being interchanged accidentally.

Hose connections will sometimes develop leaks and you might not even be aware of it. Perform the following to test a hose connection for leaks:

1. Use soapy water.
2. Open the cylinder valves.
3. Keep the torch valves closed.

NOTE: This allows the acetylene and oxygen to apply pressure to each hose so you can test the hose connections for leaks.

4. Simply pour some soapy water over the connections and look for tiny bubbles.
5. If you see bubbles, pour a bit more water to make sure you have identified the source, and then take corrective action.

If you suspect the hose itself is leaking, you can locate the leak by using soapy water on the hoses as you did on the connections or submerge the hose in clean water. Either way, look for tiny bubbles, which indicate you have found the source of the leak. If you find a leak in the hose, you can do one of the following:

- Replace the hose with a good one.
- Cut out the bad section and splice the hose with a hose coupling.

If you cut and splice, you must use a clamp to seal the joint. Any splice in a hose must withstand a pressure of 300 psi.

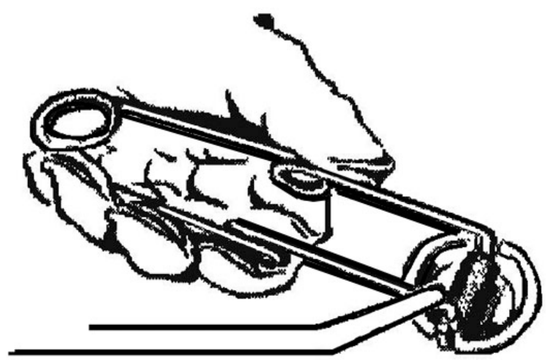
CAUTION: Never drag the hoses through any grease, oil, or dirt or oil. The hoses could become coated and conceal damaged areas. Always practice good housekeeping.

Additionally, try to route the hoses to your workstation so no one will walk on them. If you are through using the oxyacetylene equipment for a lengthy time during the day, *always shut off the cylinder valves and drain the hoses*. This eliminates the possibility of a fire hazard. Always roll up the hoses and secure them out of the way if you are leaving your duty section for any length of time.

Safety equipment

The flint lighter, welding goggles, welders' gloves, apron, and a fire extinguisher are all safety equipment used with oxyacetylene equipment. The equipment is designed to protect you from injury and to prevent damage to property.

Safety Equipment

Equipment	Description
Flint Igniter	Never use matches or a cigarette lighter to ignite the oxyacetylene torch. Use a flint igniter like the one shown in figure 3–3. Using matches or a cigarette lighter puts your hands too close to the torch tip. The result could be severe burns.  **Figure 3–3. Lighting the torch.**
Welding Goggles	You must wear welding goggles when you operate the oxyacetylene equipment. Sunglasses do not provide the required protection that welding goggles do. As you perform oxyacetylene welding, the glare from the oxyacetylene flame and molten metal can give off harmful rays of light. Welding goggles protect your eyes from these hazards. There are different shades to choose from. If you feel there is too much light or brightness from the weld, change to a darker lens for your protection and safety.

Safety Equipment	
Equipment	**Description**
Welders Gloves	Wear nonflammable gloves to protect your hands from the intense heat produced during oxyacetylene welding operations. Even though the torch flame is generally going away from you, heat reflects off the metal you are working with and can burn your skin if you are not wearing welder's gloves. Sometimes you may have to handle the hot metal suddenly and without any warning. Wearing your welders' gloves reduces the possibility of severely burning your hands in this situation.
Apron	Always wear some sort of protective clothing or apron when doing any kind of welding. You never know when sparks or tiny molten globules will land on you or your clothing. These sparks and tiny globules can burn holes in your clothing or skin before they cool off. Molten metal can explode without warning, especially with oxyacetylene welding. Wearing an apron or some other protective clothing (coveralls, leather jacket, leather sleeves, etc.) protects not only your uniform but also the front of your body and prevents severe burns from flying sparks and tiny globules of molten metal.

Torch, tips, and rods

One of the most important components of oxyacetylene equipment is the torch used to mix the oxygen and acetylene in definite proportions and to control the volume of acetylene and oxygen at the welding tip. The torch also serves as a means of directing the flame to where you need it for cutting and welding metal. The torch body (fig. 3–4) contains two needle valves; one is for adjusting and controlling the flow of acetylene, while the other is for adjusting and controlling the flow of oxygen. An individual tube leads from each of these needle valves through the torch body to within an inch or two of the opposite end of the torch body. You also use the body of the torch as a handle.

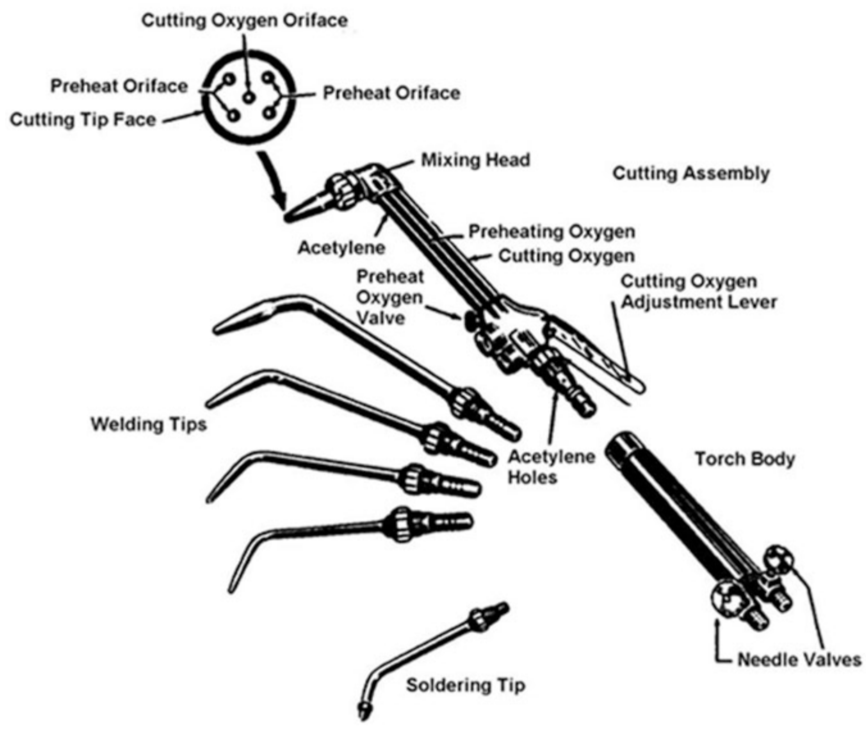


Figure 3–4. Oxyacetylene torch with tips.

Cutting assembly

The cutting assembly consists of the mixing head with an attached cutting tip face connected to three tubes. These tubes connect to the cutting assembly body that contains two oxygen-adjusting valves.

1. Rotating a needle-valve knob controls the *preheating oxygen* valve.
2. A lever controls the *cutting oxygen* valve.

Assume the cutting assembly is connected to the torch body as we explain the function of each component.

As you connect the cutting assembly to the torch body, the openings of the assembly tubes align with those of the torch body. The attaching nut secures the cutting assembly to the torch body, giving an airtight connection. (If you suspect any acetylene or oxygen leaks from this connection, use the soapy-water method *after* you open the acetylene and oxygen needle valves.) As you open the acetylene needle valve, acetylene flows freely out the cutting tip face.

As you open the oxygen valve on the torch body, oxygen flows through the torch body oxygen tube to the cutting assembly body. When the oxygen reaches the cutting assembly body, the preheating oxygen valve and cutting oxygen adjustment lever keep it from flowing any further. To use the cutting assembly, open the torch body oxygen valve all the way. This allows full oxygen flow out of the cutting oxygen orifice when you press the cutting oxygen adjustment lever. As you open the preheating oxygen valve on the cutting assembly, oxygen flows through the preheating oxygen tube into the mixing head and out the preheating orifices of the cutting tip face.

Cutting tip face

At this point, the acetylene and oxygen flow out together through the preheating orifices of the cutting tip face (fig. 3–4). Before lighting the cutting torch, first open the preheating oxygen valve. This clears any small particles from the preheating orifices of the cutting tip face. Open the valve one-eighth of a turn from completely shut.

To light the torch, you need slightly more acetylene than oxygen flowing out the orifices of the cutting tip face. To get enough acetylene, open the torch body acetylene valve approximately $^{1}/_{2}$ turn prior to lighting the torch. Opening the torch body acetylene valve first and igniting the torch (without oxygen) causes tiny particles of carbon soot to float in the air. This not only pollutes the air you inhale, but it could restrict the tiny preheating orifices in the cutting tip face.

You can attain the desired flame at the cutting tip face by adjusting the acetylene valve on the torch body and the preheating oxygen valve on the cutting assembly. The flame at the end of the torch tip will actually contain two flames, one within another (fig. 3–5). The outer or largest part of the flame is light bluish in color. The inner flame right next to the cutting tip face is practically white in color.

Figure 3–5, View A shows a flame with a feather on the end of the inner flame. This feather-like appearance indicates the flame contains excess acetylene (carburizing or reducing flame). To correct this, increase the amount of oxygen flowing out of the cutting tip face orifices. Do this by slowly opening the preheating oxygen valve until the feather barely fades away.

Figure 3–5, View B shows a neutral flame, which contains the correct amount of acetylene and the correct amount of oxygen.

Figure 3–5, View C shows a flame containing excess oxygen (oxidizing flame). As you can see, the inner flame is shorter in length in comparison to 3–5, View A and View B. A flame with too much oxygen sounds different from a neutral flame. It has a louder hissing sound and the overall flame is normally shorter. When there is too much oxygen coming from the cutting tip face orifices, the flame normally goes out, or the molten metal continually explodes as you press the cutting oxygen adjustment lever and start cutting the metal.

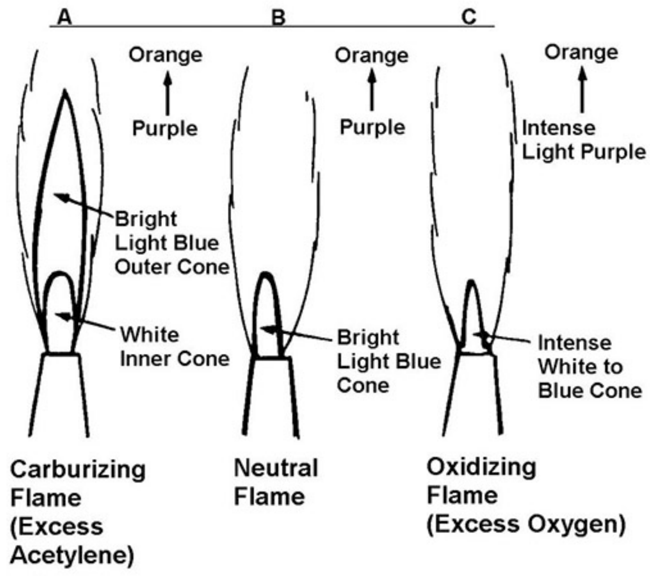


Figure 3–5. Oxyacetylene flame.

You do not need to rotate the acetylene and preheating oxygen needle control valves very much to achieve the neutral flame. Take your time and move the control knobs very slowly until you attain a neutral flame. Make sure you are wearing welding goggles as you adjust the acetylene and oxygen for the neutral flame. If you do not, the glare from the bright light of the flame can irritate and possibly injure your eyes. It is also much easier to see the current state of the flame cones in the subdued light of the torch.

You will use this neutral flame for heating the metal only, or “preheating the metal,” before starting the cutting operation. Pressing the cutting oxygen adjustment lever allows regulator pressure oxygen to flow through the cutting oxygen tube, the mixing head, and then out the cutting oxygen orifice of the cutting tip face. The cutting oxygen tube does not open into the mixing head but connects directly to the cutting oxygen orifice in the torch tip. You actually use regulator pressure oxygen from the cutting oxygen orifice to cut the metal. This oxygen causes the metal to separate (oxidize rapidly).

Tips

Tips (or nozzles) are made of copper or brass and are available in a variety of sizes. Normally, the tip size is marked or stamped on the side of the welding tip with a single- or double-digit number usually ranging from 0 to 10. The number equals a certain orifice diameter: the larger the number, the larger the orifice diameter. Each manufacturer has its own numbering system. One manufacturer might number a welding tip with number 2 and another manufacturer might number its welding tip with the same orifice diameter as a number 4.

If you are trying to weld $^{1}/_{8}$-inch metal with a number 0 welding tip and you cannot attain a molten metal pool, change welding tips to a higher number. You are not increasing the temperature of the flame by doing this; instead, you are simply increasing the volume of the flame. In oxyacetylene welding, the flame temperature is the same regardless of the size (number) welding tip you use. The temperature of the flame changes when you deviate from a neutral flame. Adding more oxygen beyond the neutral flame condition increases the flame temperature. To decrease the flame temperature, increase the acetylene beyond the neutral flame condition. Look at the examples of welding tips to the left and below the cutting assembly in figure 3–4. The lower numbered welding tips are at the bottom. As you increase the size of the welding tip, notice that the construction is larger to withstand a larger volume of heat.

Most welding torch bodies are designed to receive the different size tips. For the majority of body and fender welds, you will normally use a no. 1 or a no. 2 welding tip. A no. 10 is used for welding heavy-duty metal applications. Soldering tips are also available in different sizes and used for brazing and soldering.

Rods and sizes

Welding rods used with the oxyacetylene welding torch are called filler or oxyacetylene welding rods (arc welding rods are commonly referred to as welding electrodes). Oxyacetylene welding rods come in a variety of sizes and types. Normally, welding rods range in 28- to 36-inch lengths. They also range in various diameters—$^{1}/_{16}$, $^{3}/_{32}$, $^{1}/_{8}$, $^{5}/_{32}$, $^{3}/_{16}$, $^{1}/_{4}$, and $^{5}/_{16}$. For auto body welding (mild steels), you need smaller diameter mild-steel welding rods.

Welding Rods

Characteristic	Description
Coatings	Steel welding rods come copper-coated, which prevents corrosion prior to their use. Steel welding rods normally come in 28-inch lengths. Aluminum welding rods normally come with a flux coating on the rod; as with steel welding rods, aluminum welding rods normally come in 28-inch lengths. The flux coating helps keep impurities out of the weld and improves welding characteristics.
Numbering	The American Welding Society (AWS) has developed a classification code number system for arc welding electrodes and oxyacetylene welding rods. On oxyacetylene rods, you may see numbers like GB–45, GA–50, GA–60, and GB–60. • G indicates gas welding (oxyacetylene). • A indicates high ductility (not brittle, can be stretched, drawn, or hammered thin without breaking). • B following the letter G indicates lower ductility. The two-digit number following the alpha code indicates the tensile strength of the weld in thousand psi (e.g., the number 50 indicates 50,000-psi tensile strength).

Brass rods

These rods are used for brazing and come in 36-inch lengths with various diameters. You will probably be using $^{3}/_{32}$-, $^{1}/_{8}$-, and $^{3}/_{16}$-inch diameter rods for brazing. These rods are made of nonferrous material, which does not contain any steel or iron in it; they start melting *above* 800° F but *below* the melting point of the metal you are brazing. Steel normally starts changing to molten metal (melting) at 2,700° F, and copper at 1,950° F. When you use brazing rods, it is highly advisable to also use a welding flux. These are formulated to chemically clean the surface and exclude atmospheric oxygen during the welding process. This serves to keep impurities out of the weld and improves welding characteristics. Flux either comes in the form of a powder, paste, or a solid coating on the filler rod.

Welding body components

One major consideration in welding body sheet metal is the increased use of high-strength steels (HSS). Major manufacturers are using these materials to construct vehicle bodies to achieve fuel economy and other desirable qualities. Oxyacetylene welding is unsuited for HSS. Consult the technical order or commercial manual to determine if a vehicle body is constructed with HSS before attempting to use oxyacetylene equipment to repair vehicle body parts. If you determine the vehicle body (or portions of it) is not HSS but rather mild (low carbon) steel, then various oxyacetylene welding operations can be performed. These operations present a variety of problems in straightening and welding. For example, thin sheets of metal are formed into the various body parts such as fenders, hoods, and tops. If you weld or braze this thin metal, it heats rapidly and warps readily. This warping is more noticeable as you work with vehicle roofs and door panels. Therefore, you must exercise extreme care in selecting the proper rod for the type and thickness of the metal you are going to weld.

Identifying unmarked rods

If you come across welding rods without any markings, you can use some accurate methods for positive identification. Most carbon-steel rods are coated with a protective coating—normally copper. Copper not only protects the rod from corrosion but also adds toughness to the weld.

One easy way of identifying a welding rod is to place a magnet on the rod itself.

- If the rod is steel or iron, it makes contact with the magnet and stays there until you pull it away from the magnet.
- If the welding rod does not stick to the magnet, you have a nonferrous welding rod (aluminum, bronze, brass, etc.).

Another way of determining the kind of welding rod you have is to perform a spark test (described earlier in this unit). If you suspect you have a cast-iron rod, use this procedure. The cast-iron rod is very brittle and if you break it in half, the broken rod will have a gray color. These rods usually have a rough, sandy surface and exhibit magnetic properties.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

620. Metals

1. State the relationship of metal properties when one property has changed.

2. Match the definitions in column B with their mechanical properties in column A. The items in column B may only be used once.

Column A	*Column B*
____ (1) Breaks with little or no deformation.	a. Hardness.
____ (2) Ability to stretch.	b. Tensile strength.
____ (3) Result of stress.	c. Brittleness.
____ (4) Resists abrasive action.	d. Shear strength.
____ (5) Resistant to deformation.	e. Ductility.
____ (6) Internal reaction to externally applied force.	f. Toughness.
____ (7) Absorbs sudden shocks without breaking.	g. Wear resistance.
____ (8) Resistance to stretch.	h. Stress.
____ (9) Resistance to cutting.	i. Strain.

3. List the four shop tests you can use to identify metals.

4. What type of metal will usually *not* create a spark stream in a spark test?

5. What should you compare the spark stream with to determine a metal's identity in the spark test?

6. What type of test is the best method for distinguishing aluminum from magnesium?

7. As you perform a chip test, what type of metal would a long smooth cut indicate?

8. What does the second digit of the standard steel designation number of simple alloy steel indicate?

9. What does the number 75 mean in the standard steel designation number 1075?

621. Oxyacetylene equipment

1. The design of the acetylene cylinder permits storage of acetylene under pressure up to what psi?

2. What percent acetone does an acetylene cylinder contain?

3. What do manufacturers use to stabilize the acetylene under pressure?

4. Why does the acetylene cylinder valve fitting have left-handed threads?

5. What color is the acetylene cylinder?

6. What color are oxygen cylinders painted?

7. What type of threads does the oxygen cylinder valve fitting have?

8. What is the maximum working pressure of acetylene from the regulator?

9. What is the purpose of a regulator?

10. What is the purpose of the adjusting screw on the second stage of the regulator?

11. Why should you quickly crack open and close the cylinder valve prior to installing the regulator to the cylinder valve fitting?

12. What are the different colors and types of threads for the acetylene and oxygen hoses?

13. What substance do you use to check all fitting joints for leaks?

14. What should you do if you detect a leak in one of the hoses on the oxyacetylene welding equipment?

15. What protects your eyes from harmful rays of the molten metal pool and oxyacetylene flame?

16. What is the purpose of the two needle valves on the oxyacetylene torch body?

17. What blocks the flow of oxygen inside the cutting assembly even though the torch body oxygen needle valve is fully open?

18. In what position do you place the torch body oxygen valve when using the cutting assembly?

19. Why should you open the preheating oxygen valve first before lighting the cutting torch?

20. If you open the torch body acetylene valve first and then light the torch, what will most likely happen?

21. What does a feather-like appearance on the inner flame of the oxyacetylene flame indicate?

22. What do you call a flame that has the right amount of acetylene and oxygen?

23. When you notice the sound coming from the flame is louder than normal and the molten metal keeps exploding, what does this indicate?

24. Describe what happens as you depress the cutting oxygen adjustment lever for cutting metal.

25. What size torch tips do you use for the majority of body and fender welds?

26. What purpose does the flux coating serve on aluminum oxyacetylene welding rods?

27. What methods are used to identify unmarked welding rods?

3–2. Welding Categories

There are several different types of heat-joining processes. In the next two lessons, we will discuss the two main categories, which are fusion and nonfusion welding. Fusion welding is associated with any welding process that joins two metals together by reducing them to a molten state. Nonfusion welding is associated with any process that joins metals together through adhesion methods. Both welding categories can be applied with an oxyacetylene torch.

622. Fusion welding

Fusion welding is the joining of two metals by heating them into a molten pool and allowing them to cool into one piece. Sometimes metal will overlap enough to allow for the fusing of the metals without the use of a filler rod. However, most cases will require the use of filler rod. In this lesson, we will discuss fusion welding using the oxyacetylene torch.

Technique

Filler rod is used to fill in an area where there is a wide break in the metal. When using filler rod with the fusion process, it is imperative that both edges of the break receive the same amount of heat. This is necessary to maintain equal molten metal pools on both edges of the metal. As you add the filler rod to both molten metal pools, fusion occurs—one molten metal pool forms, leaving one bead. As previously stated, if there is sufficient overlapping metal at the break, you do not need filler rod. You can weld the overlapping metal together to form a strong bead. However, if there is a gap between the two edges of metal, you will need to add filler rod to the molten metal pool to fill in the gap.

It is best to hold the filler rod at a 45° angle to the metal surface.

- Try to hold the filler rod in line with the bead.
- Hold the rod tip close to the molten metal pool.
- Keep the rod tip out in front of the flame so it remains preheated for quick and easy melting.

If you need to add filler rod to the molten metal pool, do the following:

- Dip the rod into the pool.
- Wait until the end melts.
- Lift it out of the pool.

In other words, move the filler rod alternately up and down as the weld progresses along the bead. Do not allow the end of the rod to cool by raising it too far away from the molten metal pool and flame.

Flame movement

For successful filling, the bead needs to overlap both edges of the break with adequate penetration on both metal edges. The idea is to start a pool of molten metal approximately $^{3}/_{16}$ to $^{3}/_{8}$ inch in diameter and carry it along the metal surface consistently. If you move the flame across the metal surface too fast, the molten metal pool solidifies due to the lack of heat in one area. On the other hand, if you move the flame too slow, a large molten metal pool will develop. This will result in the bottom of the pool falling out, leaving a hole to fill in the metal.

To acquire the correct flame movement, watch the width of the molten metal pool and move the flame slower when it becomes too narrow and faster if it spreads out too much. Once you start the molten metal pool, move the flame in a circular fashion to maintain an equal molten metal pool on both metal edges while adding filler rod to the pool. DO NOT jerk the flame away if the molten metal pool becomes too wide; instead, simply speed up the flame movement.

Flame distance

The flame distance is very important in producing a good weld. Keep the inner flame of the neutral flame approximately $^{1}/_{8}$ inch from the metal surface, but not touching the metal. Remember, the closer you bring the inner flame to the metal surface, the more heat you apply to one specific area of the metal surface. In oxyacetylene welding, raise the temperature of the metal to the melting point as soon as possible to reduce the spread of heat to the adjacent metal.

Flame angle

Hold the torch body like a pencil or like the handle of a hammer; whichever is more comfortable to you. You need to have full control of the torch body to maintain a flame angle between 45° and 60° to the metal surface. This angle allows the heat from the flame to preheat the metal in front of the molten metal pool. Preheating the metal in front of the molten metal pool allows you to move the flame across the metal surface at an even pace while, at the same time, maintaining a consistent diameter of the metal molten pool. To weld most joints, you need to maintain the 45° to 60° angle and point the flame directly at the gap between the two edges of metal. You want equal amounts of heat from the flame to heat both edges of the metal equally. If you do not point the flame properly or move it in a circular fashion, it will cause uneven preheating of the metal edges and unequal expansion.

Forehand and backhand welding

It is best to weld forehand on body metal as shown in figure 3–6. Move the welding rod along ahead of the flame preheating the filler rod. If you need to add filler rod to the molten metal pool, the preheated rod will melt quickly and not take much heat away from the molten metal pool. The direction of travel of forehand welding permits you to preheat the metal ahead of the molten metal pool, permitting consistent movement of the flame across the metal surface.

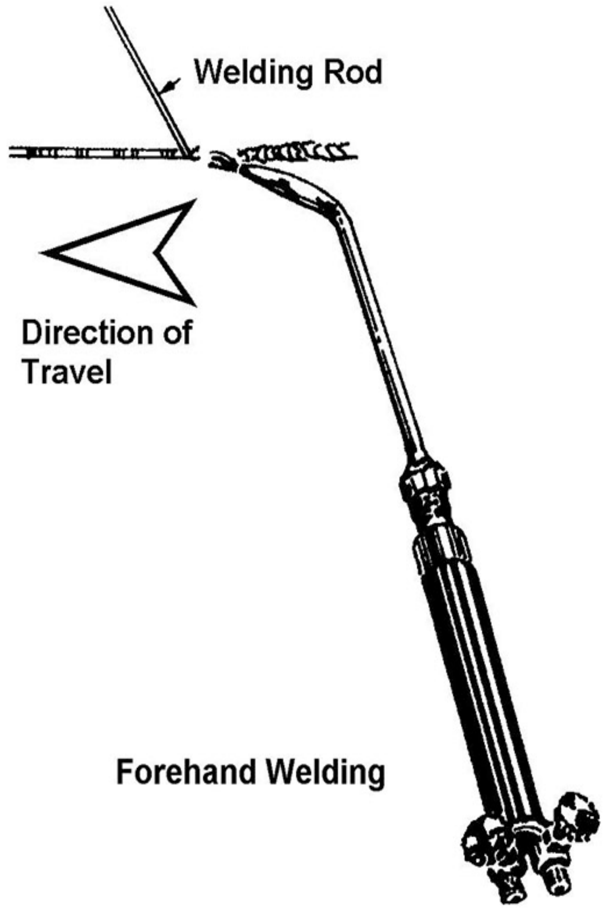


Figure 3–6. Forehand welding.

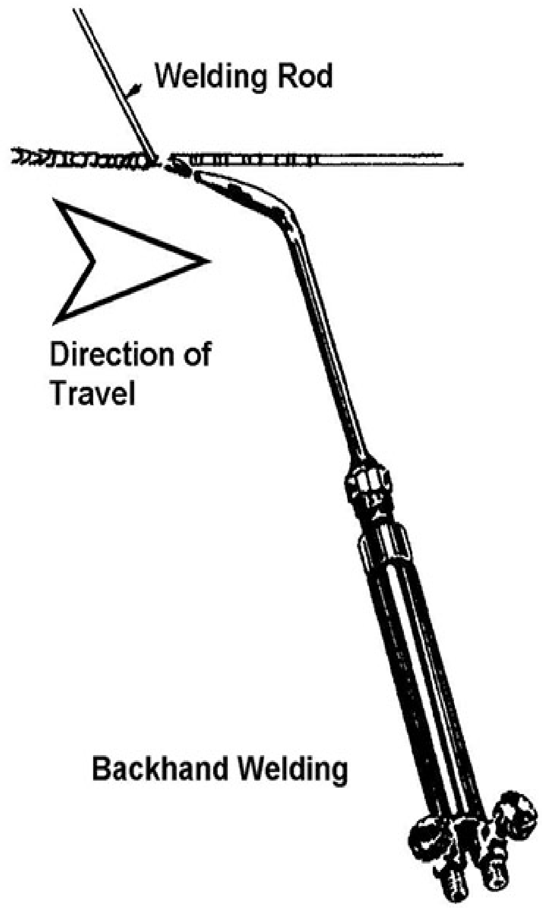


Figure 3–7. Backhand welding.

In backhand welding (fig. 3–7), you move the flame along the metal surface ahead of the filler rod. This method is slower and may cause thin fender metal to burn and the panel to stretch out of shape from the excess heat. The exact position of the filler rod varies according to the type of weld.

Weaving the flame from side to side may be advisable when running a bead. This oxyacetylene welding technique spreads the heat over a greater area; thus, you can form the bead more slowly.

- Weaving is necessary to develop heavier beads.
- Weaving provides better penetration when welding heavier metals.

Some welders find that they can move the flame at a more even rate by using a slight weaving motion. Remember, weaving is necessary for welding heavier metals but optional for welding light-gauge metal.

Cutting metal

You will often have occasion to cut metal using the oxyacetylene cutting torch. On vehicles, you may have to cut broken braces or brackets, bent panels, damaged sheet metal, or body pillars. Once you have cut these damaged areas away from the vehicle, you will normally have to cut metal from stock to replace what you cut away. For all of these operations, oxyacetylene torch cutting does a better and faster job. Keep in mind that the neater and more precise you do the task, the easier the replacement welding process is to complete.

Cutting Metal	
Process	**Description**
Flame Adjustment	We described previously how to adjust the oxyacetylene flame, as well as how to do this *without* pressing the cutting oxygen adjustment lever (fig. 3–4). Once you have adjusted for a neutral flame, you may have to make another fine adjustment after pressing the cutting oxygen adjustment lever. For example, when you press the cutting oxygen adjustment lever, you may notice a small feather on the end of the inner flame. If so, press the cutting oxygen adjustment lever again and then open the preheat oxygen valve until the feather disappears. This provides a neutral cutting flame that rapidly oxidizes the metal, generating a clean cut.
Preheating Metal	Before you can use oxyacetylene to cut metal, you have to preheat the metal to a certain temperature—normally between 1,400° F and 1,600° F or just below the metal's melting point. At this temperature, the metal glows a bright cherry red. At this point, you are ready to press the cutting oxygen adjustment lever and allow the oxygen flow to pass through the cutting oxygen orifice at regulator pressure. As the metal rapidly oxidizes, the oxygen stream blows the metal away. This occurs directly below the cutting oxygen orifice of the cutting tip face on the cutting torch leaving a narrow slot. **NOTE:** Remember, you have to preheat the metal before pressing the cutting oxygen adjustment lever. If you do not, the oxygen coming from the cutting oxygen orifice will not blow the metal away to form a cut.

You can cut some metals easily and cleanly with an oxyacetylene cutting torch; others you cannot. The hard-to-cut class of metals includes the nonferrous group and high-chromium stainless steels. Cast iron does not cut easily, but you can melt and blow the molten metal away with the oxygen coming out of the cutting oxygen orifice at regulator pressure. However, this cut leaves a rather wide and uneven gap between the edges, especially in the poorer grades of metal. You can cut wrought iron and carbon-steel metals with carbon content low enough to prevent the metal from becoming hard and brittle upon cooling. This is accomplished readily without any special preparation.

Safety

As you begin to set up for cutting the metal with the oxyacetylene cutting torch, take into consideration what metal you are cutting. Additionally, pay close attention to the surrounding area where you will perform the cutting.

Safety Considerations	
Topic	**Discussion**
Surrounding Area	Be aware of your surrounding area before you start your oxyacetylene cutting operation. Never perform oxyacetylene cutting operations around any flammable material. Why start another fire with the fire at the end of your oxyacetylene cutting torch? Look before you start cutting the metal to see where the sparks from your cutting operation will land. Make sure the sparks or tiny globules of metal are not falling on the oxyacetylene hoses or traveling to other work centers. This not only could endanger you but other personnel as well. Never lay a piece of metal directly on a concrete floor and start cutting with the oxyacetylene cutting torch. The heat you generate from the oxyacetylene flame will cause the concrete to explode and send small pieces flying in all directions. Be sure to use some kind of support to raise the metal off the floor (metal table, clean jack stands, etc.). When cutting metal on a vehicle, know what is on the other side of the metal you are cutting. If you do not, you may damage other components on the vehicle and not be aware of it until it is too late. Anytime you are operating oxyacetylene equipment, whether welding or cutting metal, have an approved fire extinguisher nearby.

Safety Considerations	
Topic	**Discussion**
Protective Equipment	We have discussed safety equipment before but it never hurts to emphasize safety around welding operations. • Wear protective equipment whenever you are performing any oxyacetylene cutting operation. • Make sure you are wearing goggles, welders' gloves, and protective clothing or leather apron. • Always make sure your pant legs cover the opening of your shoes. The sparks and tiny globules fly downwards towards the floor as you cut the metal. These could cause serious skin burns if trapped in your shoe. • Wear steel-toe shoes, because the portion of metal you are cutting from the rest of the metal will fall and may land on your shoes by accident.
Torch Tip	Occasionally, you will have to stop all cutting operations and clean the tip of the oxyacetylene cutting torch for the following reasons: • Tiny particles sometimes catch themselves in the tiny orifices of the torch tip. • The cutting tip face accidentally contacts the molten metal from the cutting process. Both events restrict the free flow of acetylene and oxygen from the orifices. If the inner flame is not as long as the other inner flames at the cutting torch tip or appears at a slight angle in comparison to the cutting tip face, perform the following: • Clean the cutting tip face orifices to remove the contamination. This not only hampers your cutting operation, but it also causes the torch flame to go out suddenly with a loud snapping noise. • When the torch flame continues to extinguish suddenly, it is a good indicator that the orifices are restricted and need cleaning. Your vehicle maintenance facility should have tip cleaners for oxyacetylene equipment. Tip cleaners come in various sizes and are small round files attached to a rod. They are packaged inside a small box about the size of a wooden matchbox. As you open the box, you will notice each file is a different diameter to match the various orifice sizes. Before inserting the tip cleaner inside the orifice to clean it of any tiny particles or molten metal, open the oxygen torch body valve and let a stream of oxygen flow out the tip. This helps remove contamination from the torch tip as you move the tip cleaner in and out of the orifice. Be sure to use the correct size cleaner for the tip being cleaned. The torch tips are made of an easily damaged soft metal material. Generally, one "cycle" (insert and remove the cleaner) into the torch orifice is enough.
Oxyacetylene Equipment	Inspect the oxyacetylene equipment before you use it. You may never know who used this equipment last. Pay close attention to all joint connections for leaks and check how they attach to other components. The oxyacetylene hoses normally come in one distinctive color for use respectively with acetylene and oxygen. Before use, inspect these hoses for possible burns, cuts, wear, and overall condition.
Regulator Pressures	You probably will not be working with any metals larger than $1\frac{1}{2}$ inches thick. **CAUTION:** For oxyacetylene cutting operations, never increase the oxygen pressure to more than 45 psi at the regulator. Set *the acetylene pressure no higher than* 15 psi. If you notice the hose pressure starting to creep upwards due to a defect in the regulator, have it repaired or replace the regulator immediately.

623. Nonfusion welding

Nonfusion welding can be best identified as metal adhesive bonding. The two most common types of nonfusion welding are brazing and soldering. Nonfusion welding with an oxyacetylene torch is accomplished in the same manner as many oxyacetylene operations. The main differences are required temperatures and bonding material.

Brazing

What is brazing? The formal definition goes something like this: Brazing is a method of welding whereby a nonferrous metal, whose melting point is lower than the base metal (but always above 800° F), is melted onto a base metal without melting the base metal. Whereas welding involves the base metal and the filler metal becoming fused, or "one" with each other, brazing is instead similar to an adhesive process: you are simply "sticking" the filler metal to the base metal.

All of the processes we have discussed have had certain procedures to follow for a successful operation. Brazing is no exception. In this lesson, we will discuss the procedure for proper brazing. As you would expect, we will begin with the preparation step.

Preparing to braze

To braze, you use the oxyacetylene torch to heat the base metal parts to the temperatures required for the melting and free flowing the brazing alloy. Be careful you do not overheat the base metal. One way to determine the correct temperature is to touch the joint with the filler rod, strip, or wire as the heating progresses. As soon as the temperature of the base metal is high enough to melt the alloy of the filler material, the filler rod, strip, or wire is positioned under the flame to perform the operation.

Brazing Preparations	
Topic	**Discussion**
Filler Material	Brass is used most often as a filler metal automotive nonfusion welding. Actually, brass is an alloy consisting of copper and zinc. This combination of metals adds some desirable characteristics to the weld by blending the characteristics from these two metals into the joint. The filler material ordinarily comes in the form of rods of varying thickness (we have briefly talked about them before).
Applying Flux	Fluxes are used to prevent oxidation of the filler metal and the base metal surface when brazing. They also promote free flowing of the filler metal. They should be chemically active and fluid at the brazing temperature. After the joint members have been fitted and thoroughly cleaned, brush an even coating of flux over the adjacent surfaces of the joint. Take care to leave no spots uncovered. The proper flux is a good temperature indicator for torch brazing because the joint should be heated until the flux remains fluid when the torch flame is momentarily removed.
Flame Adjustment	The flame for brazing should be slightly oxidizing. It permits better bonding between the filler and the base metal and suppresses zinc fumes. Do the following to get the proper oxidizing flame: • Adjust to neutral. • Close the torch acetylene valve slowly. • Continue closing the valve until the inner cone length is reduced by about one-tenth (slightly oxidizing).

Tinning the joint

Tinning is spreading out of a thin layer of molten fluxed weld metal ahead of the main deposit. This forms a coating that provides a strong bond between the base metal and filler. The tinning is due to interaction between the flame and the flux. It takes place only when the base metal is at the right temperature.

- If the base metal is not hot enough, the filler will not flow.
- If it is too hot, the molten filler will boil, fume excessively, and will form droplets on the edges of the base metal.

Proper tinning gives the appearance of water spreading over a clean moist surface. On the other hand, improper tinning looks like water on a greasy surface.

Use a liberal amount of flux, especially when the speed of brazing is rapid. This can be accomplished by heating several inches of the end of the filler rod and dipping or rolling it in a container of flux.

Where brazing progresses more slowly, as in the repair of heavy castings, it is sufficient to dip the hot end of the rod into the flux and add to the puddle as required.

Technique

As with all other types of welding, brazing requires a specific technique. Good technique will yield good results just as poor technique will yield poor results. The following steps provide a basic brazing technique; it is the basis for successful welds. Once a good basic technique is established, you can experiment to see what variations work for you.

Begin brazing by heating a small area just enough to cause the metal from the fluxed filler rod to spread out evenly and produce a tinning coat a short distance ahead of the main deposit.

1. Keep the inner cone of the slightly oxidizing flame $^1/_8$-inch away from the surface of the metal.
2. Keep the flame pointed ahead of the completed bead at a 45° angle.
3. The puddle should be under and slightly behind the flame.

The torch angle may vary, depending on the position of the joint (overhead or vertical) and the thickness of the bead being made. The motion of the rod and torch depends on the following:

- The size of the puddle being carried.
- The nature of the joint or surfaces brazed.
- The speed of brazing.

When brazing heavy sections, you may have to deposit the filler metal in layers. In such cases, the base metal must be thoroughly tinned when the first layer is deposited. Take care to ensure there is good fusion between filler material layers.

Never reheat the bead after it has solidified without adding more fluxed filler metal. If you do, the deposited filler metal becomes porous and loses strength. Brazing should be done in one pass or layer whenever possible.

Clean the finished bead with a wire brush to remove any excess flux from the surface of the metal. Because brass has a relatively low strength when hot, do not put any stress on a bonded joint until it has cooled completely.

Silver brazing (soldering)

Silver brazing, frequently called “silver soldering,” is a low temperature brazing process. The rods have melting points ranging from 1,145 to 1,650 ° F (618 to 899 degrees Celsius [° C]). This is considerably lower than that of the copper alloy (brass) brazing filler metals, but higher than the soft soldering used in radiator repair. The strength of a joint made by this process depends on a thin film of silver brazing filler metal.

Filler material

Silver brazing filler metals are composed of silver with varying percentages of copper, nickel, tin, and zinc. They are used for joining all ferrous and nonferrous metals. Exceptions to this are aluminum, magnesium, and other metals that have too low a melting point. It is essential that the joints be free of oxides, scale, grease, dirt, or other foreign matter. With few exceptions, surfaces can be easily cleaned by using a wire brush or an abrasive cloth.

Flux

Flux is generally required with a lower melting point than the silver brazing filler metal. This allows flux to clean the base metal and properly flux the molten metal. Apply a satisfactory flux to the parts to be joined using a brush. Further, apply it to the silver brazing filler metal rod. Sometimes flux is provided in the core of the silver filler material.

Technique

A *strongly reducing flame* (less oxygen than a neutral flame) is best for silver brazing with the oxyacetylene process. Apply the flame outer envelope, *not the inner cone*, to the work. (The cone of the flame is too hot.) For best filler metal distribution, joint clearances should be between .002 and .005 inch. A thin film of filler metal in a joint is stronger and more effective, and a filler buildup around the joint will increase its strength.

Heat the base metal until the flux starts to melt along the line of the joint. Do not subject the filler metal to the flame. Instead, apply the filler metal to the heated area of the base metal just long enough for it to flow completely into the joint. If one of the parts to be joined is heavier than the other, the heavier part should receive the most heat. In addition, parts having high-heat conductivity should receive more heat.

Soft soldering

The main difference between soft soldering and silver brazing is temperature; soft soldering is done at significantly lower temperatures. This is always below 800° F (427° C). In many respects, this operation is similar to the processes we covered earlier. Recall that brazing does not melt the base metal; instead, it is merely tinned on the surface by the solder filler metal.

For strength, the soldered joint depends on the solder penetrating the pores of the base metal surface and forming a base metal-solder alloy. Together this forms a mechanical bond between the parts. Soft solders are used where airtight or watertight joints (which are not exposed to high temperatures) are required. The copper water pipes found in homes are a good example of this. Another example is the soldered joints used in radiator construction.

All soldering operations require a flux in order to obtain a complete bond and full strength at the joints. Recall from earlier lessons that fluxes clean the joint area, prevent oxidation, and increase the wetting power of the solder by decreasing its surface tension. The solder used in most automotive applications typically comes in wire rolls of various thicknesses. These contain the flux in the wire's core. Rosin and acid are the two categories of fluxes in common use today, and described in the following table. Hence, the common trade terms *rosin-core* and *acid-core* solder.

Fluxes	
Type	**Description**
Rosin	Rosin fluxes are used to prevent the formation of oxides during soldering operations. The most common application of this concept is a solder connection or repair to a vehicle electrical system. Oxides are a form of corrosion. Corrosion in repairs to electrical wiring defeats the entire repair.
Acid	You will probably use this solder most. These fluxes (chemical or acid) contain zinc chloride and ammonium chloride. They may be used on tarnished surfaces to permit good tinning. You can also use a solution of zinc and hydrochloric (muriatic) acid, which tin workers commonly use as a flux.

NOTE: Muriatic acid is a form of hydrochloric acid and is very dangerous. Be extremely careful!

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

622. Fusion welding

1. Why is it necessary to use filler rod during oxyacetylene welding?

2. When is it *not* necessary to use filler rod during oxyacetylene welding?

3. How large of a diameter should you maintain the molten metal pool?

4. What happens if you move the oxyacetylene flame too slow across the metal surface?

5. How close to the metal surface should you keep the inner flame of the neutral flame during oxyacetylene welding?

6. At what angle should you maintain the flame angle to the metal surface?

7. Where should you aim the oxyacetylene flame when welding most joints?

8. What type of oxyacetylene welding are you performing if you move the flame along the metal surface ahead of the filler rod?

9. What technique of oxyacetylene welding would you use to spread the heat over a greater area so you can form the bead more slowly?

10. What are some vehicle components you may cut using the oxyacetylene cutting torch?

11. You notice a small feather-looking appearance on the end of the inner flame after you depress the cutting oxygen adjustment lever. What should you do to correct this?

12. What do you do to the metal prior to cutting it with the oxyacetylene cutting torch?

13. If you cut cast iron with the oxyacetylene cutting torch, what kind of cut does this leave?

14. Why should you be concerned about where the sparks and tiny globules of molten metal are falling during your oxyacetylene cutting operation?

15. Why should you not place a piece of metal directly on a concrete floor for oxyacetylene cutting?

16. What should you always have nearby when oxyacetylene welding or cutting metal?

17. What should you do if you notice the inner flame at the cutting tip face is at an angle to the face tip and the flame keeps going out with a snapping noise?

623. Nonfusion welding

1. How does the brazing process differ from the welding process?

2. Name one method of determining if the base metal is at the correct temperature to begin the brazing process.

3. What type of filler metal is most often used in automotive nonfusion welding, and what is its composition?

4. What are used to prevent oxidation of the filler material and the base metal surface when brazing?

5. How should the torch flame be adjusted to suppress zinc fumes when brazing? What else is gained from adjusting the torch flame in this manner?

6. Describe the torch flame adjustment procedures required to obtain a slightly oxidized flame.

7. What do you call the process of spreading a thin layer of molten fluxed weld metal ahead of the main deposit when you are brazing?

8. What do excessive fumes and droplets forming on the edge of the base metal while tinning indicate?

9. If depositing filler metal in layers becomes necessary for brazing heavy sections of material, what actions should you take to produce the highest quality repair?

10. What material must be added to maintain the integrity of the repair when reheating a finished bead after it has solidified? What type of repair will result if this material is not added?

11. What do you call the low-temperature brazing process using rods with melting points ranging from 1,145 ° F to 1,650 ° F?

12. What metals are exceptions to ferrous and nonferrous metals joined together by silver brazing filler materials?

13. Why must the melting point of the flux be lower than the melting point of the silver brazing filler metal?

14. When silver brazing by the oxyacetylene process, what part of the torch flame should be applied to the work? Why?

15. What does obtaining a joint clearance between .002- and .005-inch do for the quality of the repair?

16. Where are soft solders used?

3–3. Plasma Cutter

The plasma cutter is replacing the oxyacetylene torch as the preferred method of cutting metals. The plasma cutter's unique use of compressed gas and electrical current results in extremely clean cuts. The cuts are accomplished without degradation of the metal composition. It can also be used to cut the thinner sheet metal without warping. In the following lessons, we will discuss plasma cutter equipment and operation.

624. Plasma cutter equipment

What is plasma? When a solid is heated, it liquefies; when a liquid is heated, it becomes a gas. When a gas is super-heated, it breaks down into free electrons and positively charged ions. (An ion is part of an atom or molecule with an electrical charge.) This *ionized gas* is called plasma. It conducts electricity. A common example of plasma is a lightning bolt.

A plasma cutter works very much like a lightning bolt. Direct current (DC) high-voltage electricity arcs from a negative potential (the electrode inside the torch) to a positive potential (the work piece) through a jet of ionized gas. In plasma-arc-cutting (PAC) systems, this gas is moving at close to supersonic speeds, and its temperature is up to 50,000 ° F. Plasma cutters come in varying amperage ratings. The higher the amperage, the thicker the metal it can cut. Most body shops will have a cutter rated at 30 amperage (amps). This is more than adequate to cut body panels and metal up to $^1/_4$ inch thick.

Plasma cutter components

Plasma cutters are self-contained units. Some may have only a simple on and off switch with a ready light. Others can be as elaborate as to have built-in compressors, variable amperage output controls, and onboard coolant. However, the following are basic components (fig. 3–8) that are on all models:

1. Power supply (110 or 220 volt depending on amperage).
2. Control system.
3. Leads package.
4. Plasma Torch.

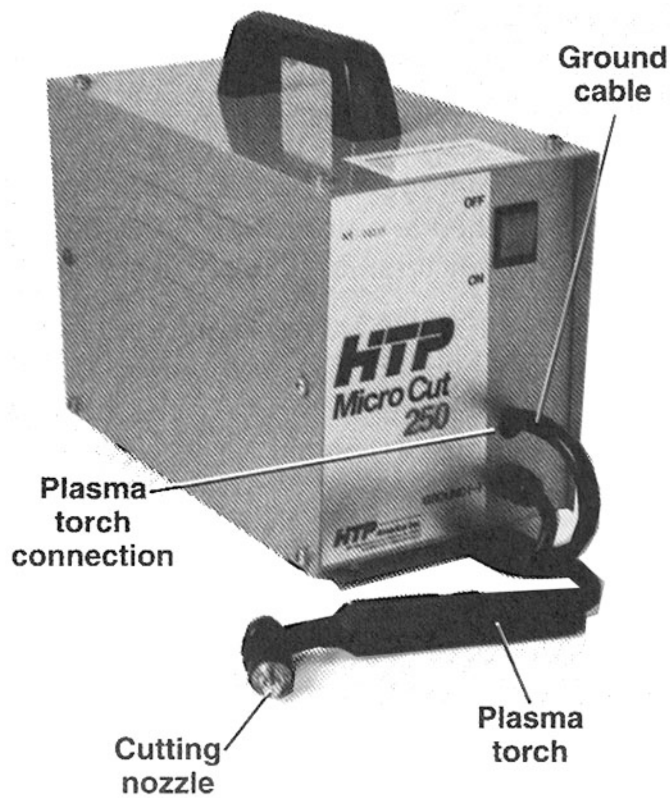


Figure 3–8. Plasma cutter equipment.

Power supply

Generally, power supplies are direct current electrode negative (DCEN). This process requires a constant source of DC at high voltage to provide a smooth direct current output to the torch. Operating voltage may range from 90 to 200 volts. Amperage output may be at a preset level or have variable settings, depending on the size of the unit.

Control system

The control system will vary with the size of the machine being used. As stated, they can be as simple as an on and off switch with a "ready to cut" light. They can otherwise be a collection of switches, dials, and gages, used to monitor gas flow, adjust amperage settings, and regulate other system functions. In either situation, be sure you know how to operate the controls system before using the machine.

Leads package

The leads package carries electricity, gas, coolant, and in some cases control signals to the torch. They are a combination of cables, wires, and hoses with the appropriate attachment fittings. They can range in length from 10 feet to 225 feet. Extension kits can be used when longer leads are needed.

Plasma torch

The torch is designed to generate and focus the plasma arc. It consists of four main components: an electrode, gas swirler, cutting nozzle, and a shield cup.

Component	Purpose
Electrode	Carries the negative charge from the power supply and generates the arc. If you use compressed air as the plasma gas, the electrode is typically copper with hafnium metal (emitting element) inserted into the center. If you use nitrogen, argon, or hydrogen as the plasma gas, the electrode insert will be made of tungsten.
Gas Swirler	Designed to spin the plasma gas into a vortex (like a tornado). Gas swirlers are usually made of high-temperature plastic or ceramic with angled holes to impart a spin on the flowing gas. Spinning the gas centers the arc on the electrode and also constricts and controls the arc as it passes through the nozzle. The direction of swirl can be either clockwise or counter-clockwise.
Cutting Nozzle	The nozzle's job is to constrict and focus the plasma arc. This increases the energy density and velocity of the plasma jet. Nozzles are usually made of copper or plated copper with a carefully sized hole (orifice). The nozzle orifice diameter determines the maximum cutting amperage for a particular nozzle. Orifice diameter can range from about $^{1}/_{25}$ to $^{1}/_{4}$ inch (about 1 to 6.4 mm). The larger the orifice, the more current it can handle. Torch nozzles should be used at, or very near, their maximum cutting rating. Overpowering the nozzle will gouge the orifice, affecting cut quality and speed.
Shield Cup	High-temperature plastic, ceramic, or copper shields (or shield cups) are designed to insulate the front end of the torch from the work piece and protect the nozzle from being spattered with molten metal. Shield cups also channel secondary gas or water.

NOTE: The torch may also contain a pilot arc or a high-frequency starting circuit. However, most plasma torches need to be touched to the work to start the arc.

Plasma cutter gasses

Plasma gas or primary gas is used to create plasma, while secondary-shield gas cools the torch, assists in blowing away molten metal, and provides a shield for the plasma arc (fig. 3–9). The most commonly used plasma gases are compressed air, nitrogen, oxygen, and argon-hydrogen. Common secondary gases are compressed air, nitrogen, carbon dioxide, and water.

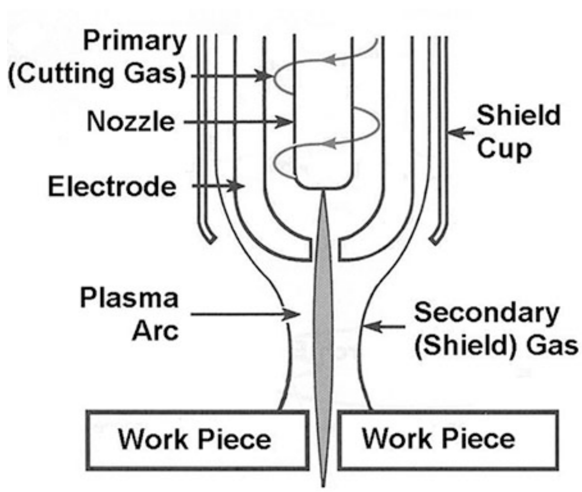


Figure 3–9. Cutting process.

The following tables show the primary and secondary gases and their recommended uses, advantages, and disadvantages.

Plasma Gas Selection Chart			
Carbon Steel, Stainless Steel, and Aluminum			
Gas	**Recommended For**	**Advantages**	**Disadvantages**
Air	Carbon Steel Stainless Steel	Clean Fast Cut on Carbon Steel Affordable Convenient	Short Electrode Life Nitriding on Cut Surface Oxidation on Stainless Steel/Aluminum
Nitrogen	Stainless Steel Aluminum Carbon Steel	Excellent Cut on Stainless Steel/ Aluminum Excellent Electrode Life Affordable	Nitriding on Cut Surface
Argon/Hydrogen	Stainless Steel Aluminum	Excellent Cut Quality and Speed on Thicker Material (> $^{1}/_{2}$ inch) Less Smoke/Fumes	Expensive Not for Carbon Steel
Oxygen	Carbon Steel	Clean Cut No Surface Nitriding Fast on Carbon Steel	Short Electrode Life Oxidation on Stainless Steel/ Aluminum

Secondary Gas Selection Chart			
Gas	**Used With**	**Advantages**	**Disadvantages**
Air	Air/Nitrogen Oxygen	Convenient Affordable	Nitriding on Cut Surface
Carbon Dioxide	Nitrogen	Good Shield for Most Metals Good Parts Life Wide Dross-Free Window	Inconvenient (may require a manifold system of cylinders) Rough Surface Finish
Nitrogen	Nitrogen Argon/Hydrogen	Excellent Cut Quality on Stainless Steel/ Aluminum	Nitriding on Cut Surface Narrow Dross-Free Window Shorter Parts Life than CO2
Water	Nitrogen Argon/Hydrogen Oxygen	Excellent Cut Quality on Stainless Steel/ Aluminum Less Smoke/Fumes	Messy Requires Good Water Quality

625. Operating the plasma cutter

In this lesson, we will discuss the use of a PAC system in cutting metals and its proper maintenance. When operating a particular PAC, you must first be fully aware of all manufacturer's recommended procedures, and be familiar with its use. This will not only allow you to employ the PAC system properly, but facilitate proper maintenance. In this lesson, we will discuss the use of a PAC system in cutting metals and its proper maintenance.

Cutting metals

When choosing a PAC, you must be well informed enough to select the proper cutter to perform the job or task you expect it to accomplish. If you use the wrong cutter to cut metal that is too thick, it can damage the unit. The following table provides a step-by-step procedure for using a simple PAC on regular body panels.

Procedure for Using PAC on Regular Body Panels	
Step	**Description**
1	To operate the unit, connect it to a clean and dry source of compressed air with a *minimum line pressure* of 60 psi at the air connection.
2	Connect the torch and ground clamp leads to the unit. Plug the machine in and connect the ground clamp to a clean metal surface on the metal to be cut. Put the ground clamp close to the area to be cut.
3	Ensure that all safety gear required is being worn and that the area is free of clutter (wires, fuel lines, and sound deadening materials), and flammable items. Further, make sure the blown metal stream trajectory is clear of all items and personnel.
4	Move the cutting nozzle into contact with an electrically conductive part of the work. This will ensure that the safety circuit will allow the machine to operate.
5	Hold the cutting torch perpendicular to the work surface.
6	Push the plasma torch down; this will force the cutting nozzle down into contact with the electrode. The plasma arc will start.
7	Release the downward pressure off the torch to let the cutting nozzle return to its original position.
8	While keeping the cutting nozzle in contact with the metal surface, drag the gun lightly across the work surface.
9	Move the plasma torch in the direction that the metal is to be cut. The speed of the cut will depend on the thickness of the metal. If the speed is too fast, the cut will not go all the way through. If the speed is too slow, it will put too much heat into the work piece and could extinguish the plasma arc.
10	After you have finished, let the torch head cool down by idling the machine for several minutes.

NOTE: Always keep in mind that a plasma cutter can cut through metal like butter. Therefore, you do not have to imagine what it can do to a body part. ***Always practice safety first when using this machine***.

Now that you know the basics in PAC operation, let us discuss some cleaning tip procedures and other things that will increase the service life of components.

Maintaining the plasma cutter

As with all equipment, there are maintenance tips and operational procedures that will extend component life.

In the plasma cutting process, the only two components listed as consumables (parts that get used up in the cutting process) are the electrode and the cutting nozzle. The following table lists tips and operating procedures that will help reduce premature wear on the PAC unit.

No.	Tips and Operating Procedures to Improve Part Life
	Several tips and operating procedures can help improve the service life of torch parts.
1	Ensure proper gas pressure and flow. The pressure and flow of plasma gas is extremely important to consumable life. If gas pressure is too high, electrode life will be significantly reduced. If gas pressure is too low, nozzle life will be adversely affected.
2	Use the appropriate standoff. The standoff chart supplied with your machine facilitates your ability to determine the proper distance between torch nozzle and work piece when cutting. For hand-held cutters, use standoff devices. For mechanized systems, manually set the standoff or use automatic height control. When piercing, if possible, set the standoff to two times the height used for cutting or the maximum height that will allow arc transfer.
3	Pierce within system limits. Do not try to pierce metals too thick for your plasma cutter. You can usually pierce up to half the thickness rating of your system. For example, a 100-amp system rated to cut 1-inch carbon steel should only be used for piercing $^{1}/_{2}$-inch steel.
4	Do not *overpower the nozzle* (running at an amperage level that exceeds the rating), as this will quickly cause the nozzle to fail. Set the amperage at 95 % of the nozzle's rating. For example, run a 100-amp nozzle at 95 amps.

No.	Tips and Operating Procedures to Improve Part Life
	Several tips and operating procedures can help improve the service life of torch parts.
5	Keep plasma gas clean and dry. A plasma system needs clean dry gas to operate correctly. Contaminated gas often is a problem with compressed air systems. It can cause short consumable life and premature torch failure. To test gas quality, purge gas through the torch in the “test mode” and hold a mirror under the nozzle. If any water vapor or oil mist appears on the mirror, track down and correct the problem.
6	Use edge starts. Whenever possible, employ edge starts rather than pierce starts to begin a cut. Edge starting can significantly improve the life of consumable parts. Use proper techniques. Start the plasma arc with the nozzle orifice centered directly over the edge of the work piece to avoid arc stretching. Arc stretching occurs at the beginning and end of a cut if the arc has to “stretch” to reach metal. This causes premature nozzle failure. This problem can be avoided by the proper edge starting technique and by the appropriate timing of the “arc off” signal.
7	Avoid unnecessary pilot arc time. The pilot arc wears out electrodes and nozzles very quickly. Always position the torch within transfer distance of the metal prior to starting. If possible, use chain cutting (linking one cut to the next) to reduce piloting time and number of pierces.
8	Use anti-spatter compound on shields. Anti-spatter sprays and dips help to keep slag from building up your shield cup. Always remove the shield from the torch before applying anti-spatter compounds.
9	Remove slag from shields. Frequently remove slag buildup from the front of the torch. Slag can cause double arcing.
10	Keep torch and parts clean. Any type of particulate contamination in the torch or consumables can substantially affect the performance of your system. When changing parts, set the consumables on a clean shop rag. Always check torch threads and clean the nozzle and electrode seating areas with electrical contact cleaner or hydrogen peroxide. Purge plasma gas for 2 to 3 minutes after part changes or any prolonged shutdown to ensure that moisture is blown out of the torch.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

624. Plasma cutter equipment

1. What is plasma?

2. What are the four components of a plasma cutter torch?

3. What type of electrode insert will be used if the plasma gas is nitrogen, argon, or hydrogen?

4. Which component of the plasma torch is designed to spin the plasma gas into a vortex?

625. Operating the plasma cutter

1. What are two important items you must be aware of when operating a plasma cutter?

2. What is the minimum air pressure needed at the air connection to operate the plasma cutter?

3. What are the two consumables in the plasma cutter?

4. Explain the term *overpowering the nozzle*.

5. What is the purpose of anti-spatter sprays and dips in plasma cutting?

6. How long do you purge plasma gas from the lines after a parts change? Why?

3–4. Heat Exchangers

In a general sense, a heat exchanger is any device such as a water radiator, oil cooler, or the like used to cool a liquid or gas by transferring heat to another liquid or gas. You learned a little bit about certain heat exchangers in earlier volumes when studying engine cooling, lubrication, and HVAC systems. Now that you are familiar with nonfusion welding techniques, like soldering and brazing, we will review and reexamine these components, and discuss how to perform needed repairs.

In this section, we will cover the operation and construction of heat exchangers, plus several methods for cleaning, testing, and repairing these units. Keep in mind, heater cores are very similar in construction to radiator cores, and the same maintenance procedures apply to both components.

626. Radiators and oil coolers

Both the radiator and oil cooler can greatly affect the life and service of a vehicle's engine and transmission. In conjunction with the radiator and cooler, the vehicle has a thermostat to keep the coolant inside the engine until it reaches a preset temperature. Once the coolant reaches this preset temperature, the thermostat opens and allows the coolant to flow to the radiator. A water pump, which is usually engine-driven via a belt-and-pulley system, moves the coolant. The pump circulates coolant throughout the engine and into the hot tank of the radiator (figs. 3–10 and 3–35). From the hot tank, the coolant travels through thin tubes with fins attached to them.

These tubes and fins make up the radiator core or assembly. The core is where heat from the coolant dissipates to the air passing through the radiator core section.

From the core, coolant enters the cool tank of the radiator (fig. 3–10 and fig. 3–11) where it flows around a heat exchanger (oil cooler) to cool the automatic transmission fluid. From the cool tank, the coolant flows into the water pump inlet, completing the cycle. It then circulates once again throughout the engine to repeat the coolant cycle. In this lesson, we will discuss the construction of radiator tanks, radiator cores, and oil coolers.

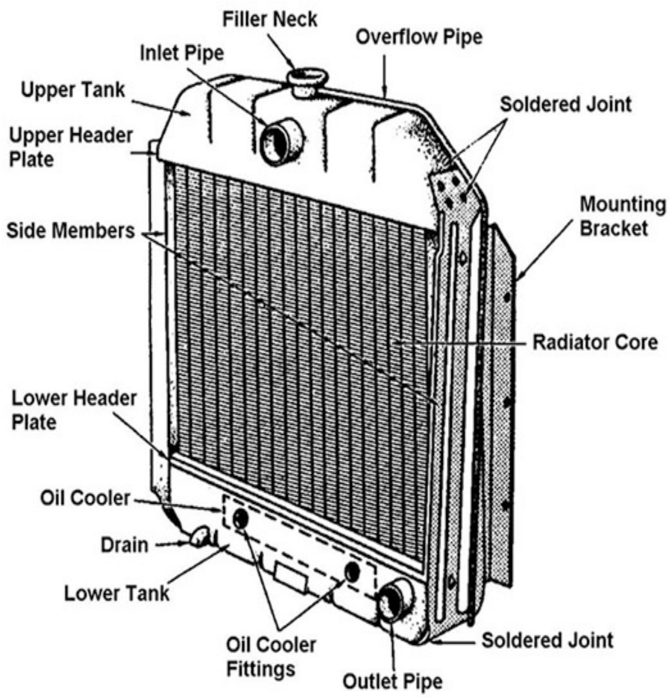


Figure 3–10. Vertical-flow radiator.

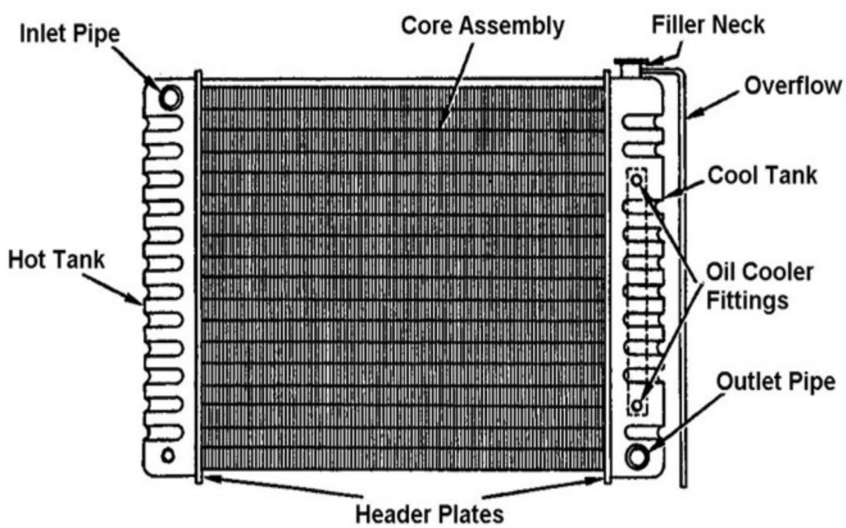


Figure 3–11. Cross-flow radiator.

The two types of radiators include the vertical-flow (fig. 3–10) and the cross-flow (fig. 3–11). While manufacturers use both types, the vertical-flow type is as old as the automobile itself. As styling and design changed, manufacturers lowered hood designs on vehicles, which required lower radiator heights. These design variations led to development of the cross-flow-type radiator.

Radiator tank construction

There are three different types of radiator tank construction. The first uses cast-iron tanks bolted to header plates (fig 3–12); the second is stamped- or drawn-out tanks soldered to core plates; the third is a nonmetallic tank. The following table describes these in more detail.

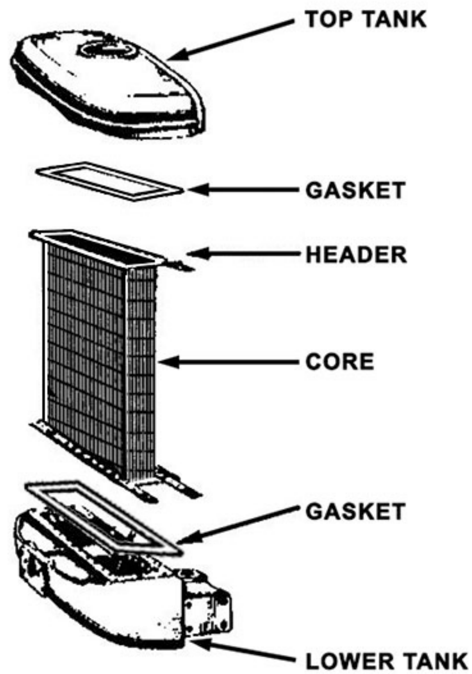
<table>
<tr><th colspan="2">Radiator Tank Types</th></tr>
<tr><th>Type</th><th>Description</th></tr>
<tr><td>Cast Iron</td><td>Cast-iron tanks bolted to the core header plates are heavy-duty tanks generally used on vertical-flow radiators. Gaskets are used between tanks and header plates to make a tight seal (fig. 3–12). Cast-iron tanks are normally used for heavy equipment such as aircraft towing tractors, truck tractors, large dump trucks, etc.


Figure 3–12. Cast iron tank radiator.</td></tr>
<tr><td>Stamped-out/ Drawn-out</td><td>These stamped-out or drawn-out tanks are soldered to the core header plates, and are most commonly constructed from sheet brass. However, steel or copper sheet metal is also used. All of these materials make a much lighter weight tank. These tanks are used on both the cross-flow and the vertical-flow radiator in many vehicles.</td></tr>
<tr><td>Composite</td><td>In recent years, a third type of radiator tank, made from various nonmetallic materials, has come into wide use. Due to the many combinations, we will simply call them “composite.” The composite tanks are secured to the header by crimp or clinch tabs. Like the cast-iron-type tanks, gaskets are used to ensure a seal between the header and the tank. While this tank is typically found on general-purpose sedans and small trucks, it can be found on larger vehicles as well.</td></tr>
</table>

Radiator core construction

Radiator core construction varies among manufacturers. The most common construction features the flat- or tubular-core radiator (fig. 3–13). As you can see, this type contains many rows of small tubes with many small, evenly spaced air fins attached to the tubes. These fins radiate heat away from the tubes as the hot coolant flows from the hot tank to the cool tank of the radiator. Air passes through the core’s tubes and fins, absorbing heat and carrying it away from the radiator. The tubes are normally made of brass though occasionally they are made of copper. The small air fins between the tubes are normally made of copper or brass. Plastic radiator tanks generally have aluminum cores (tubes and fins). The upper- and lower-header plates provide even spacing and hold the tubes together in the core. The header also provides a means to attach the core to the tank by bolts, solder, or clinch tabs.

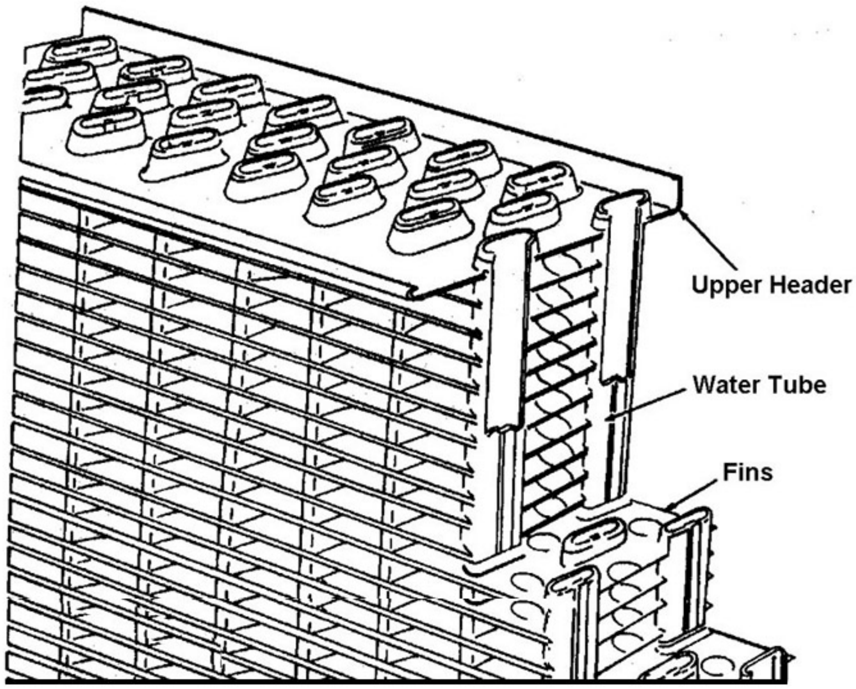


Figure 3–13. Tubular-core radiator construction.

Oil coolers

Some vehicle designs may include an automatic transmission fluid or engine oil cooler inside the radiator. This cooler resembles a miniature radiator. Automatic transmission oil lines carry the oil from the transmission to the cooler and back to the automatic transmission. This works on the same cooling principle as the radiator: vehicle radiator coolant circulates around the oil cooler (inside the radiator tank) and absorbs heat from the transmission oil before it returns to the transmission. The automatic transmission oil pump circulates transmission oil through the oil cooler continuously. As the transmission oil flows through the cooler, heat dissipates from the oil to the tubes and fins of the core. Air passing through the radiator absorbs the heat as it flows through the core, carrying the heat away. This cooler is a small, round, or flat component 6 to 14 inches long. It is illustrated by the dotted lines in figures 3–10 and 3–11. Notice that it is located in the lower tank of the vertical-flow radiator and the cool tank of the cross-flow radiator.

Some vehicles may have the automatic transmission oil cooler mounted outside, rather than inside, the radiator. In this case, it is usually located in front of the radiator, though it could be elsewhere depending on the vehicle.

In addition to transmission oil coolers, some vehicles may have an engine oil cooler. This cooler can be located inside the tank of the radiator, in front and separate from the radiator, or near the engine itself. On some large vehicles, large oil coolers are attached to the engine. Upon closer examination, you will see that this unit may be two oil coolers built into one. One-half of this unit cools engine-lubricating oil and the other half cools the transmission-lubricating oil.

If the oil cooler develops problems and is not suitable for repair, replace it with a new one. If the oil cooler is inside the radiator tank, you may want to replace the entire radiator, especially if the radiator itself is defective or has been repaired frequently.

627. Testing radiators and oil coolers

A combination test, clean, and repair bench (fig. 3–14) makes testing radiators much easier. Oil coolers are tested in the same manner as radiators. In this lesson, we will consider the testing process of both radiators and oil coolers, beginning with radiators.

Radiators

One section of the combination bench, called the hot cleaning tank in the figure (left section), is set up to boil out radiators. The second section (flow test section) comes with outlets and a flow-meter for testing a radiator's flow rate. The right section is the repair bench with the elevator work platform in the raised position. After you place the radiator on the elevator work platform, you can lower the platform to submerge the radiator in water for leak testing. This repair bench section comes with gas soldering torch equipment. You use this torch to heat the radiator metal hot enough to bond metals together with solder. Normally, there is a slide-out work platform at the lower edge of the tank on which to rest the radiator and accomplish repairs. The repair bench also has an air-blow gun to remove melted radiator solder and to blow debris from the radiator core.

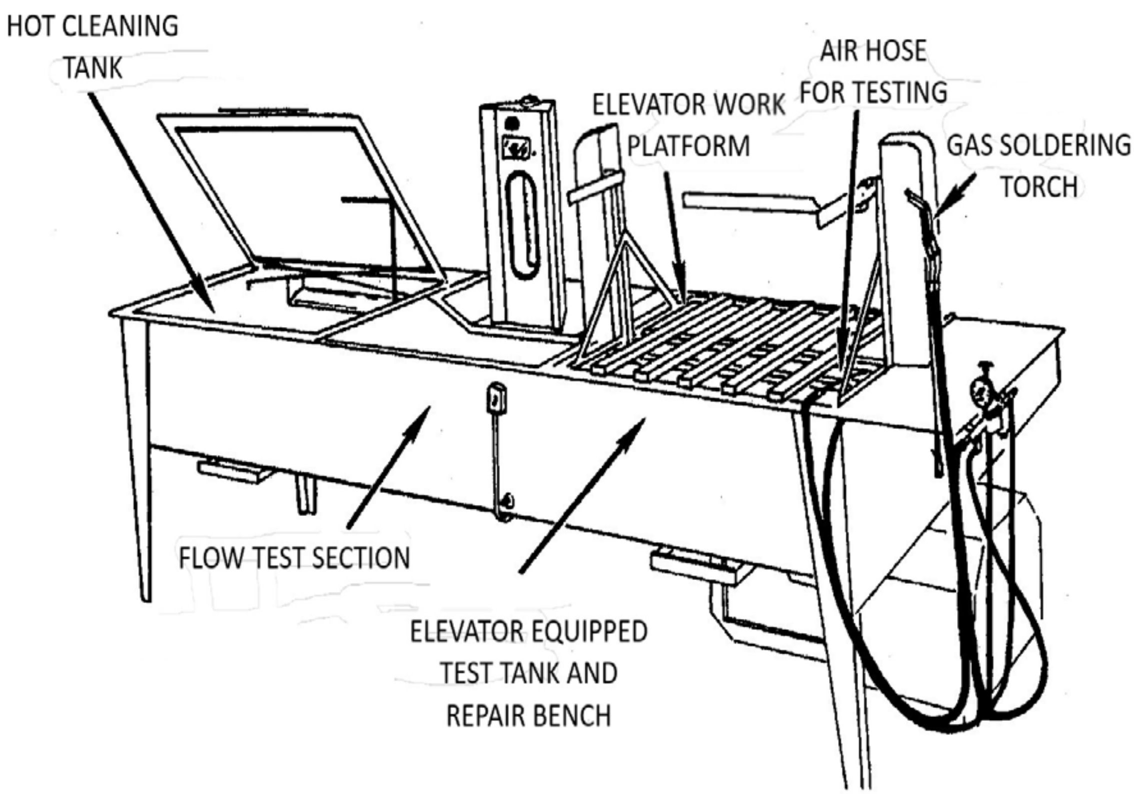


Figure 3–14. Combination test, clean, and repair bench.

Visual inspection

When making radiator repairs, your first step is to make a thorough visual inspection and repair any obvious leaks or damage. During your visual inspection, pay close attention to any coolant evaporation stains because these normally indicate a leak nearby.

Testing for leaks

After you visually inspect the radiator, plug all openings—except for the filler neck, which you seal with a filler neck adapter plug.

Refer to the steps to perform a radiator leak test in the following table.

Radiator Leak Test	
Step	**Action You Take**
1	Connect the air hose leading in from a low-pressure regulator to the filler neck adapter plug.
2	Apply the air pressure to the radiator before you submerge it in the test tank. This keeps water from entering the radiator at a leak while you submerge the radiator into the tank.
3	Start with a pressure of 3 to 5 psi and watch for bubbles. • You may have to apply air pressure that is equal to the system operating pressure. • Always consult applicable technical order specifications for this information. • The *maximum air pressure is normally* 15–17 psi.

If there is a leak (small break in the radiator metal), you will see air bubbles, which will pinpoint the leak location.

To pinpoint very small leaks, you may need to leave the radiator submerged in the test tank for 30 minutes to an hour for these bubbles to appear. If you have trouble in pinpointing exactly where the bubbles are coming from after submerging the radiator in the test tank, remove the radiator from the test tank and coat the suspected leak areas with a soapy water solution. You can also minutely maneuver the elevator platform as you lower the radiator into the water. If you are able to manipulate the platform controls finely enough, you can submerge the radiator in small enough increments to examine individual layers of the coolant tubes.

As soon as you finish the repair on a radiator, you can attach the air hose to the filler neck adapter plug for pressure testing again. Use the elevator platform to lower the radiator into the water again and test the radiator for any leaks.

Flow test

You use the flow test section of the bench (fig. 3–14) to determine the rate of coolant flow through the radiator. This flow rate is measured under gravity pressure and it is expressed in gallons per minute. Once you determine a radiator's flow rate, compare it to the technical order specifications. It is normal for one-year-old vehicle radiators to have a 10 percent obstruction in the rate of flow.

To perform the flow test, refer to the steps described in the following table.

Radiator Flow Test	
Step	**Action You Take**
1	Set the radiator upright inside the tank in front of the gauge in the flow test section (fig. 3–14). This tank extends back under the gauge.
2	Fill the tank with water.
3	Connect a hose from the water pipe in the test stand tank to the radiator inlet fitting. As you turn the tester on, water enters the radiator through the hose on the inlet fitting. • Use the tester controls to fill the radiator until the water level reaches the bottom of the filler neck. • Maintain this water level in the radiator during the test, making sure the radiator does not overflow.
4	Read the rate of flow from the flow gauge two or three times at approximate intervals of one minute apart.

The flow rate provides an indication of how severe the radiator is obstructed internally and how much radiator cleaning is necessary.

Oil coolers

You can test oil coolers the same way you test radiators. However, oil coolers normally operate with higher pressures than you find with radiators. Always consult the appropriate technical order for these pressure specifications.

CAUTION: Do not apply pressure that exceeds the working oil pressure of the oil cooler.

If you are going to test the oil cooler while it is still inside the radiator, make sure you do not plug the radiator inlet or outlet openings. If the oil cooler has a leak, the radiator probably will not be able to withstand the excess pressure you will apply to the oil cooler. Keeping the radiator inlet and outlet open provides a way for the excess higher pressure to escape without damaging the radiator. To conduct the oil cooler pressure test, perform the steps in the following table.

Oil Cooler Pressure Test	
Step	**Action You Take**
1	Plug the outlet oil line connection.
2	Attach a regulated airline to the inlet oil line connection.
3	Start applying air before you submerge the oil cooler in the water.
4	Submerge the oil cooler and look for bubbles.
5	After submerging the radiator and oil cooler in the test tank, rock the radiator back and forth to eliminate any trapped air in the radiator. If you fail to do this, the trapped air could escape and these bubbles can be mistaken for a leak in the oil cooler.

628. Soldering and repairing brass radiators

Soldering is the process of using fusible alloys for joining metals. The kind of solder used depends on the metals to be joined. Good soldering is an important part of radiator, fuel tank, and oil cooler repair. Metal cleanliness, proper tinning and flux application, and applying the correct amount of heat to the metal surface will produce a good quality solder repair.

Soft soldering concepts

This process is used for joining most common metals with an alloy that melts at a temperature below that of the base metal. This is always below 800 ° F (427 ° C). In many respects, this operation is similar to the brazing process we covered earlier. Recall that brazing does not melt the base metal; instead, it is merely tinned on the surface by the solder filler metal.

For strength, the soldered joint depends on the solder penetrating the pores of the base metal surface and forming a base metal-solder alloy. Together, this forms a mechanical bond between the parts. Soft solders are used where airtight or watertight joints (which are not exposed to high temperatures) are required. The copper water pipes found in homes are a good example of this. Another example is the soldered joints used in radiator construction.

All soldering operations require a flux in order to obtain a complete bond and full strength at the joints. Recall from earlier lessons that fluxes clean the joint area, prevent oxidation, and increase the wetting power of the solder by decreasing its surface tension. The solder used in most automotive applications typically comes in wire rolls of various thickness. These contain the flux in the wire’s core. Fluxes in common use today fall into two categories—rosin and acid. Hence, the common trade terms rosin-core and acid-core solder.

Fluxes	
Type	**Description**
Rosin	Rosin fluxes are used to prevent the formation of oxides during soldering operations. The most common application of this concept is a solder connection or repair to a vehicle electrical system. Oxides are a form of corrosion.

	Corrosion in repairs to electrical wiring defeats the entire repair.
Acid	You will probably use this solder most. These fluxes (chemical or acid) contain zinc chloride and ammonium chloride. They may be used on tarnished surfaces to permit good tinning. You can also use a solution of zinc and hydrochloric (muriatic) acid, which tin workers commonly use as a flux.

CAUTION: Muriatic acid is a form of hydrochloric acid and is very dangerous. Be extremely careful!

Radiator cleanliness

Using proper flux is important to cleaning. The flux removes oxides and other surface films from the metal surface and actually promotes a better bonding between the solder and the metal surface. It also prevents air from coming in contact with the bonded joint. If this happens, oxidation occurs during the soldering process and before the solder solidifies. Therefore, you can see that proper cleaning is the most important step in preparing metal for soldering.

You may also use muriatic acid to aid in cleaning these metal surfaces by first heating the metal. Afterwards, apply the muriatic acid to the heated surface. The “secret” is to apply enough acid to cool the metal suddenly. This sudden cooling of the metal helps dislodge lime deposits and speeds up the cleaning process.

Again, muriatic acid is hydrochloric acid and is very dangerous. Be extremely careful!

Heat

The heat source for soldering normally varies from shop to shop. The most suitable heat source is natural gas. If this is not available, bottled or liquefied petroleum (LP) gas is satisfactory. If neither of these is available, and you are very skilled, you can use the oxyacetylene torch. Keep in mind, however, that the oxyacetylene torch is not as suitable as a natural gas or LP gas torch. You have to be careful with the oxyacetylene torch because its high heat will damage lightweight metals you are soldering. If you must use the oxyacetylene torch, be sure you adjust it to a carburizing flame. Remember, a carburizing flame has a small feather on the end of the inner flame. The inner flame feather is achieved by opening the acetylene control valve slightly more than the neutral flame position. In addition to the methods we have listed, you may use a soldering gun or iron to do small soldering tasks.

Tinning

Before actual soldering or joining the metal components, apply a good commercial tinning compound to the metal surfaces. These tinning compounds normally come in a liquid or paste form. You normally apply the tinning solution to the metal surface with a brush and then heat the metal surface with a torch. The heat causes the flux to boil, which brings the oxides (impurities) and dirt to the surface. However, be careful and do not apply too much heat to the metal surface. If you do, you will “cook” the tinning solution, defeating the whole purpose of tinning. Repeat the process of applying the tinning solution and heating the metal surface until you achieve a bright shiny metal surface free of any oxides and dirt. This allows the solder to bond to the metal surfaces and seal the two metal surfaces together.

Solder

When repairing radiators and oil coolers, you normally use 50–50 solder. These numbers indicate the solder is composed of 50 percent lead and 50 percent tin. This type solder comes as either solid-wire type or acid-cored type. The melting point for this solder is 421 ° F; as the metal cools below 361 ° F, the solder solidifies and bonds to the metal surface. As you would expect, the metal surface needs to reach the melting point temperature before you administer the solder to the metal surface.

You will find that solder very seldom bonds to a metal that is cooler than the melting point of the solder. Even if you use acid-core solder, you must still use a brush or squirt bulb and add acid for cleaning the metal surfaces you are going to solder.

Tank repair

When you pressure test the radiator, always mark where the leak is regardless of whether it is on the tank or on the core. If you remove the radiator tank, mark the position where the tank and header plate mate together. This ensures that you will reattach the tank to the header plate in the same exact position.

Bolt-on type radiator tank

If the radiator tank is the bolt-on type, perform the following:

1. Remove the bolts.
2. Carefully remove the tank without damaging the gasket side.
3. Be careful not to make any marks or scratches on the gasket side of the tank or header plate.

Soldered to the head plate radiator tank

If the radiator tank is soldered to the header plate, perform the following:

1. Heat the soldered joint.
2. Blow the solder out of the joint using an air-blow gun. Be careful during this process; if the solder lands on your skin, you can receive severe burns.
3. Wear eye protection, gloves, leather apron, and protective clothing to eliminate the chances of receiving skin burns. Additionally, make sure no one is near you when you blow the solder from the joint. If you do not, innocent bystanders can sustain serious injuries.

Stamped brass tank

The quickest repair for a stamped brass tank is the following:

1. Cut a patch that will overlap the area where the crack is located. Make the patch extend approximately one inch from all points of the crack.
2. Clean the metal surface of the radiator tank with muriatic acid. Be sure to clean $^{1}/_{2}$ inch beyond the outer edges of the patch that will cover the crack.
3. Clean the face of the patch that will be in contact with the radiator tank (covering the crack).
4. Tin the area of the tank containing the crack and then tin the patch you have cut. Before you tin the patch, make sure to form the patch that will cover the crack with the contour of the radiator tank surface.
5. Once you tin the radiator tank and the patch, place the patch over the crack and solder it to the radiator tank.
6. Pressure check the radiator again, making sure your patch does not leak.

NOTE: If you remove the radiator tank for repairs, you take less risk in melting the solder at the tank and header plate joint. This avoids possibly creating additional leaks, but tank removal usually increases repair time.

Core repair

It is possible (and often necessary) for you to repair the core tubes in a radiator. At times, you will have to splice in a portion of stock tubing or portions of tubing from another radiator. In any case, you should be able to repair the core well enough for it to last the life of the vehicle. Even if the radiator receives severe damage, you should still be able to make temporary repairs until a new one arrives. Of course, some cores may receive damage so severe that repair is impossible. The following table discusses different aspects of the core repair process.

<table>
<tr><th colspan="2">Core Repair Processes</th></tr>
<tr><th>Process</th><th>What You Do</th></tr>
<tr><td>Soldering the tube</td><td>

If the core tube only has a small break in it (fig. 3–15), you can repair the damaged area by soldering the break. To accomplish this, perform the following:

1. Apply only enough heat to melt the solder.
2. Use flat-nose pliers and bend the cooling fins away from the damaged area.
3. Clean around the damaged area as best you can with a wire brush.
4. Heat the tube and apply muriatic acid for additional cleaning.
5. Tin the area you are going to repair with solder.
6. As long as the break in the core tube is small, you can solder it closed.

If the opening is large, the solder will fall through the crack and plug the tube. When this happens, no coolant will flow through the tube. To prevent this problem, pinch the tube closed where the crack is located before soldering. By doing this you are only restricting part of the tube.

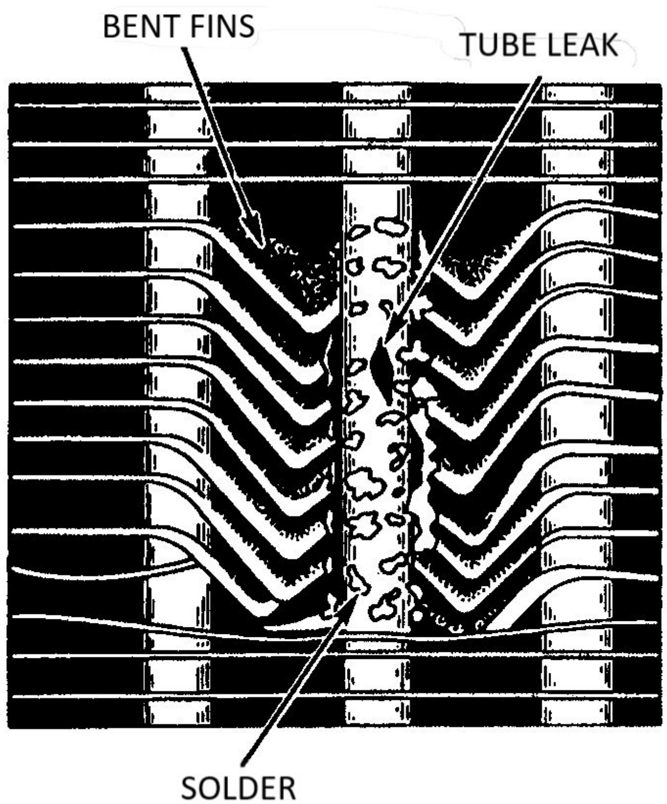


Figure 3–15. Damaged core tube.

</td></tr>
<tr><td>Patch</td><td>

If the break in the tubing is too large to solder and you do not want to restrict the core tube coolant flow by pinching and soldering, you can place a small patch over the break. To accomplish this, perform the following:

1. Move the fins out of the way.
2. Clean and tin an area beyond the size of the patch.
3. Form the patch to the contour of the tube.
4. Solder it in place.
5. Pressure test the radiator again to make sure there are no leaks.
6. Reattach the fins.
7. Spot paint the damaged area.

</td></tr>
</table>

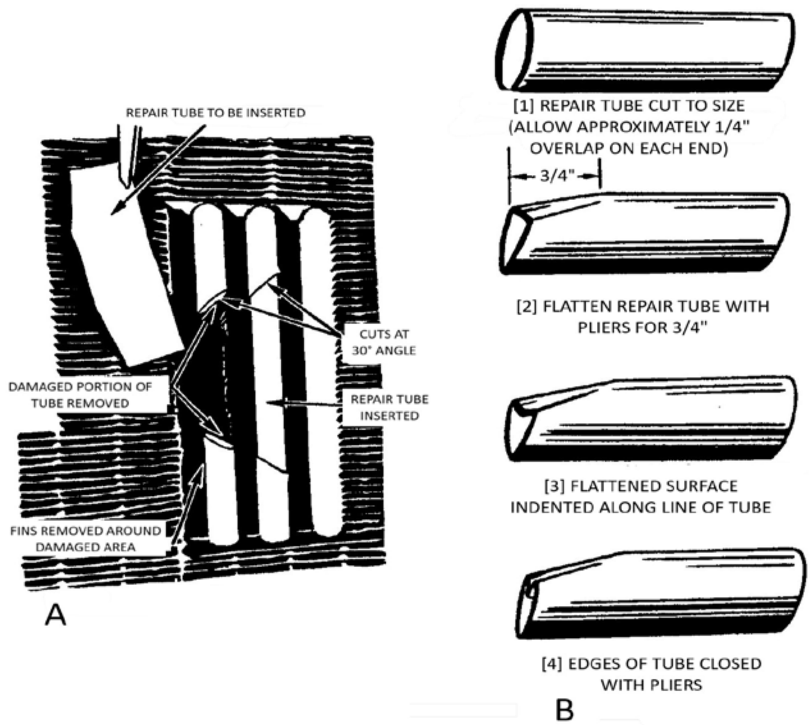
<table>
<tr><th colspan="2">Core Repair Processes</th></tr>
<tr><th>Process</th><th>What You Do</th></tr>
<tr><td>Splice</td><td>If the damage is too large and covers too much area, you will have to splice a section of tube stock or a tube from a discarded radiator with the same size tubing into the core tube. One way to splice a radiator tube is shown in figure 3–16, View A. Both ends of the tube are formed as shown by the steps in figure 3–16, View B. The replacement tube should be approximately $^{1}/_{4}$ inch longer on each end to allow for overlap and a good solder bond. Figure 3–16, View A illustrates the procedure for installing the replacement tube:
1. Make the cuts on the old tube with tin snips or a radiator core cutter.
2. Use needle nose pliers to open the collapsed tubing at the cut. This will allow you to slip the replacement splice into place.
3. Clean the replacement splice and existing tube before soldering into place.
4. Once you have cleaned the tubing, solder the tubing together.
5. If possible, attach the fins back into place.
6. Pressure test the radiator again to make sure there are no leaks.
7. If not, you are ready to reinstall the radiator into the vehicle.


Figure 3–16. Splicing radiator core tube.</td></tr>
</table>

Heater core

The honeycomb core (fig. 3–17) is another type of radiator core, though it is primarily used as the heater core. The honeycomb core is designed to hold coolant longer than the tubular style; thus, it heats the vehicle’s interior more efficiently. However, its disadvantage includes difficulty to rod out or clean if clogged. For example, while rodding this type core, you must be much more careful to avoid making holes in the core. Further, rodding is different because you must use a flexible, flat metal strip to do the rodding operation.

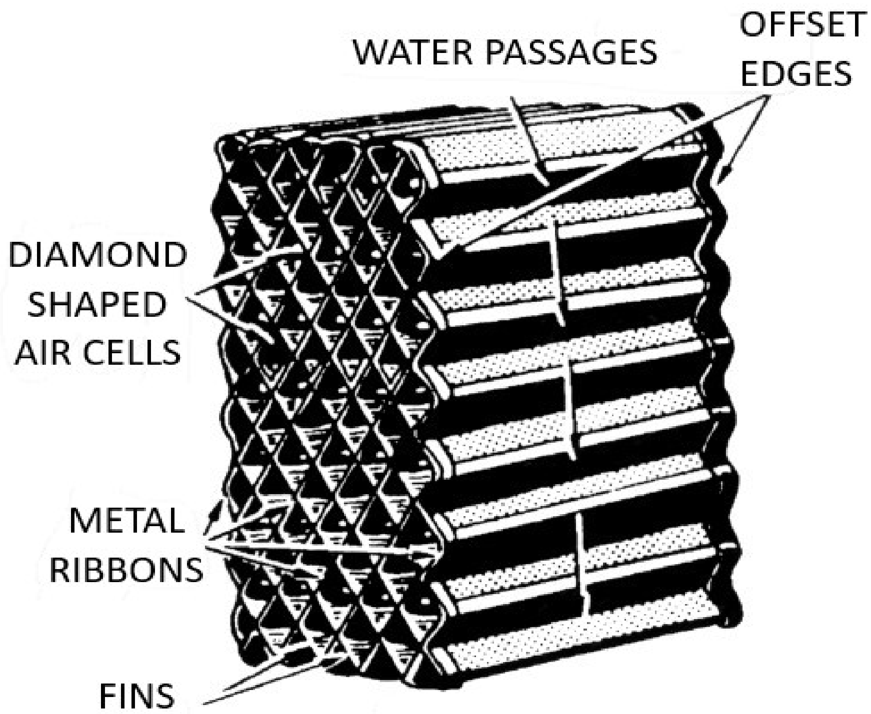


Figure 3–17. Honeycomb radiator core.

With one exception, the repair procedures for this type radiator and the one's we have already discussed are similar. The exception concerns the tubes: you cannot replace a single tube or splice it very easily. For this radiator type, if the core has severe damage, it is more economical to replace the entire core assembly. Should the occasion arise, and you have an old heater core with the same core height and core thickness, you can splice in a section as shown in figure 3–18. To make this splice, complete the following:

1. Remove the side members and the upper and lower tanks.
2. Remove the damaged section.
3. Install another section in its place.

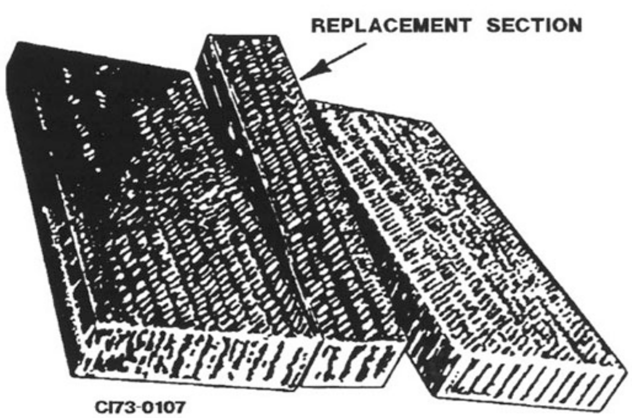


Figure 3–18. Splicing honeycomb core section.

When splicing, the replacement components must be the proper size and fit together very carefully. It is helpful to clamp the sections together for the soldering operation. Note that the soldering must run the *full length of the core on both sides*. After making the splice, pressure test and check for leaks like you would any other radiator repair.

629. Replacing radiator cores

Sometimes a core has damage that renders it beyond repair. This can be from a number of different reasons; however, the most common include accidents or the age of the core. Whenever you determine that a core is damaged beyond repair, you may have to order a new core section. To accomplish repair, you would use the tanks and side members from the original radiator when you install the new core. The replacement methods are similar for all radiator types; however, variations result from differences in construction. We will focus on those in this lesson.

Bolt-on tank

If you are working with a damaged radiator with a bolt-on tank, take the steps described in the following table when you replace the core.

Replacing a Bolt-On Tank Core	
Step	**Action You Take**
1	Remove the bolts fastening the radiator tank to the header plate of the radiator core.
2	Remove the radiator tanks from the header plates carefully, making sure you do not scratch or gouge the gasket side surfaces of the radiator tank or header plate. Scratches or gouges in these surfaces can cause leaks to develop.
3	Carefully remove the old gasket; it normally tears apart when you remove the tank from the header plate. The gasket may stick to the radiator tank or header plate. Remove it from either one, making sure you do not scratch or gouge the gasket surfaces.
4	Clean the old gasket material from the tank and header plate. Replace the gasket between the header plate and tank with a new or fabricated one.
5	Place the tank back on the header plate.
6	Inspect the bolts you removed and replace any that need replacing.
7	Tighten the bolts to technical order specifications. Be sure each bolt bonding the tank to the header plate has the same torque.

Soldered tank

If you are working with a soldered tank-to-header plate radiator, complete the steps in the following table to replace the core.

Replacing a Soldered Tank Core	
Step	**Action You Take**
1	Place the radiator on the radiator repair bench.
2	Heat the upper or lower corner of the side member. Move it slightly away from the core as the solder melts (refer to fig. 3–10 for component terminology).
3	Heat the other end of the side member until the solder melts.
4	Remove the entire side member from the core.
5	Repeat the process with the opposite side member.

Replacing a Soldered Tank Core	
Step	**Action You Take**
6	After removing the side member, remove either the upper or the lower tank by melting the solder and brushing away large portions with a wire brush. You can also use an air gun to blow away the excess solder. **CAUTION:** The solder you are brushing or blowing away is very hot. Wear protective gear. Make sure no one is near you as you never know exactly where the molten solder will land.
7	After you remove most of the solder between the header plate and core, lightly tap around the tank as it cools. Tapping with a small rubber hammer breaks the solder seam.
8	Once you break the solder seam around the tank and header plate joint, separate the tank from the core. Repeat this procedure with the other tank.
9	Before reassembling the radiator tank to the header plate, remove all traces of old solder. Clean and tin the metal surface areas of the tank and the header plate joint before soldering them together.
10	Starting with the upper or lower tank, solder the four corners first. Afterwards, solder across the ends from corner to corner. After soldering the ends, solder along the length of the tank. Repeat this process with the opposite tank.
11	After you solder the tanks to the header plates, place the side members in place and solder them.
12	Pressure test the radiator to determine if there are any leaks. If the pressure test results are satisfactory, apply a light coat of noninsulating-type paint to the radiator (for anticorrosion purposes).
13	Reinstall the radiator in the vehicle.

Aluminum/composite radiators

Many cross flow radiators are constructed with a composite tank and an aluminum core. While repairs to this type are similar to repairs you make to other radiators, there are special precautions that must be followed due to the materials that make up these radiators. Most manufacturers recommend replacing cracked or broken composite tanks; they do not develop small pinhole leaks like their brass tank cousins. The tank leaks are larger and are not economically repairable—it is cheaper to replace the tank.

Core leaks and gasket or seal leaks (fig. 3–19) are the two types of leaks you can repair on the aluminum/composite radiator. Core leaks can occur in a tube or in the joints between the tubes and headers. Gasket leaks can occur in the joints between the composite tanks and the headers or in the joints between the oil cooler fittings and the tank. Some leaks can be repaired while the radiator is on the vehicle; however, it is usually best to remove the radiator.

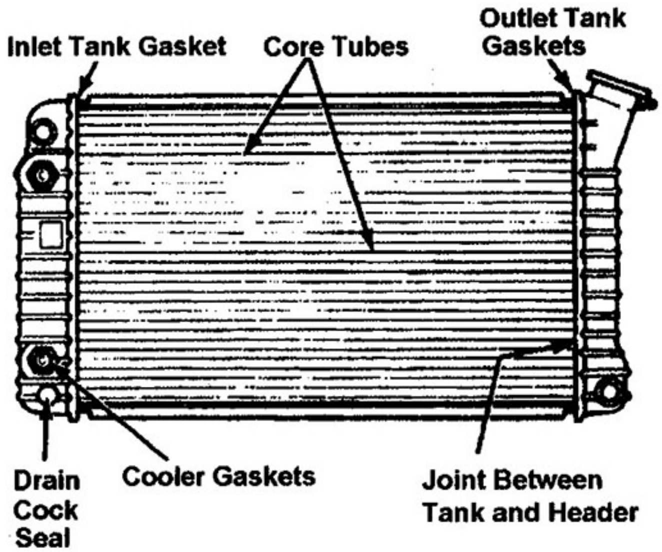


Figure 3–19. Possible leak areas in aluminum/composite radiator.

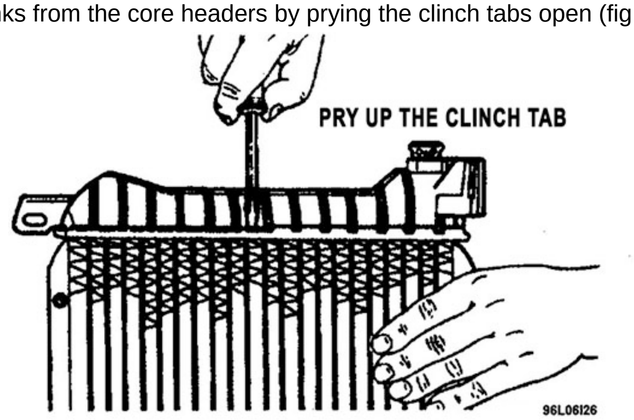
When you repair an aluminum/composite radiator, pay close attention to the following:

- Do not use boil-out tanks, vats, or other tanks that have been used for copper and brass radiators. If you do, the flux, acid, and caustic cleaners remaining in the tanks will attack the aluminum and cause the radiator to fail.
- Use a separate test tank containing clean water for servicing aluminum/composite radiators.

Replacing composite tanks

As stated previously, in some cases, the composite tank can be cracked or punctured. In this case, you can replace just the tanks instead on the entire radiator assembly. Aluminum clinch tabs hold the composite radiator tank to an aluminum core header, with a gasket in between. These tabs can be easily damaged, pry them open only enough to remove the tank and no further. Although there are many special tools made to do the job, a good medium tipped screwdriver works well for this task.

The following explains the procedures for disassembling and assembling Aluminum/Composite radiators to facilitate component replacement or repair.

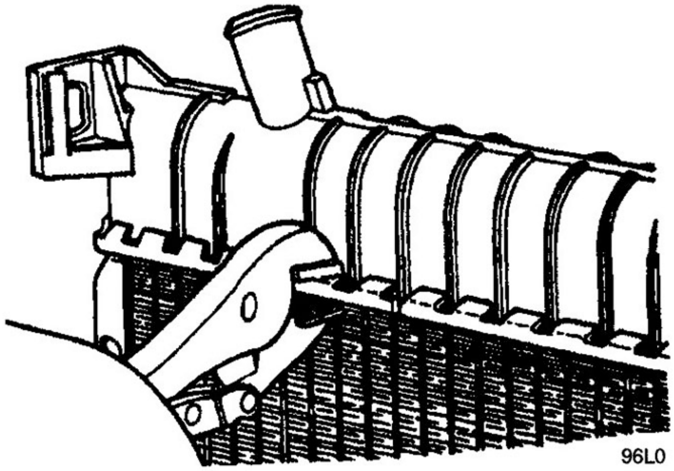
Disassembling Aluminum/Composite Radiators	
Step	**Action You Take**
1	Remove the tanks from the core headers by prying the clinch tabs open (fig. 3–20).  **Figure 3–20. Removing a composite radiator tank.**

Disassembling Aluminum/Composite Radiators	
Step	**Action You Take**
2	Remove the tank from the header.
3	Repeat the action for the other tank.
4	Both tanks may have an oil cooler (transmission and engine oil) inside; therefore, care must be taken to ensure these components are not damaged.
5	The most important task after the tanks have been removed is to inspect the gaskets thoroughly.
6	Possible gasket problems include nicks or cuts.
7	There may be chemical deposits left over from normal coolant contact with the gasket.
8	If so, clean the deposits from the gasket before any possible re-use
9	If a tank-to-header gasket is damaged for any reason, replace it.

During the installation process, make sure the gasket is not twisted. If it is, it will not allow a good seal between the tank and header.

The procedure for installing new tanks is provided in the following table:

Assembling Aluminum/Composite Radiators	
Step	**Action You Take**
1	Place the core with one header in the up position.
2	Fit the new or re-used gasket into position. Then place the proper tank into position.
3	Be sure not to nick the header tank. The entire core assembly is made of aluminum and you can mar the header surface easily. It is harder for the gasket to seal against a marred or scratched surface.
4	At this point, you may have to use a clamping tool to hold the tank against the gasket—follow the manufacturer recommendations via a technical order. In this operation, you have to be very careful and pay close attention to your work. You must not only choose the correct tank for the header you are working on but must also be sure that the outlets of the tank are facing the right direction. (Be aware that the core may have a forward facing side).
5	When everything is in place, begin tightening the clinch tabs. • Use a pair of vise grip pliers (fig. 3–21). • Start along the length of the tank in the center and alternate sides while crimping the tabs. • Work from the center outward until all tabs have been crimped into place.

Assembling Aluminum/Composite Radiators	
Step	**Action You Take**
	 **Figure 3–21. Tightening (crimping) clinch tabs.**
6	Repeat these steps for the other tank.
7	After you have installed all the tabs, do a pressure test according to the manufacturer's specifications to ensure that there are no leaks.
8	If there are no leaks, reinstall the radiator into the vehicle.

Core leaks

In the commercial industry, core replacement versus repair appears to be the prevalent method of placing a damaged aluminum/composite radiator back in service. This is probably due, in large part, to the ease with which a core can be damaged by disassembly. The clinch tabs holding the tanks and the core together are generally an integral part of the core and are easily breakable. Because of mission demands on equipment, replacement may not always be possible. As a repair technician, it is up to you to determine the best repair method.

There are several methods of aluminum core/header repair. For example, one manufacturer recommends a two-part epoxy adhesive type repair. Since we do not have the space and cannot discuss all of the possible methods, we will focus our attention on one method as representative: the hot melt adhesive process. This is the most simple and effective and is a good example of aluminum core repair. The repair materials come in kit form shown in figure 3–22. As you can see, it contains a sealed container, adhesive sticks, cotton swabs, a wire brush, and primer. The adhesive sticks are reusable. In addition, they have an indefinite shelf life, and are waste free. Keep them in the sealed container.

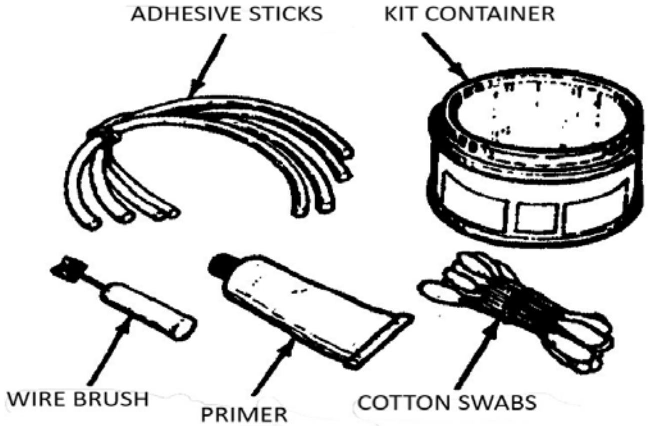


Figure 3–22. Hot melt repair kit.

As with any other radiator core repair, preparation of the repair area surface cannot be over-emphasized. If the surface area of the leak is not clean, the repair adhesive will not stick to the surface. The procedures in the following table are for using the hot melt method to repair an aluminum radiator core.

Hot-Melt Repair of Aluminum Core/Header	
Step	**Action You Take**
1	Position the core so the repair is easily accessible.
2	Apply a wet cloth or submerge the tank in water if you are working near the composite tanks or the joints between the core tubes and header. If you submerge the tank, keep the header above the water line. These two precautions will protect the composite tank and the header from heat damage. The header is especially subject to warpage from excess heat above its normal operating temperature.
3	Heat the repair area slightly with a small torch (butane or similar) or heat gun to be sure it is dry.
4	Brush the area to be repaired with the small steel brush supplied in the kit and blow dust away from the repair area. **CAUTION:** Be careful to wear personal protective equipment when working with a torch, heat gun, primer and dust. Your skin and eyes are susceptible to injury.
5	Open the tube of primer and apply primer to the repair area only. Do not heat the primer because it contains trichloroethane and use with adequate ventilation. Do not get it in your eyes or on your skin.
6	Scrub the repair area with a cotton swab until a fresh swab stays clean. The clear, yellow-brown coating, which remains, does not have to be removed.
7	Heat the repair area with a heat gun or by moving the torch in a circular pattern. • Use a soft, small, blue flame similar to a gas stove flame. • Withdraw the torch and rub the adhesive stick on the repair area. • The adhesive flows at approximately 260 º C (500 º F). • If the stick does not melt, remove it and reapply the heat. • Do not heat the stick with a flame. • High heat will burn and char the adhesive.

Hot-Melt Repair of Aluminum Core/Header	
Step	**Action You Take**
8	Continue heating until the adhesive flows, wets the entire repair area, and fills the joint. For instance, if a hole is in the center of a tube, heat the tube, let the hot surface melt, and pull in the adhesive. The force of the flame or heat gun will also tend to guide the adhesive toward the hole. For leaks between an aluminum tube and header, flow the adhesive around the tube and header joint with the tank installed. This reduces the chance of damaging the clinch tabs while trying to remove the tank and reduces the possibility of warping the header through excess heat.
9	Heat the repair area until the adhesive is bubble-free and smooth, with a light yellow color. Curing is not required.
10	When the area cools, test the radiator for leaks. If the repair area still leaks, reheat it gently to dry it. Heat and reflow the adhesive or apply more as necessary to repair the leak.

Tank gasket/seal leaks

Tank gasket leaks can be mistaken for tank or header leaks. If a composite tank leaks from the header joint gasket, tighten the clinch tabs with vise grip pliers (fig. 3–21). If this method does not seal the leak, remove the tank for further inspection and repair. The following procedures provide guidance for repairing tank gasket leaks.

Repairing Tank Gasket Leaks	
Step	**Action You Take**
1	Pry open the clinch tabs (fig. 3–20). Lift the tabs only enough to allow removal. As previously mentioned, do not over bend these tabs, as they will break off easily. If more than three tabs are broken on one side of the header or more than two adjacent tabs are broken, the core must be replaced.
2	Lift the tank out from under the tabs. You may have to tap the tank with your hand to dislodge the gasket.
3	Remove the gasket.
4	Clean the header and gasket groove of all dirt and old rubber. Additionally, clean the sealing edge of the composite tank.
5	Examine the header mating surface and gasket and tank flange for evidence of leakage. Clean or repair the surface to remove dirt, burrs, and bumps.
6	Dip or coat a new tank gasket in engine coolant (helps hold the gasket in place) and position it on the header-mating surface.
7	Position the tank and gasket to the header, clamping it in place. Secure it by bending the four clinch tabs. • One tab on each long end of the tank. • One on each narrow end.
8	Clamp the remaining clinch tabs around the header. Start at the center and work out to the ends.
9	Reinstall the drain cock if it was removed.
10	Test the radiator.

Testing

This task is mechanically much the same as for a brass radiator. Remember to not use the same radiator bench that is used to repair standard brass radiators.

Testing an Aluminum Core Radiator for Leaks	
Step	**Action You Take**
1	Install test fittings or rubber test caps in the inlet and outlet necks.
2	Seal the oil cooler fittings with metal plugs. This protects the oil cooler and keeps the fluid from running out.
3	Attach a pressure tester or measured air supply. Gradually apply air pressure. **NOTE:** *Do not exceed the* maximum operating pressure stated in the vehicle technical order.
4	Check the pressure gauge to see if there is a pressure loss. • To ensure there are no small leaks, run water over the repair area and look for bubbles. • A mild detergent is helpful. • If a water tank is available, immerse the radiator and check for air bubbles.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

626. Radiators and oil coolers

1. What keeps coolant inside the engine until it reaches a certain temperature?

2. In what radiator section does heat dissipate from the coolant to the atmospheric air passing through the radiator?

3. Name the two types of radiators.

4. What three metals do manufacturers use to construct stamped-out radiator tanks?

5. What is the purpose of the fins attached to the tubes of the radiator core?

6. Where is the transmission oil cooler located in a vertical-flow radiator?

7. Name three possible locations for an engine oil cooler.

627. Testing radiators and oil coolers

1. What is the purpose of the elevator work platform on the test tank of the combination test, clean, and repair bench?

2. If you visually inspect a radiator and notice a coolant evaporation stain, what does this stain indicate?

3. What do you look for after you attach the air hose to the filler neck adapter plug and submerge the radiator in the water of the test tank?

4. When testing a radiator for leaks, how can you pinpoint very small leaks?

5. How much obstruction in the rate of flow will a one-year-old radiator normally have?

6. How many times should you read the rate of flow from the flow gauge while performing the flow test?

7. What opening(s) should you leave unplugged when conducting an oil cooler leak test?

628. Soldering and repairing brass radiators

1. What factors do you need to produce for a good quality solder repair?

2. What is the most important step in preparing metal for soldering?

3. How does applying muriatic acid to hot metal help in cleaning the metal surface?

4. What heat sources can you use for soldering radiators, oil coolers, and fuel tanks?

5. Why is the oxyacetylene torch unsuitable for soldering lightweight metals?

6. If you use the oxyacetylene torch for soldering purposes, how should you adjust the flame?

7. What should you apply to a metal surface with a brush and heat prior to the actual soldering?

8. What types of solder are available in 50 percent lead and 50 percent tin?

9. Why should you mark the radiator tank and header plate prior to removal of the tank?

10. If you use a patch to repair a radiator tank, what should you do with the patch before tinning it?

11. If the radiator core tube has a very small break, how would you repair it?

12. If there is only one break in one core tube but it is too large to solder, what method of repair would you use to prevent restricting coolant flow inside the core tube?

629. Replacing radiator cores

1. After melting the solder around the tanks, how do you remove the excess solder?

2. When soldering the radiator tanks in place on the header plate, what areas do you solder first?

3. What type of paint do you use to protect radiators from exterior corrosion?

4. What secures the composite radiator tank to an aluminum core header?

5. Why should you be sure not to nick the header on an aluminum radiator core?

6. Why is core replacement versus repair the prevalent method of placing a damaged aluminum/composite radiator back in service?

7. Which method of aluminum radiator core repair is the most simple and effective?

8. How do you protect composite coolant tanks when you are repairing an aluminum radiator core?

9. What is the result of applying too much heat to hot melt adhesive?

10. How long should you continue heating the applied adhesive in a hot melt repair?

11. Tank gasket leaks can be mistaken for what other types of leaks?

12. How many broken clinch tabs require you to replace the entire radiator core?

Answers to Self-Test Questions

620

1. A change in one property will usually cause a change in one or more of the other properties.
2. (1) c.
   (2) e.
   (3) i.
   (4) g.
   (5) a.
   (6) h.
   (7) f.
   (8) b.
   (9) d.
3. (1) Appearance test.
   (2) Spark test.

(3) Flame test.

(4) Chip test.

4. Nonferrous metals.
5. With the spark stream of a known sample of steel.
6. The flame test.
7. Wrought iron.
8. The approximate percentage of the predominant alloying agent. It may also indicate a secondary alloying element.
9. There is 0.75 percent carbon in that metal.

621

1. Up to 250 psi.
2. Forty percent of its liquid volume.
3. Acetone.
4. To prevent connecting the oxygen regulator to the acetylene cylinder.
5. Yellow.
6. Green.
7. Right-handed threads.
8. No more than 15 psi.
9. Reduce the high cylinder pressure of acetylene or oxygen to pressures you can use for welding, cutting, and heating metals.
10. Permits the operator to select the necessary acetylene and oxygen pressure easily, quickly, and separately for an appropriate oxyacetylene flame.
11. This will blow away any dirt or other debris (which could cause a regulator malfunction).
12. Oxygen hoses (green/black in color) have right-handed threads, while acetylene hoses (red/maroon in color) have left-handed threads.
13. Soapy water.
14. Either replace the hose or cut out the bad section of hose and splice the hose using a hose coupling with clamps to seal the joint. Any splice in a hose must withstand a pressure of 300psi. .
15. Welding goggles.
16. One is for adjusting and controlling the flow of the acetylene and the other for adjusting and controlling the flow of oxygen.
17. The preheating oxygen valve and the cutting oxygen adjustment lever.
18. You fully open the oxygen torch body needle valve to allow full oxygen flow.
19. To clear any small particles from the preheat orifices of the cutting tip face.
20. Tiny particles of carbon soot will float in the air—polluting the air you breathe, and it could restrict the tiny preheating orifices in the cutting tip face.
21. The oxyacetylene flame contains excess acetylene (carburizing or reducing flame).
22. Neutral flame.
23. The oxyacetylene flame contains too much oxygen.
24. It allows regulator pressure oxygen to flow through the cutting oxygen tube, the mixing head, and then out the cutting oxygen orifice of the cutting tip face. The cutting oxygen tube does not open into the mixing head but connects directly to the cutting oxygen orifice in the torch tip. You actually use regulator pressure oxygen from the cutting oxygen orifice to cut the metal. This oxygen causes the metal to separate (oxidize rapidly).
25. No. 1 or no. 2.

26. It is formulated to chemically clean the surface and exclude atmospheric oxygen during the welding process. This serves to keep impurities out of the weld and improves welding characteristics.
27. First check the rod with a magnet to see if it is steel; and then perform a spark test.

622

1. To fill in an area where there is a wide break in the metal.
2. When there is sufficient overlapping metal at the break that can be welded together to form a strong bead.
3. Approximately $^{3}/_{16}$ to $^{3}/_{8}$ inch in diameter.
4. The molten metal pool becomes too large and the bottom of the pool will fall out, leaving a hole in the metal.
5. Approximately $^{1}/_{8}$ inch from the metal surface.
6. Between 45° to 60° angle to the metal surface.
7. Directly at the gap between the two edges of metal, maintaining at a 45° to 60° angle.
8. Backhand welding.
9. Weaving.
10. Broken braces, brackets, bent panels, damaged sheet metal, and body pillars.
11. Press the cutting oxygen adjustment lever and slowly open the preheat oxygen valve until the feather disappears.
12. Preheat the metal to between 1,400° F and 1,600° F or just below the metal's melting point (where it is bright cherry red).
13. A wide gap and an uneven cut between the metal edges.
14. This not only could endanger you but other personnel as well.
15. The heat from the oxyacetylene torch will cause the concrete to explode, sending small pieces of concrete in all directions.
16. Fire extinguisher.
17. Halt your cutting operation and clean the orifices of the cutting tip face with the correct orifice-sized tip cleaner.

623

1. During welding, the base metal and the filler metal become fused or "one" with each other. The brazing process is more similar to the adhesive process. You are simply "sticking" the filler metal to the base metal.
2. Touch the joint with the filler rod, strip, or wire as the heating progresses. As soon as the temperature of the metal is high enough to melt the alloy filler material, the filler rod, strip, or wire is brought under the flame to perform the operation (the repair process can begin).
3. Brass, composed of copper and zinc.
4. Flux.
5. The flame should be slightly oxidizing. This adjustment also permits better bonding between the filler and the base metal.
6. Adjust to neutral; close the torch acetylene valve slowly; continue closing the valve until the inner cone is reduced in length by about one-tenth.
7. Tinning.
8. The base metal is too hot.
9. The metal must be thoroughly tinned when the first layer is deposited and care should be taken to ensure good fusion between filler material layers.
10. Fluxed filler material. Failure to add flux will result in deposited filler material becoming porous with a loss of strength.
11. Silver brazing (or silver soldering).
12. Aluminum, magnesium and other metals that have too low a melting point.
13. So it will clean the base metal and properly flux the molten metal.
14. The flame outer envelope, rather than the inner cone. The cone of the flame is too hot.

15. This clearance provides for the best filler metal distribution.
16. Airtight or watertight joints not exposed to high temperatures.

624

1. Ionized gas.
2. Electrode, gas swirler, cutting nozzle, and shield cup.
3. Tungsten.
4. Gas swirler.

625

1. Manufacturer's recommended procedures and well informed enough to select the proper cutter to perform the job or task you expect it to accomplish.
2. Sixty psi.
3. Electrode and cutting nozzle.
4. Running at an amperage level that exceeds the rating.
5. Prevents slag buildup on the shield cup.
6. Two to three minutes; to ensure that moisture is blown out of the torch.

626

1. The thermostat.
2. Core section of radiator.
3. Vertical-flow and cross-flow.
4. Brass, steel, or copper.
5. Radiate heat away from the tubes as the hot coolant flows from the hot tank to the cool tank of the radiator.
6. Lower tank.
7. (1) Inside the radiator tank.
   (2) In front and separate from the radiator.
   (3) Near the engine itself.

627

1. Used to lower the platform to submerge the radiator in the water for leak testing.
2. The radiator has a leak somewhere near the evaporation stain.
3. Air bubbles coming from any small breaks in the metal of the radiator.
4. Leave the radiator in the test tank 30 minutes to one hour with air pressure applied, or remove the radiator from the repair tank and coat the suspected area with a soapy water solution.
5. Ten percent.
6. Two or three times at approximate intervals of one minute apart.
7. The inlet and outlet openings to the radiator.

628

1. Cleanliness, proper tinning and flux application, and the correct amount of heat.
2. Proper cleaning.
3. It suddenly cools the metal and dislodges lime deposits; this helps in speeding up the cleaning process.
4. Natural gas, bottled or LP gas torches; if neither of these is available, an oxyacetylene torch is acceptable.
5. The oxyacetylene torch develops high heat which will damage the lightweight metals.
6. Adjust to a carburizing flame—one having a smaller feather on the end of the inner flame.
7. Tinning solution.
8. Solid wire type and the acid cored type.
9. To ensure you replace the tank in the same exact position.
10. Form the patch that will cover the crack with the contour of the radiator tank surface to ensure a proper fit.

11. By soldering the break.
12. Place a small patch over the break.

629

1. With a wire brush or air-blow gun. Wear protective gear due to hot solder. Make sure no one is near you as you never know exactly where the molten solder will land.
2. The four corners.
3. Noninsulating paint.
4. Aluminum clinch tabs.
5. It is harder for the gasket to seal against a marred or scratched surface.
6. The clinch tabs which hold the tanks and the core together are generally an integral part of the core and are easily breakable.
7. The hot melt adhesive process.
8. Apply a wet cloth or submerge the tank, keeping the header above the water line.
9. High heat will burn and char the adhesive.
10. Until the adhesive flows, wets the entire repair area, and fills the joint.
11. Tank or header leaks.
12. If there are more than three tabs broken on one side of the header, or more than two adjacent tabs together.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to AFCDA.

39. (620) If you are measuring tensile strength of a substance in a cross-section area, then what term will you use?
    a. Tons per square foot.
    b. Tons per square inch.
    c. Pounds per square foot.
    d. Pounds per square inch.

40. (620) What does the second digit of a standard steel designation number indicate?
    a. Kind of metal.
    b. Brand of metal.
    c. Process of how the metal is manufactured.
    d. Percentage of predominant alloying agent.

41. (621) What type of threads does an oxygen cylinder valve fitting have?
    a. Metric.
    b. Left-handed.
    c. Self-locking.
    d. Right-handed.

42. (621) When using acetylene from an acetylene cylinder and pressure-reducing regulator, what is the *maximum usable* pressure in pounds per square inch (psi) that you can use?
    a. 15 psi.
    b. 25 psi.
    c. 35 psi.
    d. 45 psi.

43. (621) What should you use to check all fitting joints for leaks on oxyacetylene equipment?
    a. Oil.
    b. Flame.
    c. Diesel fuel.
    d. Soapy water.

44. (622) How large of a diameter should you maintain the molten metal pool in oxyacetylene welding?
    a. $^{3}/_{16}$ to $^{3}/_{8}$ inch.
    b. $^{1}/_{2}$ to $^{5}/_{8}$ inch.
    c. $^{3}/_{4}$ to $^{7}/_{8}$ inch.
    d. 1 to $1^{1}/_{8}$ inch.

45. (622) Before you can do any oxyacetylene cutting of metal, you must preheat the metal
    a. to just above its melting point or until it reaches between 1,000° Fahrenheit (F) and 1,200° F.
    b. to just below its melting point or until it reaches between 1,400° F and 1,600° F.
    c. until it turns a bright white or until it reaches between 1,000° F and 1,200° F.
    d. until it turns a bright blue or until it reaches between 1,400° F and 1,600° F.

46. (622) If you place a piece of metal directly on a concrete floor and begin cutting the metal with an oxyacetylene cutting torch, the
    a. metal will heat up too quickly and develop holes.
    b. metal will heat up too slowly and be hard to cut.
    c. concrete will explode into small pieces.
    d. concrete will become “tempered.”

47. (623) When brazing silver, what kind of flame is used?
    a. Less oxygen and less neutral.
    b. More oxygen than neutral.
    c. Strongly reducing.
    d. Neutral.

48. (623) Which part of the torch flame should be applied to the work in the silver brazing process?
    a. Tip.
    b. Cone.
    c. Inner flame.
    d. Outer envelope.

49. (624) When a gas is superheated, it then breaks down into tiny molecules with an electrical charge called plasma, also known as
    a. argon gas.
    b. ionized gas.
    c. hydrogen gas.
    d. carbonized gas.

50. (624) Which plasma torch component carries the negative charge from the power supply?
    a. Electrode.
    b. Shield cup.
    c. Gas swirler.
    d. Cutting nozzle.

51. (625) What is meant by the term *overpowering the nozzle* when using the plasma cutter?
    a. Pushing down too hard on the nozzle.
    b. Exceeding the amperage level rating.
    c. Shielding gas pressure is too high.
    d. Use of an improper electrode.

52. (625) After a part change, how many minutes are required to purge plasma gas from the lines and ensure any moisture is blown out of the torch?
    a. 1 to 2.
    b. 2 to 3.
    c. 3 to 4.
    d. 4 to 5.

53. (626) Which section of the radiator permits heat to dissipate from the coolant to the atmosphere?
    a. Radiator core or assembly.
    b. Stamped-out tank.
    c. Overflow tube.
    d. Cast-iron tank.

54. (626) If it is necessary to use a radiator at a lower height to accommodate a hood design, then which type of radiator would work best?
    a. Up-flow radiator.
    b. Down-flow radiator.
    c. Cross-flow radiator.
    d. Reverse-flow radiator.

55. (627) With a radiator submerged in the test tank to check for a radiator leak, you should be looking for bubbles coming from the
    a. filler neck adapter.
    b. inlet tube plug adapter.
    c. outlet tube plug adapter.
    d. break in the radiator metal.

56. (627) How much rate of flow obstruction does a one-year-old radiator *normally* have?
    a. 10 percent.
    b. 20 percent.
    c. 30 percent.
    d. 40 percent.

57. (627) Before you conduct an oil cooler pressure test, you must first
    a. make sure the inlet and outlet openings to the radiator are open (not plugged).
    b. make sure the inlet and outlet openings to the radiator are closed (plugged).
    c. attach an oil line to the radiator outlet.
    d. attach an oil line to the radiator inlet.

58. (628) Which heat source is *most* suitable for soldering a radiator?
    a. Acetylene.
    b. Natural gas.
    c. Direct current arc.
    d. Liquefied petroleum.

59. (628) If you are repairing a cracked radiator tank, how far should a patch extend from all points of the crack?
    a. 1 inch.
    b. 2 inch.
    c. 3 inch.
    d. 4 inch.

60. (629) Which method of repairing an aluminum/composite is the most simple and effective?
    a. Hot melt adhesive method.
    b. Oxyacetylene welding method.
    c. Two part epoxy adhesive method.
    d. Metal inert gas (MIG) welding method.

61. (629) When applying stick adhesive to repair an aluminum radiator core, use a
    a. soft, small, blue flame.
    b. sharp, small, orange flame.
    c. crackling, medium, blue flame.
    d. crackling, medium, orange flame.

Please read the unit menu for unit 4 and continue ➔

Unit 4. Shielded Metal Arc, Gas Metal Arc, and Gas Tungsten Arc Welding

IN THE PREVIOUS unit, you learned about the basic welding procedures using the oxyacetylene torch. You also learned about the newer cutting technology of the plasma cutter. In this unit, we will discuss electric arc welding. Shielded metal arc welding (SMAW), gas metal arc welding (GMAW), and gas tungsten arc welding (GTAW) make up the three most common types of welding you will encounter. Although oxyacetylene and SMAW welding have been a mainstay for the industry, research and development of newer metals used in the automotive construction generated the need to adopt new welding processes. Since the high temperatures of oxyacetylene distort HSS and weaken the molecules, it is now standard practice to use GMAW for HSS and GTAW for aluminum.

We must keep in mind that the welding processes discussed in this unit, although referred to as new, have been in existence for many years. What you will be welding with today are highly refined versions of technologies developed in the 1920s, 1930s, and 1940s. As stated in the prior unit, improved metal manufacturing processes and their use in auto body components have made welding a highly technical process. Mastering these essential skills is another step toward becoming an effective vehicle management Airman.

It is important to note that all three welding methods discussed in this unit are forms of arc welding. Arc welding is simply welding with an arc. Consumable and nonconsumable electrodes are the two basic types of arc welding. SMAW and GMAW are of the consumable type; the electrode is melted in the arc during welding. GTAW is of the nonconsumable type; filler is added separately. The names of the types of welding may be unfamiliar to you. To clarify, the common names for the different types of SMAW include arc welding or “stick” welding. GMAW is also known as metal inert gas (MIG) welding, and GTAW is also called tungsten inert gas (TIG) welding.

4–1. Shielded Metal Arc Welding

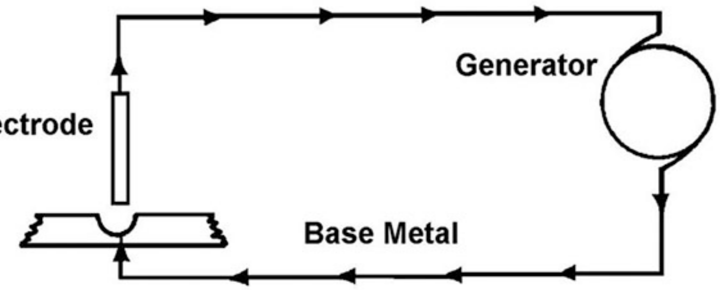
Next to oxyacetylene welding, SMAW welding is one of the oldest welding procedures. From its beginning of hooking leads to a battery and using crudely formed electrode rods to today’s state-of-the-art machines, this welding technique is the most widely used when welding all types of metals.

630. Shielded metal arc welding equipment

Arc welding consists of a local progressive melting and adhering together of the adjacent edges of metal by arc temperatures ranging from 50 ° F to 10,000 ° F. This process is developed between a suitable electrode or electrodes and the parent metal. In other words, it is the melting and fusing of two pieces of metal. Although this unit begins with SMAW, the basic principles discussed within this lesson apply to the other forms of arc welding as well.

Electrical terms and supply details

A good understanding of arc welding begins with knowing the purpose and use of electricity in the arc welding process. We will begin this lesson with a discussion of some elemental electrical facts as well as the basic arc welding circuit. These will provide the foundation for your understanding of the principles, equipment, and electrodes used in the arc welding process.

Electrical Terms	
Term	**Definition**
Circuit	Electrical current cannot flow without a complete conducting path, known as a circuit. As you can see, the arc welding circuit (fig. 4–1) is made up of the welding leads (one attached to the electrode and the other to the base metal), electrode, and an arc (between the electrode and the base metal).  **Figure 4–1. Arc welding circuit.**
Voltage	Electricity needs a push to move through the circuit. The push is supplied by an electromotive force commonly known as voltage. Voltage is created by a difference in potential of electricity. The welding generator builds up an electrical charge greater than the resistance in the circuit to create this difference in the potential. The voltage then forces the electric current through the welding lead and electrode. As the current reaches the end of the electrode, the voltage builds up until it has the necessary push to force the current across the arc gap.
Ampere	If you are going to control the amount of electricity in any given circuit, you need a way to measure it. The unit of measurement for electricity is called an ampere. The amperage is the amount of electrons flowing past a given point each second. (An electron is one negative particle of an atom. Depending on the material, atoms have a certain number of electrons in the valence ring surrounding the atom.)
Ohm	The amount of resistance in the circuit determines the amount of current flowing in the circuit. Resistance is measured by a unit known as an ohm. Each metal has its own resistance. In welding, you need leads made from a metal with low resistance such as copper. Copper is one of the best conductors and is used in most electrical appliances, generators, lines, and welding leads. Steel contains a much higher resistance and becomes too hot for any use in welding other than its use as an electrode.

Current

If an electrical circuit breaks, the current continues to flow across the gap aided by superheated atmospheric gases and minute metal particles; this is how current helps in establishing an electrical arc. A great deal of electrical energy converts into heat because the resistance is very high in the arc. The correct arc length causes the metal exposed to it to melt instantaneously.

Arc length

In metallic arc welding, the proper arc length is necessary to make good welds. If you have the proper arc length, the heat is concentrated on the base metal. If you have a long arc, much of the heat is lost by radiation to the atmosphere. In addition, you will create excessive voltage and the arc stream will wobble with splattering. Too short an arc length causes reduced voltage and does not create enough heat to melt the base metal for proper fusion.

When this happens, the bead will be too high on the base metal, there will be no penetration, and there is a good chance of the electrode continually sticking to the base metal.

In the case of SMAW, the *proper arc length* is normally *the same length as the diameter* of the *electrode.* This arc is more stable than a long or short arc and gives you more control of the molten pool. If you have the proper arc length, vapors from the burning electrode coating surround the electrode metal and the molten pool, preventing air (impurities) from reaching these hot points. If any impurities reach the molten metal during welding, it weakens the bonding of the two metals. The proper arc length produces a sharp crackling sound as you weld.

Polarity

The use of the term *polarity* in arc welding is based upon the fact that electrical circuits have negative and positive terminals or poles. In a DC circuit, the current flows in one direction only, one lead is negative, and the other is positive.

If you use a bare or lightly coated electrode, 60–75 percent of the heat releases at the positive side of the circuit and 25–40 percent at the negative side. You usually connect the base metal to the positive, or hot, side of the circuit if you weld with bare or lightly coated electrodes. The reason for this is the fact that the mass of the base metal you are welding is larger than the mass of the electrode. This condition is known as straight polarity (SP) and is illustrated in figure 4–2, View A.

Before you begin welding, check the leads and the current flow directions. If you are welding cast-iron with certain types of heavily coated ferrous and nonferrous electrodes, connect the negative lead to the base metal and the electrode to the positive lead. In this case the electricity flows from the electrode to the work. This condition is known as reverse polarity (RP) and is illustrated in figure 4–2, View B.

If you use an alternating current (AC) welding machine, there is no polarity choice. Why? Look no further than the name, alternating current. This simply means that this type of current changes its polarity twice during each cycle. Since this is inherent in AC, you cannot set polarity. In addition, since you cannot set polarity, you cannot use AC machines for all types of welding. Having said that, you might think that you will need separate machines for DC and AC welding. Happily, in most cases an AC welding machine also generally supplies both straight and reverse polarity DC.

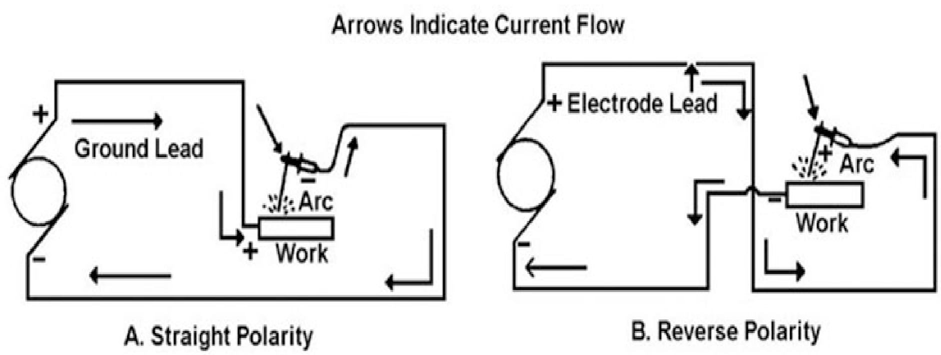


Figure 4–2. Welding current polarity.

Direct-current SMAW machines

The primary function of an electric arc welding machine is to provide the necessary current for welding. Although SMAW machines are of different types, you need to be aware of the type of current producing the arc. DC welding machines are suitable for use on all metals. They normally produce satisfactory results on thin metals requiring low-current settings. Your choice of the type of machine best suited for SMAW depends upon many things. The main difference between AC and DC welding is that AC equipment has lower initial cost and lower operating cost.

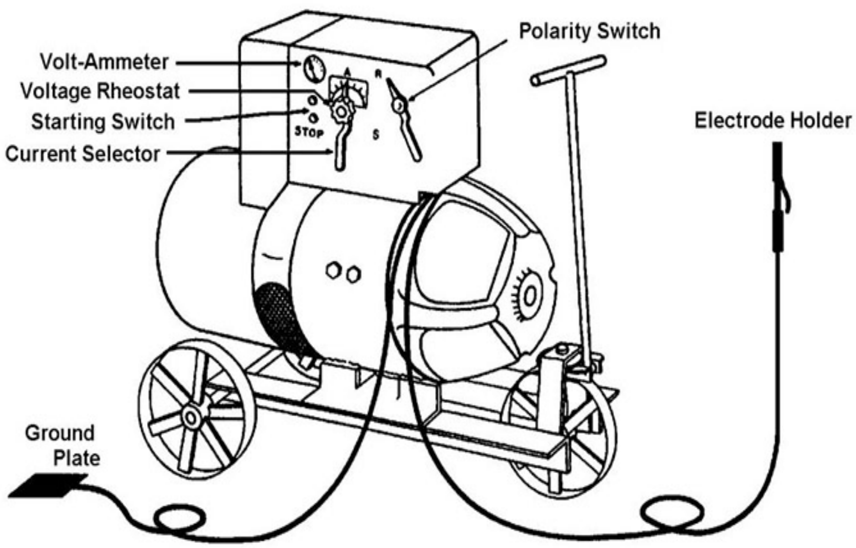
<table>
<tr><th colspan="2">DC SMAW Welders</th></tr>
<tr><th>Type</th><th>Description</th></tr>
<tr><td>Electric-Motor-Driven Generator</td><td>The most widely used welding machine is the electric-motor-driven generator welder. It uses 220 volts alternating current (VAC) to produce DC for arc welding. The rotor of the electric motor and the armature of the DC generator mount on the same shaft. Ball bearings support the shaft at each end, and the machine is manufactured as compactly as possible. This welder contains a controller mechanism for controlling welding current.
• Thinner metals require less current and smaller diameter electrodes.
• Thick metals require higher current settings and larger diameter electrodes.
Some machines provide a switch for changing polarity, while others require you to reverse the position of the welding cable leads. An on-and-off switch located on the control panel allows you to start and stop the machine and provides overload protection for the driving motor.
Most SMAW welding machines have manually operated dials so you can set the amount of amperage you need. Some shop machines are on a separate chassis that allows them to move around the shop. These mobile machines are either horizontally or vertically mounted. Figure 4–3 shows a portable electric-motor-generator arc welder.


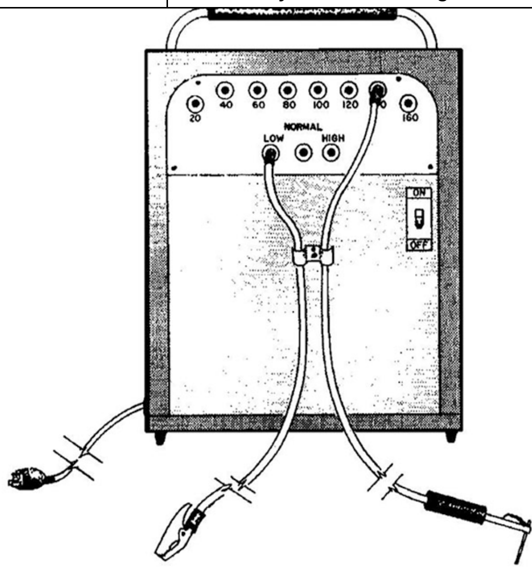
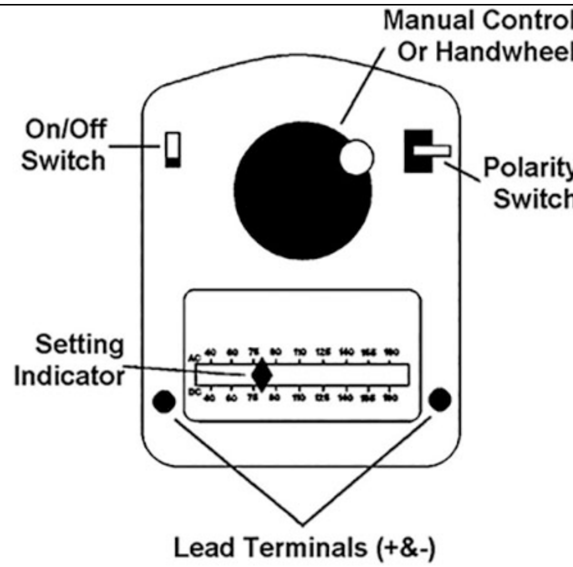
Figure 4–3. Portable electric-motor-driven generator welder.</td></tr>
<tr><td>Internal Combustion Engine-Driven Generator</td><td>Mobile trailer-mounted welders are often seen in the Air Force, especially in shops that must support heavy equipment or must deploy with the in-house capability to provide welding services. These welding machines typically use a gasoline or diesel engine to drive the welding generator. The engine comes with a governor to control the demand on the generator. This type of welder normally mounts on a trailer-type chassis so you can tow it to the location where the welding needs to be accomplished.</td></tr>
</table>

Alternating-current arc welders

Transformer and rotating machines the two general types of AC welders suitable for shielded metallic arc welding. Most AC SMAW welding machines are static transformers that offer the following three advantages:

1. Low initial cost.
2. Low operating cost.
3. Low maintenance cost.

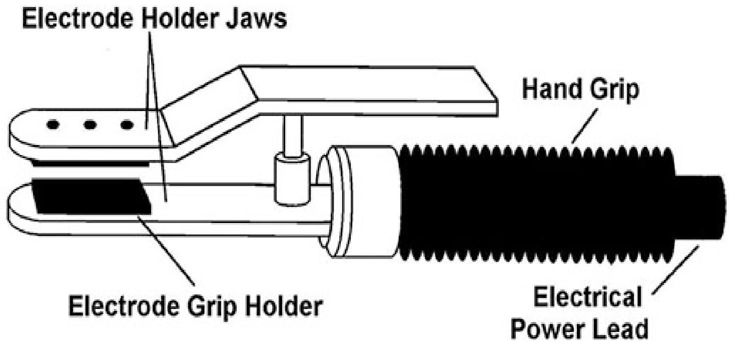
These low costs are possible because these machines *do not* have the rotating components found in DC machines.

AC SMAW Welders	
Type	**Description**
Transformer Type	This AC welding machine uses a transformer to step down the AC line voltage to an AC voltage the welder can use. Some machines have the transformer windings available at different receptacles (fig. 4–4) to permit making changes to the amount of welding current. You can increase or decrease the current by inserting the electrical lead (wire with either electrode holder or ground clamp) ends into two of the various receptacles (ones with numbers below the receptacle or ones with “low,” “normal,” and “high”) shown in figure 4–4. Other AC welding machines have a variable resistor that you control by turning a hand wheel like the one shown in figure 4–5. This alters the current according to the position of a movable coil or core. The ratings of transformer machines are available in a wide range of current. Since the transformer draws current only when in use, the machines are remarkably economical in electric power consumption. In addition, they are easy to adjust to the necessary current settings and require little maintenance.
 **Figure 4–4. AC welding machine (receptacle).**	 **Figure 4–5. AC welding machine (hand wheel).**
Rotating Type	This AC welding machine may be of either the motor-generator, frequency-changer, phase-changer, or combination type. The driving motor connects to the power line, and the generator or rotor of the frequency changer connects to the welding cables. A two-position switch permits the current output to be changed from a high to a low value, and an auxiliary control permits fine current adjustments.

Accessories

All SMAW welding machines require certain accessories to make up a complete welding outfit. These are described in the following table.

Welder Accessories	
Type	**Description**
Welding Cables	SMAW welding machines have rubber insulated, multi-strand copper cables made specifically for welding. Their size depends on the normal welding current and the distance of the welding machine from the base metal. For distances up to 50 feet use the following: • A 200-ampere machine requires a # 2 cable. • A 300-ampere machine requires a # 0 cable. • A 400-ampere machine requires a # 00 cable. The greater the number of strands in a given size cable, the more flexible and convenient they are for movement.

Welder Accessories	
Type	**Description**
Electrode holder	This device attaches to one end of the two cables leading from the welding machine and is insulated on the end. As you can see on figure 4–6, it is like a clamping device you can open to insert the bare rod end of the electrode. As the figure illustrates, the holder has grooves at various angles. These are formed in the face of both jaws to accommodate the round shape of the electrode end. Various sizes are available in accordance with the amperage capacity of the welding machine.  **Figure 4–6. Arc welding electrode holder.**

Electrodes

SMAW electrodes come in various diameters. They are available in sizes from $^{1}/_{16}$- to $^{5}/_{16}$-inch diameter. It is important to note that the diameter of an electrode *does not include the coating added* to the electrode or wire. As a rule, *you should not* try to weld with an electrode diameter larger than the thickness of the base metal. The $^{3}/_{32}$- and $^{1}/_{8}$-inch diameter are the most common electrodes you will probably use. Electrodes come in different lengths according to the diameter of the electrode:

- Electrodes $^{1}/_{16}$ inch in diameter are nine inches long.
- Electrodes $^{3}/_{32}$ inch in diameter are 12 inches long.
- Electrodes $^{1}/_{8}$ inch in diameter are 14 inches long.
- Electrodes $^{5}/_{16}$ inch in diameter are 18 inches long.

The coating manufacturers add to the electrode provides a gaseous shield that surrounds the arc and molten metal during a welding operation. This gaseous shield prevents oxygen or any impurities from coming in contact with the molten metal. If impurities are exposed to the molten metal, they weaken the strength of the weld. The coating also leaves a slag covering over the molten metal once it solidifies. This slag covering keeps the impurities away from the hot metal and protects the weld until it cools down. Once the weld cools down, you can take a chipping hammer and strike the slag lightly and it will break away from the weld.

The AWS has established a number code for electrodes. This code is made up of either a four- or five-digit number and provides the tensile strength of a properly made weld using a specific electrode (E). The number also indicates the type of current to use and the recommended welding position to use for the respective rod.

Four-Digit Number Electrodes
All mild-steel and low-alloy electrodes have a coding with four-digit numbers, such as E 6010, E 7020, and E 8030. Most of these numbers are printed on the electrode coating below the grip end. This is the end of the electrode to be inserted in the jaw-like electrode holder at the end of the wire lead. If you do not see the number right away, rotate the electrode slowly and look closely for the four- or five-digit number normally stamped in ink on the electrode coating. The following is a breakdown for electrode E 6010.

Four-Digit Number Electrodes	
Digit(s)	**Description**
1st & 2nd	Always read the first two digits together as they designate the *minimum* tensile strength in thousands of psi. For example: • The E 6010 electrode has a minimum tensile strength of 60,000 psi. • For an E 7020 electrode, the minimum tensile strength is 70,000 psi.
3rd	This digit (the 1 in E 6010) specifies the position (or positions) in which to use the electrode most satisfactorily. This digit can be a 1, 2, or 3. The number indicates the recommended welding positions as follows: 1 – All positions. 2 – Flat and horizontal positions. 3 – Flat position only.
4th	This digit refers to the following: • Type of electrode coating. • Type of current to use. • Welding characteristics. It may be any number from 0 to 8. Examples of what the fourth digit represents are as follows: 0 – DC reverse polarity if the third digit is 1. 0 – AC if the third digit is 2 or 3. 1 – AC* or DC reverse polarity. 2 – DC straight polarity or AC. 3 – AC* or DC straight polarity. 5 – DC reverse polarity (lime or titanium sodium low hydrogen). 6 – AC* or DC reverse polarity (titanium or lime potassium low hydrogen). 8 – AC* or DC reverse polarity (iron powder plus low hydrogen sodium covering). * Preferred.

Electrodes with five-digit numbers are also available. The only difference in reading these numbers is the first three digits occur together.

Five-Digit Number Electrodes	
For example, E 10010 designates an electrode having a tensile strength of 100,000 psi. The fourth and fifth digits correspond to the third and fourth digits of a four-digit number and specify the same thing. The following is a breakdown for the five-digit number of electrode - E 10010:	
Digit(s)	**Description**
1st, 2nd & 3rd	Tensile strength in thousandths of psi.
4th	Recommended welding position.
5th	This digit refers to the following: • Type of electrode coating. • Type of current to use. • Welding characteristics.

631. Welding operations

Before we get into our lesson, we need to stress the first requirement for good welding: a clean working surface. If you allow oil, dirt, and other, foreign matter to get on the metal, you can expect defects such as lack of fusion, porosity, and slag. With these thoughts firmly in mind, let us look at the welding setup factors that play an important role in any welding process.

Setup factors

As you set up to perform SMAW welding, you must consider several factors. These include the following:

1. Type of base metal.
2. Type of welding machine.
3. Type of electrode.
4. Current setting.
5. Safety.

The first four factors are very closely related and are dependent upon each other to accomplish the correct setup in producing a sound weld. Safety is always a factor no matter what stage of the welding process. You have to think safety all the time in any welding operation.

The type of base metal and the position you have to weld influence your selection of electrodes. They also affect the current setting and determine the type of machine to use. If your welding task requires deep penetration of a thick base metal, you need a different electrode than is used on thin base metal. A good rule to remember, as mentioned previously, is never try welding with an electrode diameter (bare wire diameter, not including the coating) larger than the thickness of the base metal. The diameter of the electrode normally dictates how you will set the current setting, or amperage, of the arc welder. The following table of welding electrodes and current settings should help you in deciding how to set the current settings on an arc welder. Current settings are typically displayed as a range. When welding, adjust the amperage to a level within the range that suits your technique.

NOTE: This illustration is only an example. ***DO NOT*** use it as an accurate guide for setting current settings on an arc welder. Always use the electrode manufacturers or technical order's recommendation for proper current settings.

Example Current Setting Range (in Amps) by Electrode Size							
AWS Number	**Electrode Polarity**	**3/32" Size**	**1/8" Size**	**5/32" Size**	**3/16" Size**	**7/32" Size**	**1/4" Size**
6010-A	DC+					200–275	250–325
6010-B	DC+	40–75	75–130	90–175	140–225		
6011	AC		75–120	90–160	120–200	150–260	190–300
	DC+		75–110	80–145	110–180	135–235	170–270
7010-A1	DC+	50–90	75–130	90–175	140–225		
7010-G	DC+		75–130	90–185	140–225	160–250	
8010-G	DC+		75–130	90–185	140–225	160–250	

Penetration and proper electrode selection are very crucial as you weld. These are probably two of the most important factors you can control in SMAW welding. Of course, they are not the only factors in welding, but they do have a large effect in making a good weld. Penetration means you have to burn the bead *into* the two pieces of metal you are fusing together. Some factors are very important to keep in mind:

- Be careful you do not lay the bead on top of the two pieces of metal. You have to melt the two pieces of metal before fusion will occur.
- If you use too small (diameter) of an electrode, it becomes too hot, melting the coating off the electrode. This results in insufficient protection of the weld.

- If you set the current too high, you will create excessive melting of the base metal, leaving a hole in the metal.
- With current and voltage settings too low, you have to maintain a close distance between the electrode and base metal surface. This will lay a bead on top of the base metal surface with no penetration. The electrode will normally keep sticking to the metal surface because you have to keep the electrode very close to the metal surface to maintain an arc.

If you use too small (diameter) of an electrode, the electrode becomes too hot, melting the coating off the electrode resulting in insufficient protection of the weld.

Practice and experience are the best teachers of these first four factors we are discussing.

NOTE: In the flat position, you can use higher current than for vertical or overhead position welding with an electrode of the same size.

Each person may set up for welding in a slightly different way due to individuality. However, regardless of differences between individuals, SAFETY is the one thing each person much practice.

Welding positions

All welding can be classified according to the position of the work piece or the position of the welded joint on the plates or sections being welded. There are four general positions in which welds are required to be made. These are designated as flat, horizontal, vertical, and overhead positions as shown in figures 4–7 through 4–10. Fillet or groove welds may be made in all of these positions.

Flat position

In this position, the welding is performed from the upper side of the joint and the face of the weld is approximately horizontal.

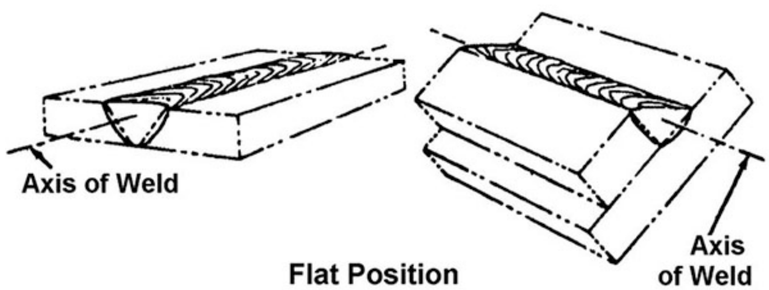


Figure 4–7. Flat position.

Horizontal position

The horizontal position actually has four subpositions with varying difficulty:

1. Fillet weld—In this position, the welding is performed on the upper side of an approximately horizontal surface and against an approximately vertical surface.
2. Groove weld—In this position, the axis of the weld lays in an approximately horizontal plane and the face of the weld lies in an approximately vertical plane.
3. Horizontal fixed—In this pipe welding position, the axis of the pipe is approximately horizontal and the pipe is not rotated during welding.
4. Horizontal rolled—In this pipe welding position, the welding is performed in the flat position by rotating the pipe.

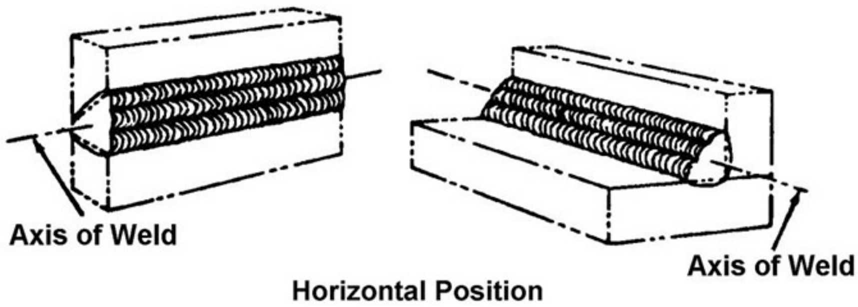


Figure 4–8. Horizontal position.

Vertical position

In this position, the axis of the weld is approximately vertical. In vertical position pipe welding, the axis of the pipe is vertical and the welding is performed in the horizontal position. The pipe may or may not be rotated.

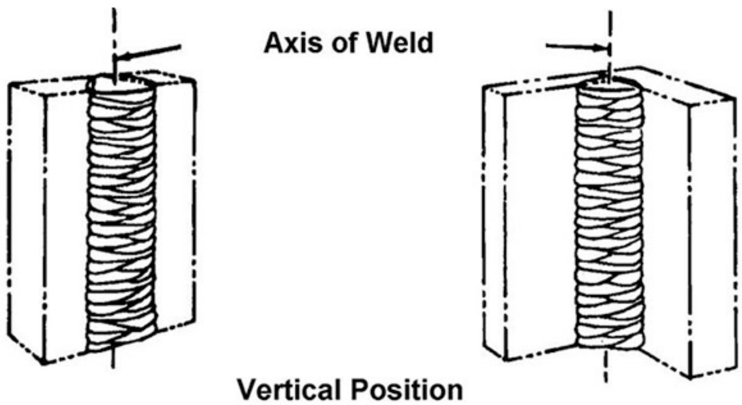


Figure 4–9. Vertical position.

Overhead position

In this position, the welding is performed from the underside of the joint. As the name implies, welding in this position is often performed above the welder. Overhead welding is considered by many to be the hardest position in which to weld. Overhead welding also requires extreme caution due to the relationship of the work to the welder. For example, molten metal could potentially fall from the work causing severe burns.

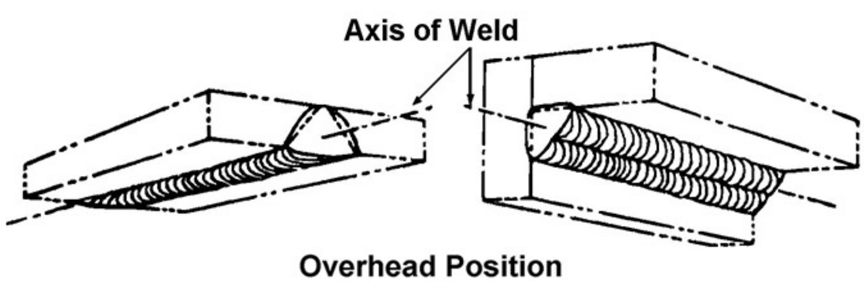


Figure 4–10. Overhead position.

NOTE: The axis of a weld is a line through the length of the weld, perpendicular to the cross section at its center of gravity.

Safety

Defective equipment, deliberate violation of safety precautions, or ignorance or neglect of safety rules or practices can cause many accidents. In the event of an emergency, or when you are in doubt about something we do not cover in this lesson, refer to TO 34W4–1–5, *Welding Theory and Application*, Chapter 4, *Safety Precautions in Welding Operations.* Further, the shop you will be welding in on a regular basis must have a permit from the installation fire department. This is due to the fire hazards related to welding. We will begin our discussion of safety with a look at a very important piece of safety equipment: the welding helmet.

Welding helmet

The welding helmet is not only necessary, but it is also the most important of all safety equipment items. The dark glass the welding helmet houses protects your eyes and keeps them from becoming burned by ultraviolet and infrared rays given off by the arc. The dark lens in the helmet filters out 99 percent of the harmful rays. If you, or anyone, stare long enough at the bright arc (even up to 50 feet away) without a proper dark lens protecting the eyes, serious damage to the eyes or possible blindness can result. For this reason, always use a screen, booth, or curtains to shield the bright light of the arc from everyone else near your welding operation. If you must weld in the open, warn persons working nearby against the hazard of exposing themselves to, or looking directly at, the bright light of the arc. It may be in their best interest to secure proper eye protection.

There is a clear piece of glass in front of the protective (dark) lens. It is to protect the dark lens from spatter or flying sparks, which could damage the dark lens. If this clear lens becomes obstructed with a large amount of spatter, replace it. The dark lens comes in various shades of darkness. The lower the number, the more light admitted (less light is filtered out). A no. 10 or no. 12 is suitable for arc welding; however, anytime you feel the arc is too bright, you can remove the lens and insert one with a higher number (e.g., no. 14) to reduce the brightness. Keep in mind that you have to be able to see all of the following:

- The arc.
- The tip of the electrode next to the arc length.
- The molten metal pool.
- The path along which you are moving the electrode.
- The base metal you are welding.

If you cannot see all of these items, you need to change to a lower-number dark lens in the helmet so you can see the entire welding operation comfortably. If you have to squint your eyes because the light of the arc is too bright, you need to put a higher-number dark lens in the welding helmet. If your shop does not have the various shades of dark lenses, speak with your supervisor about ordering them from supply or purchasing them with the government purchase card (GPC) program. This is for your own safety and the safety of others working with you. For further assistance in determining the proper lens for the welding or cutting task, refer to TO 34W4–1–5.

The helmet itself comes with an adjustable headband. Adjust it so the helmet fits snugly on your head. You will notice the helmet not only protects your eyes from receiving serious injury, but it also covers your entire face and part of your neck. If the helmet did not cover your face and the front of your neck, you could receive serious skin burns from the flying sparks. In addition, the intense bright light produced when welding a considerable length of time can actually cause a type of skin burn. Some helmets come with a flip-up lens holder on the front of the helmet. The protective lenses we have already discussed are located in the holder. A second piece of clear glass is located in the helmet. This second clear piece of glass protects the backside of the dark lens; it can act as safety glasses if you flip up the lens holder. You can leave the helmet secured to your head with the lens holder flipped up while you chip the slag off the bead of the weld. As you will learn from experience, striking the slag with a chipping hammer makes the slag fly in all directions.

If the helmet you are using does not have a flip-up lens holder, you have to manually swing the helmet up at the hinged band. Since this exposes your eyes to flying slag if you use a chipping hammer to break the slag off the weld, *wear safety glasses*. You arrive in this world with one set of eyes; do not lose them foolishly.

The basic welding helmet we just discussed is found in most shops. You may be fortunate enough to have an electronic auto-darkening welding helmet. The lenses on this type of helmet are clear during normal conditions but will darken automatically once you begin welding. This is very convenient because you do not need to use your hand to flip up the helmet or lens. This enables you to concentrate on and keep both hands on the work.

Clothing

Wear gauntlet-type leather gloves to protect your hands from the heat and injurious rays emitted by the arc. These gloves should have a cuff that extends and covers half way up your forearm. *Do not* roll up your sleeves while welding because this exposes your arms to potential burns caused by flying sparks and the intense light from the arc. A leather apron is good protection from particles of molten metal that would otherwise come in contact with your uniform, and prevents burning tiny little holes in it. If you have to straddle a vehicle component or piece of equipment, *do not sit down to weld*. The sparks or a small globule coming off the welding process can be trapped between your uniform and the component you are sitting on. Since it takes a considerable amount of time for this small globule to cool off, it could set your uniform on fire and result in serious injury. Get comfortable as you weld; however, it is safest to stand when possible as this allows you to react more quickly. A leather jacket and sleeves are necessary for vertical and overhead welding. If you feel safer and comfortable with the leather jacket and sleeves on for other types of welding, wear them. Wear high-top shoes with the bottom of the pant legs covering the shoe tops to keep sparks and small globules from falling down inside your shoe. If this should happen, you will discover just how good a dancer you are. *Do not* leave any of your pockets open or roll up pant legs while welding; they are apt to catch sparks or tiny globules. For the most hazardous operations, wear leggings.

Hazards of electrical shock

The AC and DC welding circuit voltages are less than voltages used for lighting circuits and motor-driven shop tools (110 VAC). However, these voltages can still cause severe shock when you are perspiring. Consequently, always check the welding equipment to make certain that the electrode connections and the insulation on the holders and cables are in good condition.

- Keep your hands and body insulated from the base metal, the electrode, and the electrode holder.
- Avoid standing on wet floors or coming in contact with grounded metal surfaces.
- Perform all welding operations within the rated capacity of the welding cables.

Excessive heat from high-current settings (up to 500 amps) will impair the cable insulation and damage the cable leads. Inspect the cables periodically for looseness at the connections, defects from wear, or other damage. Defective or loose cables are a fire hazard. Replace defective electrode holders and tighten connections at the holder whenever they become loose.

Ventilation

As the electrode coating burns, it gives off toxic fumes. For this reason, proper ventilation is very important and prevents inhalation of these fumes as you weld. Metals with paint on them also give off toxic fumes.

NOTE: Ventilation is a *must* if you are welding galvanized metal. If your shop does not have adequate ventilation, open a window or use a floor fan to move the fumes to where they can be picked up by other ventilating devices and taken out of the shop. Consult with bioenvironmental engineering to determine if you have adequate ventilation for welding operations.

Hot metal

Never pick up hot metal you have welded with the welding gloves you are wearing. You may not feel the intense heat right away; however, when the gloves absorb enough of the heat, your fingers and hands will feel the heat for some time! Always use pliers or some other gripping device to pick up the hot metal. If you have to leave the area where you are welding, mark the hot metal in some way so that someone else does not come along and grab it. Before leaving the area where you are welding, cool the metal if possible. Remember, quenching (rapidly cooling) sometimes ruins certain metals.

Surrounding area

Be aware of your surrounding area before you start welding. Make sure there are no ignitable materials that could start a fire. When you are welding, it is hard for you to see, hear, or smell a fire starting because of the noise of the arc and the smell of the burning electrode coating. Always have an operational fire extinguisher nearby as you arc weld.

If you cannot remove the component from a vehicle for welding purposes, do the following:

1. First, disconnect the battery.
2. Then cover the surrounding components with an appropriate noncombustible barrier to prevent them from igniting or melting.

It will take some time to adequately protect the area, but it will save you from injury and component damage.

If you have to weld where moisture is present, take the following precautions:

- Do not stand in water.
- Remove as much moisture from the area as possible.
- Make sure your ground lead is adequately grounded.
- Shut the welder off each time you insert a new electrode in the electrode holder.

You do not want to “volunteer” yourself as a path for the live current to travel through your body from the welder to the wet floor! It is not a pleasant experience and could be very hazardous to your health and well-being.

632. Joint welding

An important part of welding is selecting the best type of joint for the repair at hand. Conditions sometimes dictate the selection of a welding joint, but very often, you can make the decision. Of course, the best joint in welding is the one that will stand up under the usage of the vehicle. In this lesson, we will look at three joints commonly used in all welding processes: laps, tees, and butts.

Lap joint

This joint (fig. 4–11) is formed by placing one piece of metal on top of another (lap over) and welding the two pieces together:

- Place one metal plate flat against another flat metal plate.
- The edge of one of the two plates passes over the other between 1 and 3 inches.
- They are welded together, binding the edge of one plate to the surface of the other plate.

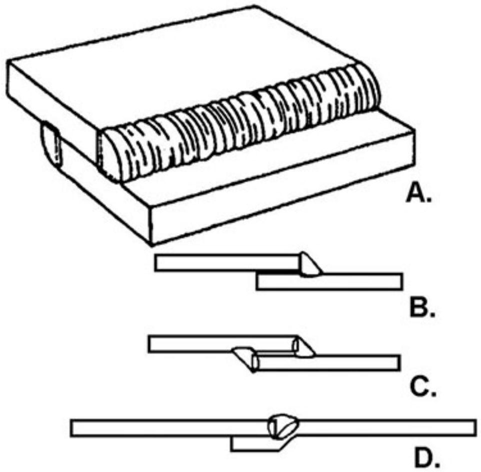


Figure 4–11. Lap joints.

You frequently use lap joints where flush surfaces are not needed. The three most common lap joints you use are discussed in the following table.

Lap Joints	
Type	**Description**
Single Fillet (fig. 4-11B)	You use the single fillet lap joint when it is not possible to weld on the reverse side of the two plates. This type of joint does not require grinding to fit the edges of the plate. If the load applied to this type of joint is not too severe, you can weld plates of all thicknesses; but if the joint experiences fatigue or encounters impact loads, stress will be concentrated at the edge of the weld. Under tension, the plates will pull out of line, thus, subjecting the weld to bending.
Double Fillet (fig. 4-11C)	The double fillet lap joint is suitable for more severe load conditions at the joint than the single fillet lap joints.
Joggled (fig. 4-11D)	You use the joggled lap joint for one even plane (that is, completely flat) surface. The joggled lap joint can handle load distribution better than the single or double lap joint.

NOTE: Lap joints are not desirable where fatigue or impact occurs to the joint, but they are able to withstand shear and tension stresses.

If you are joining metal thickness greater than $^1/_8$ inch, the edges of the metal should overlap approximately three to four times the metal thickness.

Hold the electrode at a 30° angle (from the vertical position) and tilt the top of the electrode to a 15° angle in the direction of travel (fig. 4–12). Make sure your welding helmet is in place, covering your face and neck. If your helmet has the flip-up lens cover, make sure you flip the lens cover down before striking the electrode to the metal surface. Use the scratching or tapping technique to start the arc. (If you use the scratching technique, scratch the tip of the electrode across the metal surface as if you would scratch a wooden match across the sandpaper side of a matchbox.)

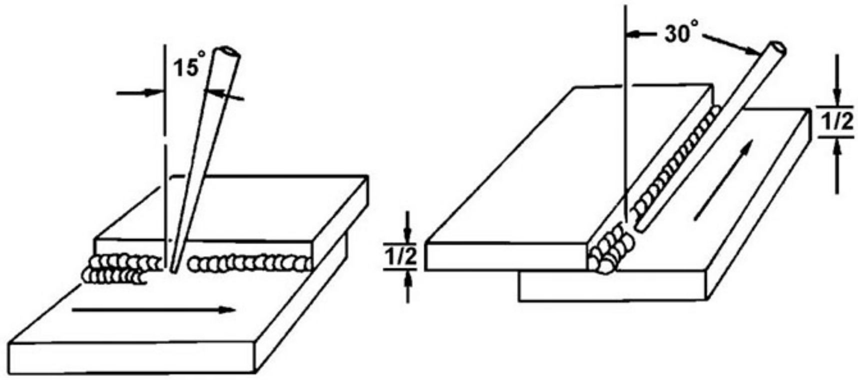


Figure 4–12. Angle of electrode.

As soon as the arc forms, move the tip of the electrode immediately to the left where the joint begins and start maintaining your correct arc length for the weld. If you are left-handed, scratch the tip of the electrode immediately to the right and start maintaining your arc length at the beginning of the joint. If you do not seem to have any luck with the scratch technique, try the *tapping technique* as follows:

- Tap the tip of the electrode lightly against the metal surface until the arc starts to form.
- Move the tip of the electrode immediately to the beginning of the joint and start maintaining the arc length for a good weld.

Hold a slightly long arc for a short time at the start of the weld to ensure penetration. Due to heavy plates conducting heat away more quickly than light plates, slow down the speed of travel and use higher current values on heavy metals. Direct the arc so you obtain even penetration in both the upper and lower plates. If you are welding on plates of different thickness, tilt the electrode so that penetration occurs more in the thicker plate. Even though you are directing more heat into the thicker plate, enough heat from the arc will melt the thinner plate to form an even amount of molten metal between the two plates. Be careful not to overheat or undercut the thinner plate edge. You must control the arc so that the penetration on both pieces of the metal is equal.

Tee joint

A tee joint is formed when you join the edge of one plate approximately perpendicular to the face of another plate. You use a fillet weld in this joint, approximately triangular in a cross-section view. It's a very rigid joint used extensively in structural work. Figure 4–13, View A shows how to use a square edge or plain tee joint for joining metals up to $^{5}/_{16}$-inch thick in which no edge preparation is necessary. You may weld from one or both sides, depending on the strength desired. If you use heavier metal, up to $^{3}/_{8}$ inch, use a single-bevel tee joint as shown in figure 4–13, View B and weld the joint from one side. Figure 4–13C shows how to use a double-beveled tee joint on steel over $^{1}/_{2}$-inch thick. You would weld this joint from both sides.

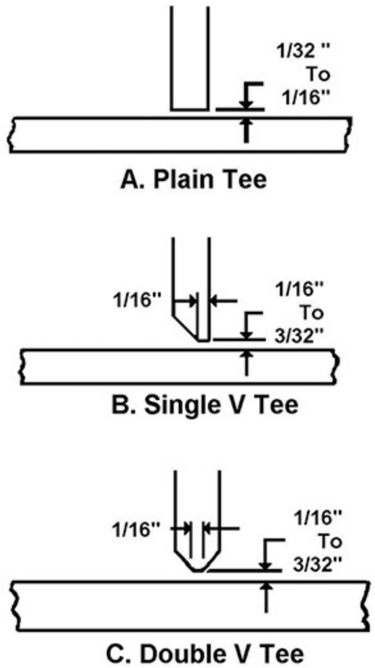


Figure 4–13. Tee joint preparation.

Tee joints can be welded in flat, horizontal, vertical, and overhead positions. Make the first bead (root weld) so the penetration into both plates is equal. Hold the electrode at a 45° angle to both plates and a 75° angle to the direction of travel (fig. 4–14). Contraction normally occurs during the cooling down of the metal. This will make the vertical plate tip beyond the 90° angle to the base plate. If you are going to weld on only one side of the vertical plate, tilt the perpendicular plate slightly over the 90° angle and begin welding the root weld. As the cooling down period expires, the vertical plate will pull back to the 90° angle to the base plate. If you are going to weld the vertical plate on both sides, perform the following:

1. Weld a short bead on one side.
2. Transfer to the other side and weld a short bead slightly ahead of the bead you just welded on the first side.
3. After welding the full length of the joint, go back and fill in the areas you left vacant, alternating from side to side.

Make the fillet weld in a tee joint by weaving the electrode to form a wide bead (fig. 4–15). Before you make the fillet weld, make sure you remove any slag from the root bead. Weave the bead so you cover the root bead and cause penetration evenly on both plates.

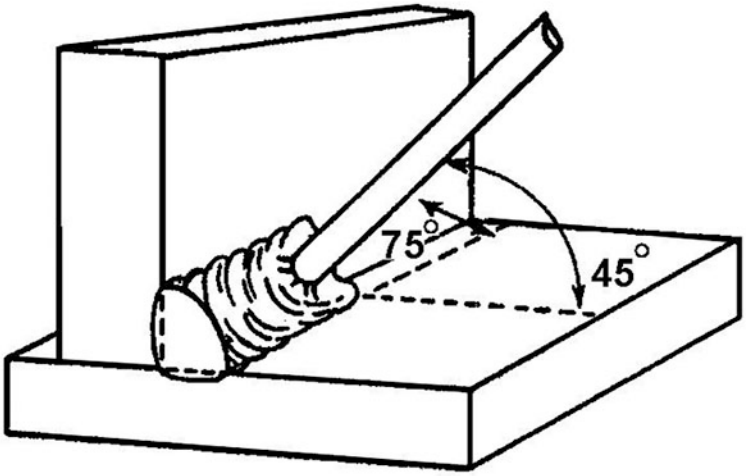


Figure 4–14. Electrode angle for a tee joint.

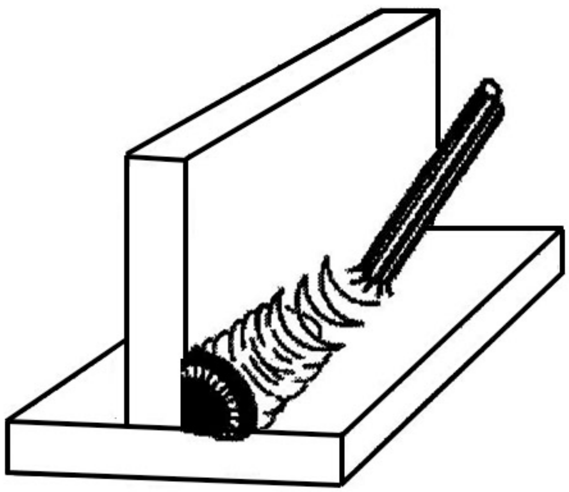


Figure 4–15. Electrode weave motion.

Butt joints

Butt joints are used to join two flat metal plates of the same thickness together edge-to-edge. There are several methods of edge preparation for joints to make butt welds that you can use; the most important are shown in figure 4–16.

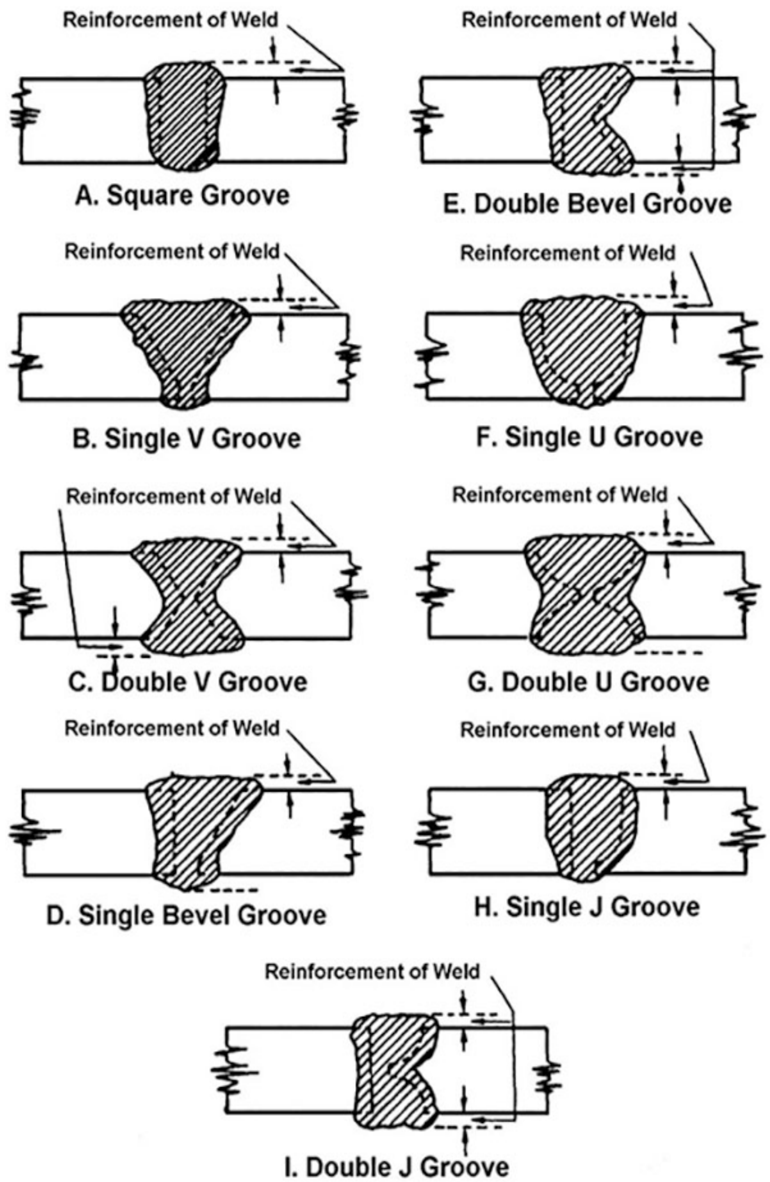


Figure 4–16. Butt joints.

Joint preparation

One factor influencing the method of joint preparation is the equipment you have available for beveling or grooving. You can prepare joint edges by flame cutting, shearing, flame grooving, machining, chipping, or grinding.

Type	Description
Square Groove (fig. 4–16, View A)	If possible, you can weld metal up to $^1/_8$-inch thick with no special edge preparation by welding both sides of the butt joint.
The Single "V" (fig. 4–16, View B)	This weld differs from the single bevel in that you single bevel the edge of each metal plate. The total angle of both metal plate bevels should be approximately 60°. Each side of the metal plate that you double "V" bevel should also be from 60° to 75°.
The Double "V" Bevel (fig. 4–16, View C)	This weld requires approximately one-half as much electrode as the single "V" bevel butt joint. In general, butt joints with a double "V" bevel are easier welded, produce less distortion, and ensure better weld-metal qualities than the butt joints prepared from one side only.

Type	Description
Single Bevel Groove (fig. 4–16, View D)	If welding on both sides is not possible, use a single bevel to weld metal plates $^{3}/_{16}$- to $^{3}/_{8}$-inch thick. Bevel the metal plate edge to a 30° to 35° angle. If you cannot bevel one of the plates because of its shape or location, use the single bevel In this case; you would make the weld from one side.
Double Bevel Groove (fig. 4–16, View E)	Use the double bevel for welding thicker metal plates. While this restricts you to beveling only one metal plate, you can still weld on both sides of the metal plate.
Single “U” Groove (fig. 4–16, View F)	For joining $^{1}/_{2}$- to $^{3}/_{4}$-inch metal plates, you can use the single “U” joint in place of the single or double “V.” The “U” joint is more effective and requires less filler metal than the single “V” for welding heavy metal plates or welding in deep grooves. Normally, you will weld on the “U” side only; however, if possible, weld on the opposite side of the “U” after you weld on the “U” side. As you weld on the opposite side of the “U,” make sure you have adequate penetration.
Double “U” Groove (fig. 4–16, View G)	Use the double “U” for joining heavy metal plates $^{3}/_{4}$-inch to 1-inch thick. It requires less weld metal than the single “U” and you weld both sides.
Single “J” Groove (fig. 4–16, View H)	You use the single “J” joint to weld plates 1-inch thick or thicker from one side. Make sure your weld penetrates into the root of the weld; penetration is promoted by the correct root openings. Less filler metal is necessary in making the single “J” than the single “V,” and the same is true of double “J” and “V” joints.

The depth of fusion in the beveled edges of the joint should be at least $^{1}/_{16}$ inch. This allows the heat from the arc and the molten metal to melt the metal in the root for fusion of the two metal plates. A reinforcement height of $^{1}/_{8}$ inch is generally enough for a heavy plate. Regardless of the thickness of the plate, the penetration for butt welds must be 100 percent of that thickness. For double-sided penetration, you need to obtain 50 percent of penetration from each side to produce the necessary full base metal penetration.

NOTE: The one important thing you need to keep in mind as you bevel edges is that the weld should be about $^{1}/_{8}$-inch wider than the top opening of the bevel.

Welding butt joints

Arc welding produces heat (up to 9,000 ° F) at a joint, causing the metal to expand and melt. After it cools, it contracts an equal amount, which causes distortion (fig. 4–17). If you restrain the expansion of the metal being welded, buckling or warping may occur. On the other hand, if you restrain the contraction, you may distort the metal. You can adjust for this contraction by using a wedge to hold the edges of the metal apart. Move the wedge forward as you weld. Using a wedge for spacing depends upon the type of metal and its thickness. Space two pieces of metal with up to $^{1}/_{8}$-inch of thickness, one-half the metal thickness apart (in this case, $^{1}/_{16}$ inch).

Another method to control expansion and contraction of the metal during the welding process is to “tack” both ends of the butt joint before you start welding the two metal plates together. To tack means to maintain an arc long enough to form a molten pool of metal for a brief moment (2 to 3 seconds) at each end of the butt joint. This will bond the two plates together at the ends and maintain the proper space between the two metal plates during your welding process.

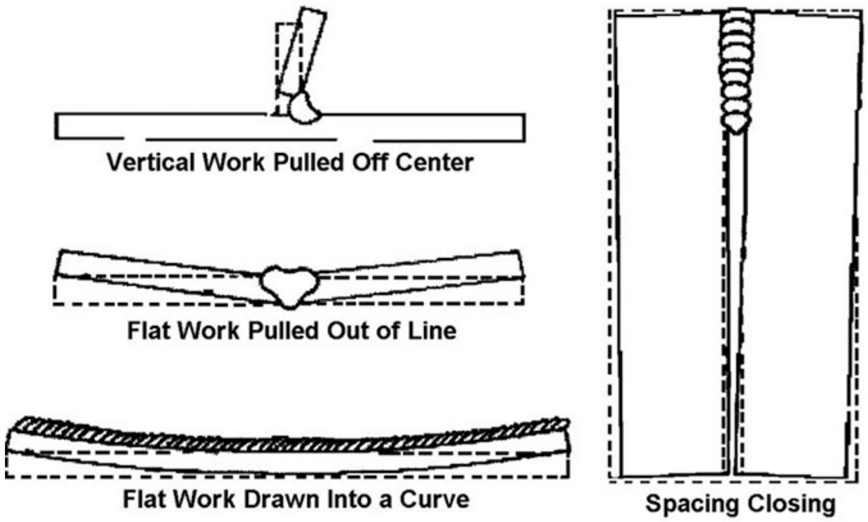


Figure 4–17. Results of weld metal shrinkage.

Welding thick metal plate (metal over $^{3}/_{16}$ inch thick) presents additional problems. To meet the weld requirements (penetration) for heavy metal plates, you need to bevel the joint edges. This is necessary to penetrate the weld into the root of the joint. The root of the joint is the distance from the bottom edge of the bevel to the bottom side of the metal plate and the distance between the two metal plates (fig. 4–18). As you bevel the metal plate edges, you normally want to leave $^{1}/_{16}$ to $^{1}/_{8}$ inch for the construction of the root. In other words, bevel the metal plate so the root face is approximately $^{1}/_{16}$- to $^{1}/_{8}$-inch high from the bottom of the metal plate, and the distance between the two metal plates is between $^{1}/_{16}$ to $^{1}/_{8}$ inch, and no more than $^{1}/_{8}$ inch for heavy metal plate. You would move the thinner metal plates ($^{3}/_{16}$ to $^{3}/_{8}$ inch) closer together ($^{1}/_{16}$ to $^{1}/_{8}$ inch). This allows proper penetration of the metal as you weld your first bead (root) between the two metal plates. After you place your first bead between the two metal plates, you will notice there is still a depression from the top of the bead to the flush surface of the metal plates. This welding a series of either stringer or weave beads is called *multiple-pass welding*.

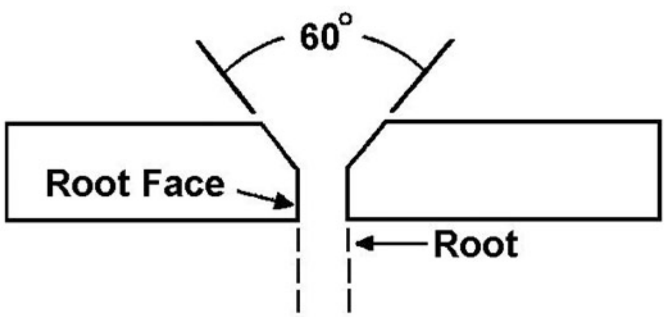


Figure 4–18. Butt joint root.

You use the multi-pass technique to weld thick metal plates and avoid too large a pool of molten metal that can cause slag contamination or cold spots in the weld. A large molten pool of metal is difficult to control. The high heat and slow speed of travel results in excessive grain growth and unnecessary melting down of the joints. The first weld you make is the root weld, where penetration of the two metal plates takes place at the very bottom of the metal plates. As you multiple-pass weld, you are covering the root weld. You create a flat, even, flush surface with the metal plates. Then, finish connecting the two plates for 100 percent penetration of the two metal plates.

Before welding on top of another weld, you need to remove the slag with a chipping hammer. This allows for absolute bonding of the all-metal surfaces.

You can easily control the final layer to obtain a good smooth surface. The lower layer of weld metal often cools to a dark shade of blue and reheats to a temperature high enough to permit grain refinement. This is in effect, a form of heat treatment. The depth of metal affected by this action depends upon the penetration of the welding heat. If you desire grain refinement in the top layer of the welded joint, you can deposit an excess layer of weld metal on the finished weld and then grind it off. The purpose of this last bead is to supply enough welding heat to refine the weld metal in the final layer at the surface of the joint.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

630. Shielded metal arc welding equipment

1. Briefly explain the following terms:

   (a) Circuit.

   (b) Voltage.

   (c) Amperage.

   (d) Ohm.

2. When you are performing SMAW welding, why is a long arc length *undesirable?*

3. What polarity is present when the electricity flows from the electrode to the work?

4. On an AC welding machine, how often does the polarity change during each cycle?

5. If an electric-motor-driven welder has no polarity switch, what must you do to change the polarity?

6. On an internal combustion engine-driven generator welder, what controls the demand on the generator?

7. State three advantages of most AC SMAW welding machines.

8. What determines the size of the electrode holder?

9. What diameter electrode should you use for welding $^{1}/_{8}$-inch-thick base metal?

10. What is the purpose of the electrode coating that acts as a gaseous shield during an arc welding operation?

11. What organization established the number code used on electrodes?

12. Where do you look for the AWS number code on the arc-welding electrode?

13. What do the first two digits of a four-digit AWS number code indicate?

14. If the third digit in a four-digit electrode code number is 1, what does this indicate?

15. Explain the meaning of the electrode number E 12030.

16. What digit of a five-digit electrode code number recommends the welding position?

17. What digit in a five-digit electrode code number indicates the current to use?

631. Welding operations

1. List the factors you should consider in setting up for SMAW welding.

2. What is a good rule to remember when deciding what diameter of electrode you should use for the thickness of the base metal?

3. If you are welding with $^{7}/_{32}$" diameter 6011 electrode, what is the range for the AC current setting for this electrode? (Use table shown in lesson 631 to make your determination.)

4. What are the two most important factors in SMAW welding?

5. What will normally happen if you try to SMAW weld with too low of a current and voltage setting?

6. What are the four general welding positions?

7. What is the most important safety equipment item of SMAW welding?

8. What should you use to shield the bright light of the arc from everyone else in the vicinity of your welding operation?

9. What should you be able to see during the welding operation if you are using the proper shade of lens filter?

10. What protective clothing is necessary for vertical and overhead welding?

11. Name the welding equipment that will be affected by excessive heat from high-current settings during welding operations.

12. What should you use to handle hot metal that you finish welding?

13. What precautions should you take if you are unable to remove a component that requires welding from a vehicle?

632. Joint welding

1. Where would you use a lap joint?

2. What type of lap joint do you use if you are limited to welding on only one side of the joint?

3. Describe the scratch technique for starting the arc in welding.

4. How should you hold the electrode when you are welding a lap joint that contains two different thicknesses of metal?

5. Name the welding joint you would use to bond one plate approximately perpendicular to another.

6. At what angle should you hold the electrode for welding tee joints?

7. How should you hold the perpendicular metal of a tee joint if you are going to weld on one side only?

8. How is a butt joint used?

9. What thickness of metal can you arc weld without preparing the edges for a butt joint?

10. Approximately how much less electrode usage does a double “V” bevel butt joint take than the single “V” butt joint?

11. What angle should you bevel the metal plate for a single-bevel butt groove joint?

12. What type of butt joint is recommended if you have to weld metal plates with $^{1}/_{2}$- to $^{3}/_{4}$-inch in thicknesses?

13. What type of butt joint is recommended if you have to weld metal plates with $^{3}/_{4}$-inch to 1-inch in thicknesses?

14. What type of butt joint is recommended if you have to weld metal plates with 1-inch or more in thicknesses, but from one side only?

15. What height of reinforcement is normally sufficient when butt welding a heavy metal plate?

16. When welding butt joints, what is minimum penetration?

17. Besides the use of wedges, what other method can you use to maintain spacing as you weld metal?

18. What is the root of a butt joint?

19. Name the welding process where you weld a series of either stringer or weave beads.

20. Why should you use a chipping hammer to remove the slag before welding on top of another weld?

4–2. Gas Metal Arc Welding

GMAW welding is a way to obtain high-quality fusion welds. When it comes to using this equipment, you will find it is probably the easiest welding process to master (as gas shielded welding processes go). It is much faster and takes less coordination than other forms of gas shielded welding. In addition, you can use GMAW to weld most of the same metals you weld with other welding techniques. To begin our discussion, let us start by seeing how you set up the welding equipment.

633. Gas metal arc welding equipment

GMAW uses direct current and a gas shield of argon, helium, carbon dioxide (CO_2), or various mixtures of these gases. A small diameter wire serves as both the electrode and the filler metal. It is fed continuously and automatically from a spool or reel holder. The equipment we have described works together to initiate gas coverage and automatically feed the electrode into the weld area when the arc is struck. When the arc is established, a welding pool is formed immediately. Welding is accomplished by moving the welding gun along the line of the joint. You progress at a rate that builds up a bead to the desired dimensions. During welding, the electrode and weld pool are protected from oxidation by the gas shield. No flux is required. You might even say the gas serves a purpose similar to flux.

There are a number of advantages to using the GMAW, including the following:

- Faster welding speeds.
- All position welding.
- High visibility to the operator.
- No slag.
- High-quality welds with a smaller heat-affected zone (HAZ).

With GMAW, about 90 percent of the metal deposited remains in the molten pool. This compares very favorably with the 60 percent deposited with SMAW. In addition, the HAZ is smaller due to the faster speeds. The HAZ is the area around a weld that does not melt. Although the metal does not melt, the mechanical properties of the metal (tensile strength, brittleness, etc.) are altered because of the welding process.

There are numerous types and models of GMAW equipment available. Figure 4–19 shows a typical GMAW set-up. Regardless of the model or type, all GMAW sets share the following basic requirements:

- A source of DC reverse polarity (DCRP).
- A wire feed unit for the wire filler metal.
- A control unit for automatic feed of the wire filler metal and shielding gas.
- A welding gun to direct the wire filler metal.
- Shielding gas supplied to the weld area.

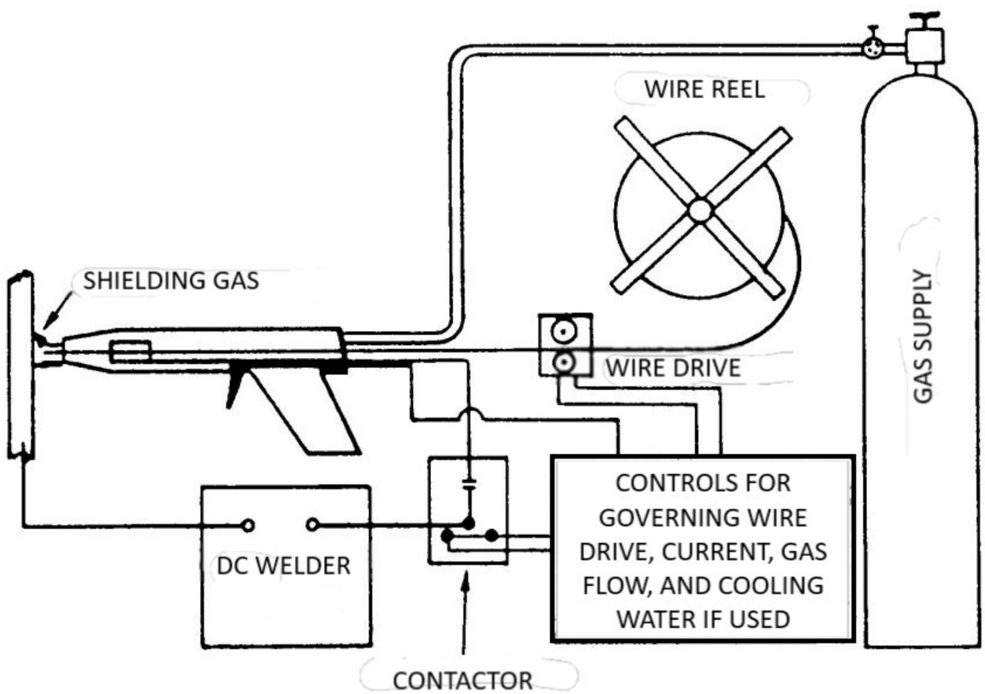


Figure 4–19. GMAW equipment.

Though GMAW welding is relatively easy, there is more to be considered when setting up the equipment. For example, GMAW uses a constantly feeding spool of wire fed at a determined speed into the molten pool. Variables such as the amount of voltage, wire speed, wire size and types of shielding gas all determine the mode of metal transfer. To build upon this general introduction, let us now look at the components in a GMAW station.

Power source

The SMAW machine we discussed in the previous section just will not work for GMAW welding. This is because the SMAW welder is a *constant-current* machine and GMAW welding requires a *constant-voltage* power source.

Constant-voltage means the machine will *automatically* adjust the amperage output to maintain the same voltage. The output voltage is determined by a rheostat on the front of the machine, similar to the amperage adjustment on a constant-current machine.

The power source can be either a DC rectifier or a motor or engine-driven generator.

Wire feed unit

On most machines, the wire feed unit sits on or near the power source and has its own set of controls. The unit controls determine how fast the electrode wire feeds into the molten pool; consequently, it also determines the amperage output. Rollers on the wire feed unit push the wire through a cable/conduit to the welding gun. There is an electronic governor that can vary wire speed from 50 to 900 inches per minute (IPM). To ensure smooth flow of the wire from the spool to the molten pool, the *rollers* in the wire feeder must be properly aligned. If the alignment is off, the wire can easily turn into a massive tangled mess, something akin to a bird's nest. An inch button on the wire feeder allows the unit to slowly feed the wire through the conduit to the gun so you can check alignment. Some units may have a *gas purge switch* located on the wire feed unit. Pressing this button allows the system to temporarily begin gas flow, in cubic feet per hour (cfh), and purge any impurities before welding.

Welding gun

The welding gun and cable assembly place the electrode wire, shielding gas, and current at the weld location. In some ways, it is much like the electrode holder used in standard arc welding (it directs current and the electrode). Of course, it is much more complicated than what we have described. As figure 4–20 indicates, the gun also houses the "on/off" trigger switch to initiate the entire current-gas-wire-feed process.

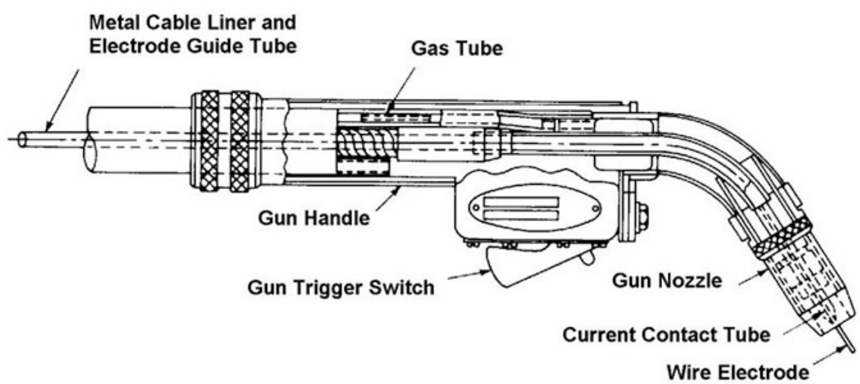


Figure 4–20. GMAW gun.

GMAW guns are either air-cooled or water-cooled. In most shops, you will find the air-cooled guns are more popular because they are less complex. Air-cooled guns are capable of currents up to 400 amps and are usually the "push-type." This means the drive mechanism is located at the wire feeder (as mentioned previously). Water-cooled guns (either the "push-pull type" or the "pull-type") can carry heavier welding wire and are primarily used for fully automated welding. There are also small guns that contain 5-pound spools of wire (on board) for light duty, soft-alloy-electrode welding.

Shielding gases

The earth's atmosphere is largely composed of nitrogen, oxygen, and water vapor, with several other trace elements. Although the atmosphere is quite beneficial to us, it is not so beneficial to the welding process. In fact, the various elements that keep us alive can destroy weld quality. For this reason, inert and reactive gasses are used in gas-shielded welding to protect a weld from these various elements. In essence, these gasses shield the welding process and prevent the weld from being contaminated with impurities from the atmosphere. The term *inert gas* means a chemically inactive gas; that is, it will not combine with any other element. Conversely, *reactive gasses* combine with other elements; however, their use is beneficial to the weld process.

Gas shielding has a dramatic effect upon the weld quality. A number of inert and reactive gases can be used alone or mixed to vary operational smoothness, weld appearance, quality, and speed, and include the following:

- Argon (Ar).
- Helium (He).
- Oxygen (O_2).
- CO_2.

Figure 4–21 shows the effects these various shielding gases have on the weld, and the following table discusses them in some detail.

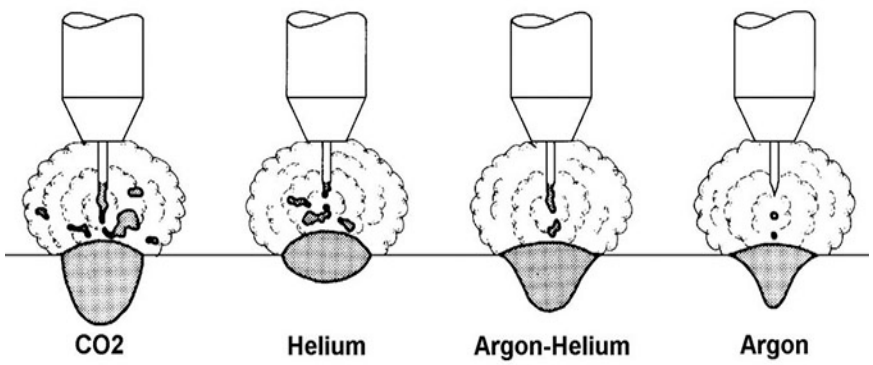


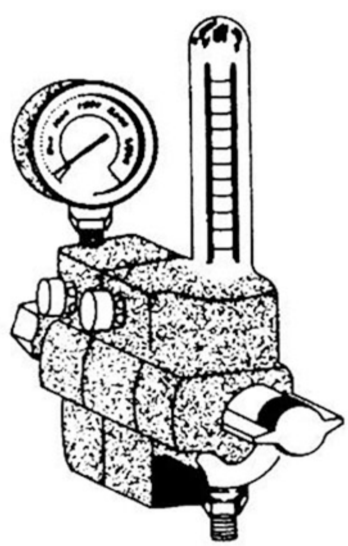
Figure 4–21. Effects of shielding gas.

Shielding Gases	
Gas	**Description**
Argon	Used primarily on aluminum alloys, magnesium alloys, nickel alloys, and reactive metals such as titanium alloys. On these materials, it provides a stable arc, good penetration, and a smooth bead. When used alone on steels, it does not provide good properties; instead, it tends to cause undercutting, poor or insufficient penetration, and bead contour. It ionizes much easier than helium. It also does not have as high an arc voltage requirement for a given arc length. It is heavier than air so you do not have to use as much to maintain coverage in the flat position.
Helium	You can achieve higher temperatures with helium, which is used to weld highly conductive metals. Alone, helium produces more spatter than argon, has a wider bead, and shallower penetration. It also requires higher gas flows because it is lighter than air. Generally, helium is used in a mixture with some of the others gases mentioned here.
Carbon Dioxide	The prime advantage of carbon dioxide is cost. It has higher heat conductivity than argon and requires higher voltage. However, because it is heavy, it does not require a high gas flow. When used alone on carbon and alloy steels, the arc is harsh with deeper penetration and increased spatter. Mixing it with argon smooths the arc and reduces spatter.

Shielding Gases	
Gas	**Description**
Argon-Carbon Dioxide	A 75% argon/25% carbon dioxide mixture is the most common and best-suited shielding gas for welding the mild, high-strength, and high-strength low-alloy steels in today's auto bodies.
Argon Oxygen	Oxygen alone is not used in GMAW. Mixing oxygen with argon produces high quality welds on low-alloy and stainless steels. The bead contour is better and undercutting is eliminated. Oxygen also smooths out the arc and reduces spatter.
Argon-Helium-Carbon Dioxide	This mixture is used to weld austenitic stainless steels. Using it, you can have a smaller HAZ, no undercutting, and minimal warping. Used on low-alloy steels, you can get excellent arc stability with little spatter.

Control of gasses

Since there are so many shielding gasses used in the GMAW process, you need to know how to control them as they make their way to the weld site. Two common methods are regulators and flow-meters, which are discussed in the following table.

Shielding Gas Control Methods	
Method	**Description**
Regulators	This regulator is similar to an ordinary two-stage oxygen regulator in both construction and purpose: reducing high cylinder pressure to the desired low, constant working pressure necessary for welding. If you use helium as a shielding gas, use a hydrogen regulator. If you only have an oxygen regulator, use an adapter to attach it to the helium cylinder. An adapter is also necessary for attaching the hose to the regulator gas outlet fitting.
Flow-meter	This is the most accurate means of measuring shielding gas flow. Position the flow-meter as close as you can to the regulator, yet between the regulator and the torch. The flow-meter indicates gas flow to the torch in liters per minute or cfh. You can determine gas flow in cfh from the flow-meter setting (a flow of 1 liter per minute is equivalent to a flow of 2.12 cfh). The cylindrical tube of the flow-meter must be vertical to allow the lightweight metal ball in the tube to operate freely. The ball rises as gas flow increases and descends as flow decreases, thus indicating the rate of flow. Combination regulator-flow-meters (fig. 4–22) are often provided. These combination units reduce the high cylinder pressure to the required lower working pressure; at the same time, they indicate the gas flow rate.  **Figure 4–22. Regulator flow-meter.**

If you set the *flow rate* too fast, the shielding gas exits the nozzle with too much velocity and causes turbulence around the arc, wire electrode, and molten metal pool. This condition will not provide an adequate gas shield, resulting in contamination. If you set the flow rate too low, the shielding gas will exit the nozzle with a low velocity rate; this will not provide an adequate gas shield around the arc, wire electrode, and molten metal pool. This will also result in contamination.

Electrodes

As mentioned previously, the GMAW process uses a continuous, solid-filler wire. These wire electrodes can vary in diameter from 0.020 inch to 0.125 inch. Smaller diameter wires generally cost more, but the melt rate is much faster and you can attain higher weld speeds with better control in out-of-position welding. This is what makes GMAW excellent for vehicle bodywork. Faster weld speed means less heat buildup; therefore, there is less warping of thin sheet steel.

You must match the wire to the base metal. When using CO_2 (a reactive shielding gas) you must also consider the fact the gas causes oxidation of the weld. For this reason, deoxidizers such as manganese, silicon, and aluminum are added to the wire.

In the following table, we show a correlation between wire size, voltage, and travel speed for welding carbon steel using CO_2 shielding and short circuit transfer. (We will discuss transfer methods shortly). Keep in mind that changing the base metal/wire and type of gas changes wire and travel speeds.

Material Thickness	Number of Passes	Wire Size	Voltage	Amps	Gas Flow (cfh)	Travel Speed (IPM)
0.023	1	0.030	15–17	30–50	15–20	15–20
0.030	1	0.030	15–17	40–60	15–20	18–22
0.035	1	0.035	15–17	65–85	15–20	35–40
0.060	1	0.035	17–19	90–110	20–25	30–35
0.120	1	0.035	19–22	120–140	20–25	20–25
0.190	1	0.045	19–23	180–200	20–25	18–22
0.250	1	0.045	20–23	180–200	20–25	12–18

Steel classification

The AWS has given a classification number for GMAW wire. Wire for steel is classified by tensile strength, wire type, and chemical composition. In the following chart, you can see how to determine which type of wire to use for carbon steels such as ER80S–4.

ER80S–4				
E	**R**	**80**	**S**	**4**
Welding electrode	May also be used as filler rod	Tensile strength (× 1000 psi)	Solid core wire	Chemical composition of wire

The following table provides some recommended electrodes for welding carbon steels with GMAW. You should become familiar with the various classifications of these electrodes. Doing so will aid you in determining the proper types to use on the various materials used to construct today's vehicle body components.

Electrode Classification	Comments
ER60S–1	Used on low and medium carbon steels, contains silicon deoxidizers. Use argon or Ar-CO_2 shielding.
ER60S–2	Higher quality wire for pipe and ship welding. Contains aluminum, zirconium, and

Electrode Classification	Comments
	titanium. Silicon and manganese deoxidizers. Use argon or Ar-CO_2 or Ar-O_2 shielding.
ER60S–3	High quality welds. Use argon, Ar-CO_2, or Ar-O_2 shielding.
ER70S–1B	Low-alloy wire for carbon, low-alloy, and high-strength steels.
ER70S–6	Good for welding on oxidized metal. High deoxidizer content (silicon and manganese). Silicon deoxidizers. Use CO_2, Ar-O_2, or CO_2-Ar-O_2.

Other metal classifications

On other materials, the wire is classified and coded according to the alloy's chemical composition. The following two charts provide samples of electrodes for stainless steels and aluminum alloys, such as ER308–Si and ER4043.

ER308–Si			
E	**R**	**308L**	**SI**
Electrode	Wire may be used as filler material	AISI stainless-steel designation	Contains extra silicon

ER4043		
E	**R**	**4043**
Electrode	Wire may be used as filler material	AA aluminum-alloy designation

634. Welding operations

As mentioned earlier, a distinct advantage to GMAW is that it is a very easy process to learn when everything is set up correctly. By some welder's standards, GMAW is considered "monkey welding"; in other words, they believe "you can teach a monkey to weld in 30 minutes." Even with this being the case, it is not always the welding of choice. Initial costs are one factor, and limited application is another. It also takes time to understand and recognize when the machine is set up incorrectly and when the welding technique is incorrect. However, as the use of specialized steels (mentioned previously) in auto body construction increases, so does the need to use the GMAW welding process to complete repairs. With this in mind, let us look at some of the operation's variables (adjustments made to the equipment or variations between operators), which include preselected and adjustable variables.

Preselected variables

These variables are considered preselected because they must be determined ahead of time, dependent on the material being welded. These include the welding position, weld deposition rate (how much wire is converted into solid metal), and mechanical properties. Mechanical properties include the following:

- Electrode wire type.
- Electrode wire size.
- Shielding gas type.
- Shielding gas flow rate.

In the discussion of equipment within the previous lesson, we looked at these variables. We will not go into any more detail here except to say that once they are set, you cannot change them with welding technique.

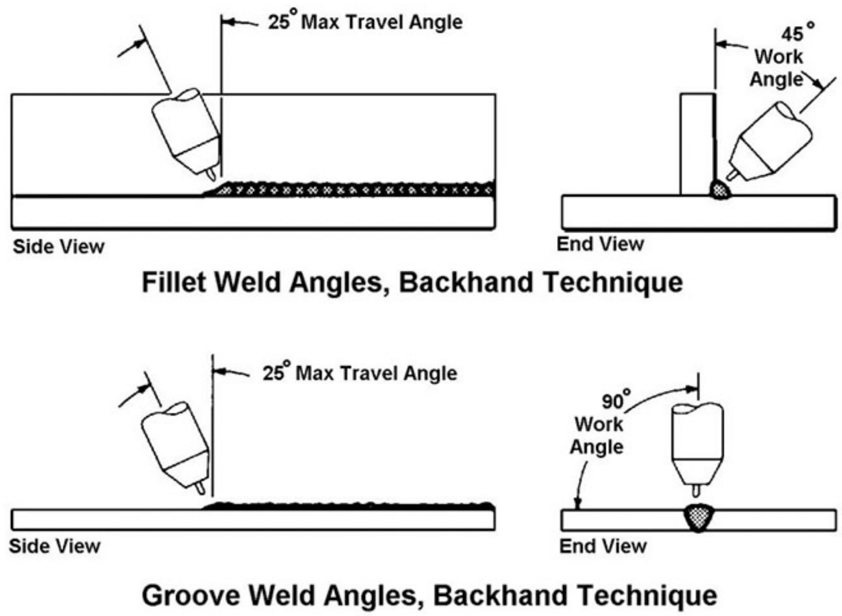
Adjustable variables

Once the preselected variables are set according to the type and thickness of metal, weld position, and so forth, there are some *primary variables* that you can adjust. These affect the penetration, bead width, bead height, arc stability, deposition rate, and weld soundness:

- Arc voltage.
- Current.
- Travel speed.

There are also some *secondary variables*; these can cause desired changes in bead formation *during welding*. These secondary variables also cause minor changes to the primary variables and include stickout, nozzle angle, and wire speed.

Secondary Variables	
Variable	**Description**
Stickout	Electrode extension, or stickout, refers to how much wire is outside the nozzle. • If the stickout is short (about $^{1}/_{4}$ inch), amperage increases and the bead produced is narrow with deep penetration. • If the stickout is long (up to $^{3}/_{4}$ inch), resistance increases, resulting in a decrease in amperage and the bead widens with shallower penetration. • Stickouts between $^{1}/_{4}$ inch and $^{3}/_{4}$ inch are considered normal or satisfactory. If the stickout is *less than* $^{1}/_{4}$ inch, a number of problems can result. There will be an increase in amperage. This will result in excessive spattering and the welding process is harder to see because the nozzle gets too close to the weld. This excessive spatter, called burn back, can clog the gun, causing restrictions in the gas passages. If the nozzle touches the molten pool, contamination can result as the nozzle begins to overheat and melt. Overheating can also cause the wire to melt and weld itself to parts of the gun. • Stickouts greater than $^{3}/_{4}$ inch are also harmful because the weld will not receive adequate shielding. Without adequate shielding, the weld will have porosity. The arc will be difficult to start as well and the molten pool difficult to control.
Nozzle Angle	Two essential nozzle angles to consider while welding include work angle and travel angle. Figure 4–23 illustrates the different welding angles. • Work angle is the angle relative to the surface of the work piece and is generally half the distance between the surfaces you are welding. • Travel angle is the angle of the nozzle in relation to the direction of travel. In the section on SMAW welding, you learned that angles have a great effect on weld quality. They also have an effect on the weld in GMAW. Figure 4–23 shows backhand, or pulling, welding that results in a narrower bead with deeper penetration. Forehand, or pushing (not shown in figure 4–23), allows the bead to widen, resulting in shallower penetration.

Secondary Variables	
Variable	**Description**
	 **Figure 4–23. Weld characteristics with backhand welding.**
Wire Speed	By adjusting the wire speed and voltage for a given shielding gas and wire size, you can obtain different metal transfer methods. The *short-circuit* transfer method requires the voltage to be rather low. In this method, the positively charged wire actually touches the negatively charged base metal, resulting in a short circuit. This causes the arc to extinguish and the current to increase. As the wire melts, the arc reestablishes and the process begins again. When you are welding, this cycle occurs as many as 230 times per second. When set up properly, the sound made is very similar to bacon frying. Some operators actually pay more attention to the welding sound using this method than molten pool because the sound indicates the quality. In *spray arc* transfer, the wire atomizes before touching the pool. The molten metal transfers across in a spray directed by the arc. This is very high current welding and is used on thick material. Compared to other processes, spray arc is very fast as the deposition rate is very high. Spray arc will *not occur* if straight CO_2 is used for shielding. Generally, argon or a mixture of Ar--CO_2 or Ar--O_2 is used. Spray arc can also be used for out-of-position welding, such as overhead, since the force at which the molten metal is transferred across the arc is greater than the force of gravity.

Basic welding procedures

When you weld with a standard SMAW welder, to obtain a quality weld *you* must control the arc length, the welding speed, and the angles.

With GMAW, arc length is controlled by the machine. You do have to watch the stickout though. Welding speed is determined by the appearance of the weld. This means you must ensure that the weld is neither too high nor under filled. Gun angles are very important too; they affect the bead width, penetration, and location of the weld on the joint (fig. 4–24).

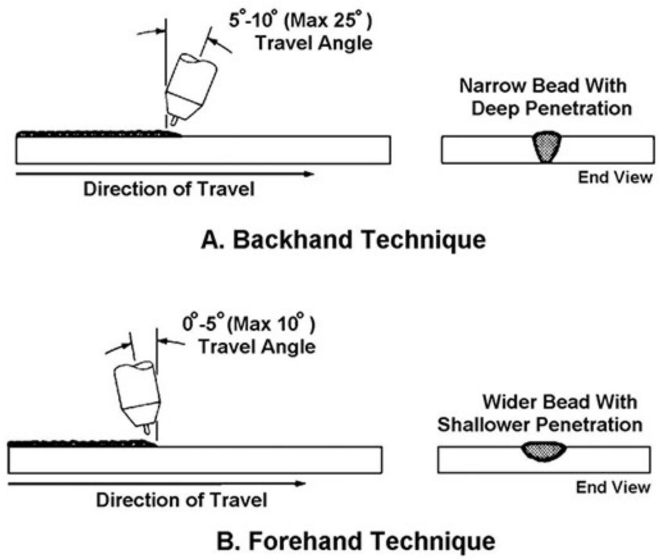


Figure 4–24. Gun angles.

Wire speed, size, and stickout are all variables that control the quality of the penetration. Coupled with faster wire speeds and smaller stickouts, smaller wire size results in deeper penetration. Once you learn how to adjust the machine, you will be quite surprised at just how easily you can produce quality welds. Over time, it will become just “point and shoot.”

Basic Welding Procedures	
Procedure	**Description**
Starting the Arc	Most GMAW welders have a separate switch or button to feed the filler rod out of the gun nozzle without bringing the filler rod in contact with the metal surface. To begin, perform the following: • Activate the wire feed mechanism inch button and feed out the wire electrode until it emerges approximately $^1/_2$ inch past the tip of the gun nozzle. • Activate the trigger on the gun assembly. This sends current to the wire electrode and opens a solenoid valve, allowing shielding gas to flow. • Make sure your welding helmet is in place, covering your face and eyes before you touch the wire electrode to the metal plate. • Lower the gun nozzle until the wire electrode touches the metal plate approximately 1” ahead of where you want to start welding. • Once the arc starts, move the gun nozzle back quickly to the point where you want to start welding, maintaining an even stickout during this process. • Once you touch the wire electrode to the metal plate, you complete the circuit of the welder. When this happens, the wire feed motor automatically starts and begins feeding wire out of the torch head nozzle to continue the welding process.
Stopping the Arc	When you want to stop the arc, ensure the following: • Do not raise the gun nozzle from the metal plate. • Release the trigger on the gun nozzle. This opens the circuit of the welder and stops the flow of shielding gas and halts the wire feed mechanism. If you raise the gun nozzle before releasing the gun trigger, the arc continues until the gap between the metal plate and the wire electrode is large enough to halt the current flow. This puts an overload on the wire feed motor.

Weld defects

In spite of the ease of GMAW, defects can happen if things get out of adjustment. The following table is a list of defects and some of the ways to solve them. In addition, figure 4–25 presents the information more visibly in the form of a troubleshooting guide.

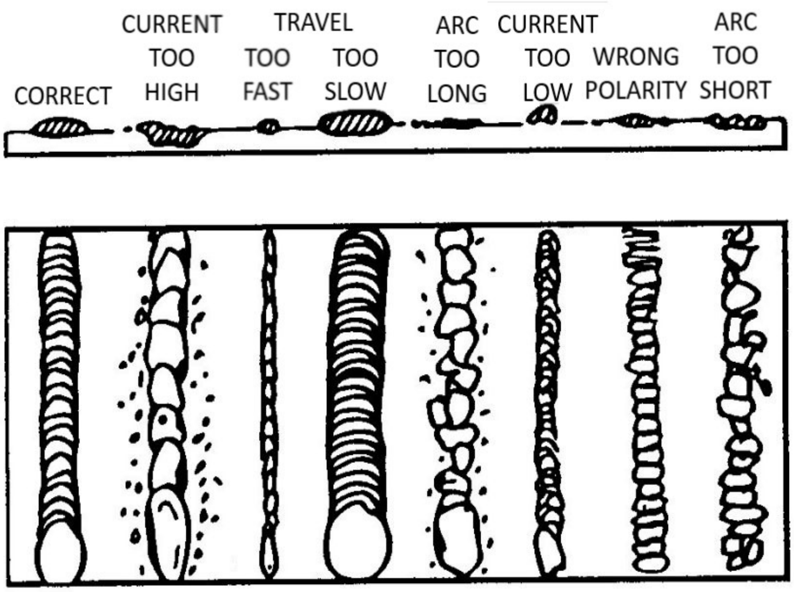


Figure 4–25. Weld bead appearance.

MIG Discontinuities		
Discontinuity	**Possible Cause**	**Probable Solution**
Whiskers	Excessive wire pushes past molten pool, exiting the back side of the molten pool, remaining unmelted.	Cut off ball on wire. Slow travel speed. Use a whipping motion.
Incomplete Fusion	Improper technique	Concentrate electrode on leading edge of molten pool.
	HAZ dirty.	Clean HAZ.
	Large weld pool.	Decrease weaving.
	Low heat input.	Increase wire speed and voltage.
Lack of Penetration	Improper technique.	Ensure proper travel angle. Change to backhand technique.
	Low heat.	Increase wire speed and voltage.
	Improper joint design.	Ensure access to bottom of groove welds. Maintain correct stickout. Reduce groove-face height.
Large, Wide Bead	Travel speed too slow.	Raise travel speed.
Excessive Penetration Burn-through	Electrode too small.	Increase electrode and gas cup size.
Porosity	Inadequate shielding gas flow.	Increase shielding gas flow. Decrease gas flow—too much turbulence.

MIG Discontinuities		
Discontinuity	**Possible Cause**	**Probable Solution**
		Eliminate drafts. Reduce stickout. Slow travel speed.
	Excessive weld current.	Lower arc voltage.
	Rust, grease oil, dirt, or moisture on metal surface.	Ensure cleanliness of base metal and filler.
	Impurities in base metal such as sulfur and phosphorous.	Change to different base metal.
	Contaminated or wet shielding gas.	Replace gas.
	Contaminated wire.	Check for lubricants from wire feeder. Clean wire.
Cracking	Excessive penetration.	Increase arc voltage or decrease wire feed speed to widen bead.
	Weld bead too small.	Decrease travel speed.

635. Welding automotive high-strength steels

In recent years, there has been an increase in the use of high-strength, low-alloy (HSLA) steels. Manufacturers that have HSLA information available recommend certain precautions and procedures be used when working with high-strength steel. These recommendations are discussed in the following paragraphs.

Preferred method

GMAW is the preferred method for welding HSLA components. Due to HSLA steel's structural properties, it should not be heated over 1,400 ° F. However, on some vehicles this range can be 700 ° F, 900 ° F, and 1,200 ° F. If heated above recommended temperatures, the steel loses its structural strength.

Welding HSLA components should be performed as close to factory seams as possible, and all spot-welding should approximate the factory weld as closely as possible. When cutting HSLA components from damaged vehicles, use a plasma cutter, grinding wheel disc, air chisel, and/or a metal cutting saw whenever possible. If absolutely necessary, you can use an oxyacetylene torch to cut HSLA components, provided the torch cut is *at least 2 inches away* from the final desired cut line. This is due to sheet metal within the HAZ losing strength when subjected to the high-heat levels of the oxyacetylene torch. Try to limit the torch time on HSLA to *less than* three minutes.

NOTE: DO NOT let the torch temperature at the HSLA part exceed the manufacturer's recommended heat range. If it does, the part will have to be replaced because of weakness.

After torch cutting, use a grinding wheel, air chisel, or metal saw to make the "final" cut at the desired cut line. This final cut should be located beyond the HAZ created while using the torch.

Electronic components

Many vehicles have multiple computers, including the ECM, body control modules (BCM), individual computers for antilock brake systems (ABS), and electronic suspension systems. You must protect or remove these computers before exposing the vehicle to high heat. Never connect or disconnect these units with the ignition switch on, or while charging the battery.
Before servicing or performing any maintenance, first ground yourself; afterwards, ground the work area to discharge stored static electricity. You can ground yourself by touching the vehicle body.

Removing original spot-welds

Many of the vehicle bodies you will work on are unitized with many of their components spot-welded together. As mentioned previously, welding of HSLA components should be performed as close to factory seams as feasible and should duplicate original factory welds as much as possible. This often entails removing the original welds, which may be accomplished by drilling them out. A regular handheld drill with an appropriately sized bit will do the job. When you drill the weld, drill through both welded panels. Spot-welds can also be cut out using a plasma cutter. This method can be quicker than drilling, but it does not produce neat holes and may require the use of an air hammer with a chisel tip to separate the panels.

Plug welding

Closely duplicating original factory welds may be accomplished in one of two ways: plug welding and continuous welding. Plug welding is most commonly used with the previous welds made in prepunched or predrilled holes in the outside piece.

For example, you have just removed a damaged body panel by drilling out all its securing spot-welds. What is left is a body panel with holes along its joining edges (because you drilled through both welded panels). The replacement panel has no holes. You can produce a good plug weld by using the new panel as an inside panel and securely fitting it in place. Depending on the specific job, you may not be able to do the repair in this manner.

With the new panel secured in place, you can bring the GMAW welding tip to bear. Bring it to a 30º to 90º angle to the exposed hole and touch the wire electrode to the inner or back panel (fig. 4–26). As the arc establishes, continue welding in a circular motion around the hole until it is filled. As you weld, the hole is filled with molten metal, which fuses the two metal pieces together. To avoid generating too much heat, it is a good idea to “plug weld” only every other weld location. Wait for your work to cool for a time and then return to finish welding the remaining plug locations.

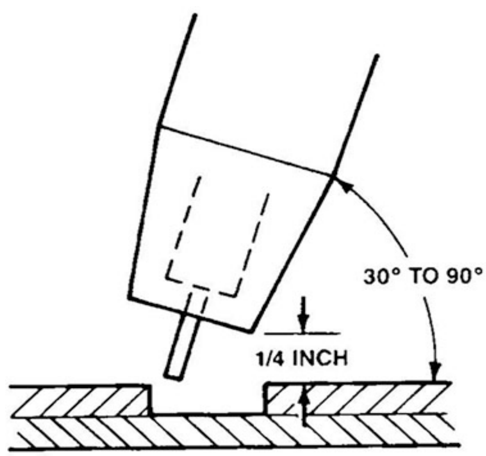


Figure 4–26. Plug weld technique.

Continuous welding

Continuous welding is another way you can sometimes approximate the original manufacturer’s weld. It is in-line welding of a butt joint (previously discussed in this unit). To make a butt joint with GMAW, use the following procedure:

1. Hold the tip of the welder at the most effective travel angle of 30º to 45º at the appropriate work angle.
2. Weld in small stitches of no more than $^3/_4$ inch. Picture welding for $^3/_4$ inch, skipping approximately two stitch lines in repeating fashion until you reach the end of the weld. Minimizing the stitch length will help prevent metal distortion.

3. Allow time for the weld area to cool naturally.
4. Rotate your welds (skip stitches) until a continuous bead is formed. Go back over the weld area, welding new $^{3}/_{4}$ inch stitches inside the areas you skipped. Connect the stitches to one end of the beads you placed during the last path. Again, allow time for the weld to cool naturally. Return to the remaining gaps in the weld and stitch them in.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

633. Gas metal arc welding equipment

1. What are the advantages of the GMAW welding process?

2. List the basic requirements of a typical GMAW unit.

3. What polarity is used for GMAW?

4. What type of power source is required for GMAW machines, and how is it different from SMAW machines?

5. When employing GMAW, what effect does argon have on steels when used alone as a shielding gas?

6. When employing GMAW, what effect does CO_2 have on steels when used alone as a shielding gas?

7. What is the advantage of using smaller diameter wire electrodes?

8. How does AWS classify GMAW wire for steel?

9. How does AWS classify GMAW wire for most other materials?

634. Welding operations

1. Why do we consider some variables for welding with GMAW to be *preselected*?

2. Once the preselected variables are set, what are some *adjustable variables* you can manipulate? Why would you do this?

3. What is *stickout*, and how much is considered normal or satisfactory?

4. What is the difference between the short-circuit and the spray-arc transfer methods? Which method achieves the fastest travel speed?

5. How is arc length controlled with GMAW?

6. What are *whiskers* and how do you prevent them?

7. Generally, a lack of penetration results from too low of a heat input (which may be caused by low wire speed or too low of a voltage). What are some other reasons?

8. You have made a weld that has porosity located in it. You do not have problems with either the shielding gas or the base metal. What could cause your problem?

9. What are some possible solutions for cracking welds?

635. Welding automotive high-strength steels

1. What's the preferred method of welding HSLA components?

2. What happens to HSLA materials if they are heated beyond the manufacturer's recommendations?

3. List the cutting tools that are *best* used on HSLA materials; further, identify the *one* that may be used, if necessary, to cut this material.

4. How far from the final cut line should the oxyacetylene torch be kept when cutting HSLA materials?

5. What is the maximum time the oxyacetylene torch should be used when cutting HSLA materials?

6. When cutting metal with a torch, what should you do if the manufacturer's recommended heat range has been exceeded? Why?

7. After cutting HSLA material with an oxyacetylene torch is complete, where must you make the "final" cut? What tools should be used to complete this final task?

8. When planning to make a weld on a vehicle equipped with an ECM or BCM, what precautions should be taken beforehand?

9. Why would you remove the original welds when making HSLA component repairs? What tool(s) are used to remove spot-welds?

10. What are the two methods used to duplicate original factory welds?

11. How can you avoid generating too much heat when plug welding?

12. What travel angle is best used for continuous welding?

13. Why do you limit the weld length to no more than $^{3}/_{4}$ inch?

4–3. Gas Tungsten Arc Welding

GTAW welding has become a popular choice among welding processes when high-quality, precision welding is required. It is generally used to repair different kinds of aluminum and stainless steel alloys. It is one of the hardest welding processes to master due to the dexterity required. Although you may not see many shops with GTAW capability, you still need to be aware of the basics of this welding process. Again, as mentioned numerous times in this unit, the advancement of metal technology and its incorporation into auto body construction is necessitating the need for advancements in welding applications.

As a result, the need for GTAW welding application is growing every day. During your career in the Air Force, you may see a day when the GTAW process is the primary welding technique used in auto body repair. Until that time, we will cover only basic knowledge for GTAW in the following lesson. The actual welding techniques will have to be learned hands on.

636. Gas tungsten arc welding equipment

Though still a form of arc welding, gas tungsten arc welding has some qualities that set it apart from SMAW and GMAW. The biggest difference is that GTAW does not use a consumable electrode like SMAW and GMAW. Instead, the arc is transferred through a nonconsumable electrode, and a filler rod is used in much the same way as with oxyacetylene welding. As mentioned in the previous paragraph, GTAW is probably the most difficult welding method to master. This is due to the dexterity needed to create quality welds. There are more variables left to the skill of the welder; proper technique is essential in order for the GTAW welds to be successful.

The basics of how GTAW works are as follows. In GTAW, an arc is formed between a nonconsumable tungsten electrode and the metal being welded. Gas is fed through the torch to shield the electrode and molten weld pool. The heat of the arc causes the edges of the work to melt and flow together. Filler rod is often required to fill the joint and is fed into the pool as needed. During the welding operation, the weld area is shielded from the atmosphere by a blanket of inert shielding gas. A steady stream of gas passes through the torch. It pushes the air away from the welding area and prevents oxidation of the electrode, weld puddle, and HAZ. The basic equipment requirements for manual GTAW welding are shown in figure 4–27. This consists of a power supply, welding torch, shielding gas, and a water inlet and outlet.

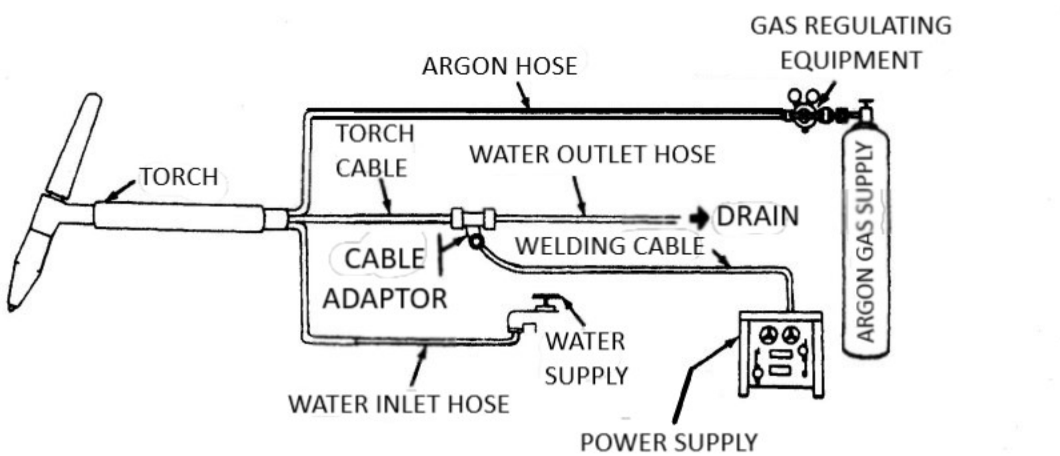


Figure 4–27. GTAW equipment setup.

Power source

With GTAW welding, an AC power source is generally used. Aluminum forms an oxide layer on the surface that can contaminate the weld. An AC power source switches the polarity of the arc between positive and negative. When the polarity of the arc is positive, current flows from the work surface towards the electrode, producing a cleaning effect that blasts the oxide away from the surface. When the arc switches back to negative, energy flows from the electrode to the work surface, producing heat that melts the metal. By increasing or decreasing the duration of the positive or negative phase of the AC cycle, the cleaning and welding characteristics of the arc can be modified. Some GTAW welders have a “squarewave” control feature that allows the electrode negative (EN) portion of the AC cycle to be increased up to 90 percent.

Welding torch

The GTAW welding torch is designed to accommodate the nonconsumable tungsten electrode, electrode cable, shielding gas, and water for cooling. Figure 4–28 shows the breakdown of the GTAW torch. As you go through the components in the following list, locate them in figure 4–28; afterwards, familiarize yourself with how they are incorporated into the torch.

- Cap–Made of plastic; shields the tungsten electrode and prevents the escape of gas from the top of the torch. It also locks the electrode in place.
- Collet–Made of copper; the tungsten electrode fits inside and when the cap is tightened, it squeezes against the electrode and locks it in place.
- Gas orifice nut–Allows the gas to escape out of the torch.
- Gas nozzle–Directs the flow of shielding gas onto the weld puddle. Two types of nozzles are used; the one for light duty welding is made of a ceramic material, while the one for heavy-duty welding is a water-cooled copper nozzle.
- Torch handle–Made of plastic to reduce the chance of grounding the torch.
- Hoses–Three plastic hoses, connected inside the torch handle, carry water, gas, and the electrode power cable. The power cable is located inside the water drain line; this allows the cable to stay cool while carrying high amperage.

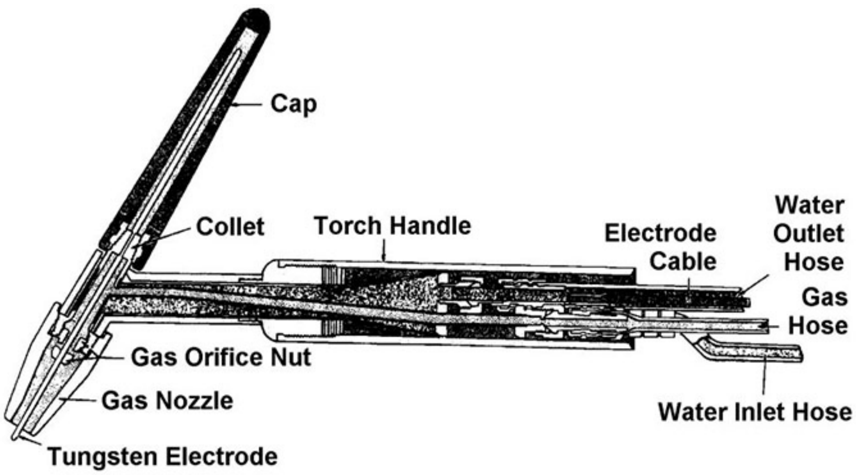


Figure 4–28. GTAW welding torch.

Shielding gas

The shielding gas of choice for GTAW welding is argon, which is supplied in steel cylinders containing approximately 330 cubic feet at a pressure of 2,000 psi. Single- or two-stage regulators may be used to control the gas flow. A specially designed regulator containing a flow-meter, as shown in figure 4–29, may be used. The advantage of the flow-meter is that it provides better gas flow control. The flow-meter is calibrated in cfh. The correct flow of argon to the torch is set by turning the adjusting screw on the regulator. The flow rate depends on the kind and thickness of the metal to be welded.

Blanketing of the weld area is provided by a steady flow of argon gas directed through the welding torch. Since argon is slightly more than $1^{1}/_{3}$ times as heavy as air, it pushes the lighter air molecules aside, thereby effectively preventing oxidation of the welding electrode, the molten weld puddle, and the heat-affected zone adjacent to the weld bead. Although argon is the gas of choice, it can be mixed with other gases to produce higher quality welds. Helium is generally added to increase heat input (increase welding speed or weld penetration). Hydrogen will result in cleaner looking welds and increase heat input; however, hydrogen may promote porosity or hydrogen cracking.

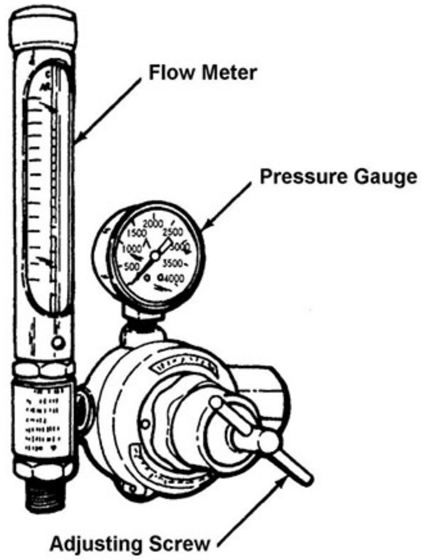


Figure 4–29. Argon regulator with flow-meter.

Water inlet and outlet

The tremendous heat of the arc and the high current often used usually necessitate water cooling of the torch and power cable (fig. 4–27). The cooling water must be clean; otherwise, restricted or blocked passages caused by particles in the water source may cause excessive overheating and damage to the equipment. As a result, it is advisable to use a suitable water strainer or filter at the water supply source. If a self-contained unit is used, such as a mobile field unit where the cooling water is recirculated through a pump, antifreeze is required if it is to be used outdoors during the winter months or freezing weather. Some GTAW welding torches require less than 55 psi water pressure and will require a water regulator of some type. Check the operating manual for this information.

GTAW welding benefits and limitations

As with any welding process, there are benefits and limitations. GTAW welding is no exception. However, as you view the following table, you will see that the GTAW process produces the best quality welds of the three methods covered in this unit.

Benefits	Limitations
Superior quality welds. Welds can be made with or without filler metal. Precise control of welding variables (heat). Free of spatter. Low distortion.	Requires greater welder dexterity than GMAW or SMAW. Lower deposition rates. More costly for welding thick sections.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

636. Gas tungsten arc welding equipment

1. Why is GTAW welding the hardest welding technique to master?

2. What are the basic equipment requirements for manual GTAW welding?

3. What type of power source is generally used for GTAW welding?

4. What happens when you increase or decrease the duration of the positive or negative phase of an AC cycle during the GTAW welding process?

5. What GTAW welding torch component is made of copper and locks the tungsten electrode in place?

6. What is the advantage of using a gas regulator equipped with a flow-meter?

7. Why would you use a strainer to filter the cooling water for the torch?

Answers to Self-Test Questions

630

1. (a) A circuit is a complete conducting path to allow electric current to flow.
   (b) Voltage is an electromotive force created by a difference in potential of electricity. This electricity is in-turn pushed by voltage through a circuit.
   (c) The amperage is the amount of electrons flowing past a given point each second.
   (d) The ohm is the unit of measurement for resistance. The amount of current flowing in a circuit is determined by the amount of resistance in Ohms within the circuit.
2. With a long arc, much heat is lost by radiation to the atmosphere.
3. Reverse polarity.
4. Twice.
5. Reverse the position of the welding cable leads on the welder.
6. A governor.
7. (1) Low initial cost.
   (2) Low operating cost.
   (3) Low maintenance cost.
8. The amperage capacity of the welding machine.
9. One-eighth diameter or smaller electrode.
10. Prevents oxygen or any impurities from coming in contact with the molten metal.
11. The AWS.
12. It is normally printed on the electrode coating below the grip end.
13. Minimum tensile strength in thousands of psi.
14. The electrode may be used in all positions.

15. Electrode E 12030 means the electrode has a tensile strength of 120,000 psi. Further, it can be used in the flat position only, and it should be used with alternating current.
16. The fourth digit.
17. Fifth digit.

631

1. Type of base metal, welding machine, and electrode; safety; and current setting.
2. Never try to weld with an electrode diameter larger than the thickness of the base metal.
3. Between 150 and 260.
4. Penetration and proper electrode selection.
5. You will lay the bead on top of the base metal with no penetration; the electrode will keep sticking to the base metal.
6. (1) Flat.
   (2) Horizontal.
   (3) Vertical.
   (4) Overhead.
7. Welding helmet.
8. Screen, booth, or curtains.
9. Arc, the tip of the electrode, the molten metal pool, the path of the electrode, and base metal.
10. Leather jacket and sleeves.
11. Cable insulation and cable leads.
12. Pliers or some other griping device.
13. Disconnect the battery and cover the surrounding components with a noncombustible barrier to prevent them from igniting or melting.

632

1. Where flush surfaces are not needed.
2. Single fillet lap joint.
3. Scratch the tip of the electrode across the metal surface as if scratching a wooden match across the sandpaper side of a matchbox.
4. Tilt the electrode so penetration occurs more in the thicker plate of metal. Enough heat from the arc will melt the thinner plate to form an even amount of molten metal between the two plates.
5. Tee joint.
6. Forty-five degree angle to both plates.
7. Tilt the perpendicular plate slightly over the 90° angle and begin welding the root weld. As the cooling down period expires, the vertical plate will pull back to the 90° angle to the base plate.
8. Welding two flat metal plates of the same thickness together edge to edge.
9. Up to $^{1}/_{8}$-inch thick.
10. Approximately one-half as much.
11. Between a 30° to 35° angle.
12. Single "U" groove butt joint.
13. Double "U" groove butt joint.
14. Single "J" groove butt joint.
15. One-eighth inch.
16. One-hundred percent.
17. "Tack" both ends of the butt joint before you start welding the two metal plates together.
18. The distance from the bottom edge of the bevel to the bottom side of the metal plate and the distance between the two metal plates.
19. Multi-pass welding.

20. It allows for absolute bonding of all metal surfaces.

633

1. Faster welding speeds, may be used when welding in all positions, high visibility to the operator, no slag, and high quality welds with a smaller HAZ.
2. A source of DCRP, a wire feed unit for the wire filler metal, a control unit for automatic feed of the wire filler metal and shielding gas, a welding gun to direct the wire filler metal, and shielding gas supplied to the weld area.
3. DCRP.
4. DC rectifier or a motor or engine-driven generator, each with constant-voltage; a constant-voltage power source adjusts the amperage output to maintain the same voltage.
5. Causes undercutting, poor penetration, and bead contour.
6. It produces deeper penetration but has a harsher arc with increased spatter.
7. The melt rate is much faster and you can attain higher weld speeds with better control in out-of-position welding.
8. By tensile strength, wire type, and chemical composition.
9. According to the alloy's chemical composition.

634

1. They must be determined ahead of time and are dependent on the material being welded.
2. Arc voltage, current, travel speed, stickout, nozzle angle, and wire speed. To adjust penetration, bead height, arc stability, deposition rate, and weld soundness.
3. It refers to how much wire is outside the nozzle. Stickouts between $^{1}/_{4}$ inch and $^{3}/_{4}$ inch.
4. With the short-circuit transfer method, the electrode wire actually touches the base metal before melting. The spray arc transfer method results from the wire transferring across the arc in a melted state. The spray arc method is faster.
5. By the machine.
6. When excessive wire pushes past and exits the backside of molten pool, leaving it unmelted; cut off the ball on wire, slow the travel speed, and use a whipping motion.
7. Improper technique (such as poor travel angle, or use of forehand instead of backhand), improper joint design (preventing access to bottom of groove welds, incorrect stickout, or excessive groove-face height).
8. Weld voltage too high (resulting from excessive current) or wire contamination.
9. Increase arc voltage or decrease wire feed speed to widen the bead, and decrease travel speed.

635

1. GMAW.
2. They lose their structural strength.
3. Plasma cutter, grinding wheel disc, air chisel and/or a metal cutting saw. You may use an oxyacetylene torch if absolutely necessary.
4. At least 2 inches.
5. Less than three minutes.
6. The part will have to be replaced due to weakness of the material.
7. The desired cut line (beyond the HAZ created while using the torch). Grinding wheel, air chisel, or metal saw.
8. The ECM or BCM should be protected or removed before exposing the vehicle to high heat. Never connect or disconnect these units with the ignition switch on or while charging a battery with the battery cables connected. Before any welding, ground yourself and ground the work area to discharge stored static electricity.
9. Original welds may have to be removed to allow duplicating the factory welds. The welds may be removed using a regular hand drill with the appropriate drill bit. Spot-welds may also be removed with a plasma cutter. An air hammer with a chisel tip may be used to separate the panels.

10. Plug welding and continuous welding.
11. Plug weld only every other location. Wait for the work to cool for a time and then return to finish the job.
12. Between 30º to 45º travel angle.
13. It helps to prevent metal distortion by minimizing the stitch length.

636

1. This is due to the dexterity necessary to create quality welds.
2. Power supply, welding torch, shielding gas, and a water inlet and outlet.
3. An AC power source.
4. The cleaning and welding characteristics of the arc can be modified.
5. The collet.
6. Provides better gas flow control.
7. To prevent hose restrictions and blockages caused by particles in the water source.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to AFCDA.

62. (630) What electromotive force “pushes” electricity through an electrical circuit as you arc weld?
    a. Amperage.
    b. Voltage.
    c. Current.
    d. Ohm.

63. (630) If you are shielded metal arc welding (SMAW) cast-iron with a heavily coated ferrous electrode, how would you connect the leads for polarity?
    a. Linear.
    b. Straight.
    c. Reverse.
    d. Diagonal.

64. (631) If you are welding from a flat position, then the welding is performed
    a. on the upperside of the joint and the face of the weld is approximately horizontal.
    b. on the upperside of an approximately horizontal surface and a vertical surface.
    c. in the horizontal position with a pipe rotated on its axis.
    d. from the underside of the joint.

65. (631) If you have to arc weld where moisture is present, what precaution should you take before inserting a new electrode in the electrode holder?
    a. Tap the electrode three times on a wood surface.
    b. Tap the electrode three times on a metal surface.
    c. Shut the welder off.
    d. Unplug the welder.

66. (632) What *maximum* metal thickness can you successfully arc weld with no special edge preparation when welding both sides of the butt joint?
    a. $^{3}/_{4}$ inch.
    b. $^{1}/_{2}$ inch.
    c. $^{1}/_{8}$ inch.
    d. $^{1}/_{32}$ inch.

67. (633) What characteristic is most noticeable when gas metal arc welding (GMAW) *steel* parts using 100 percent argon shielding gas?
    a. Excessive heat-affected zone (HAZ) size.
    b. Lower voltage requirement.
    c. Higher heat conductivity.
    d. Insufficient penetration.

68. (633) If you set the shielding gas flow rate too fast for gas-shield welding,
    a. bead slag will result.
    b. arc glare will be reduced.
    c. the gas will ignite and burn.
    d. gas turbulence is produced, resulting in contamination.

69. (634) Excessive stickout (greater than ¾”) may result in the gas metal arc welding (GMAW) discontinuity called
    a. porosity.
    b. cracking.
    c. whiskers.
    d. lack of penetration.

70. (635) When cutting high-strength, low-alloy (HSLA) components from a damaged vehicle, which tool may be used when it becomes absolutely necessary?
    a. Air chisel.
    b. Metal cutting saw.
    c. Grinding wheel disc.
    d. Oxyacetylene torch.

71. (635) When using the oxyacetylene torch to cut high-strength, low-alloy (HSLA) materials, how far from the final desired cut line should you stay to prevent weakness in the metal?
    a. $^{1}/_{2}$ inch.
    b. $^{3}/_{4}$ inch.
    c. 1 inch.
    d. 2 inches.

72. (635) At what angle should the tip of the gas metal arc welder be held during continuous welding?
    a. 5º to 15º.
    b. 10º to 20º.
    c. 15º to 25º.
    d. 30º to 45º.

73. (636) Why is gas tungsten arc welding (GTAW) the hardest welding technique to master?
    a. Requires greater dexterity to create quality welds.
    b. Components are difficulty to handle.
    c. The process is very technical.
    d. Limited use applications.

Please read the unit menu for unit 5 and continue ➔

Student Notes

Unit 5. Auto Body Refinishing, Corrosion Control, and Damage Estimating

NOW THAT YOU HAVE COMPLETED all the needed body repairs on a vehicle, using some or all of the procedures mentioned in this volume, you are ready to paint. Painting is one of the most important tasks you will encounter in auto body repair. This is where all your work will either "shine", or "not shine." Of course, unsatisfactory finishes will require you to start all over again. Whatever the final outcome, it is a reflection of your workmanship. Keep in mind that an effort to do it right the first time will definitely pay off when it comes time to apply the paint.

To an observer, the job performance of skilled painters can be fascinating. They seem to know exactly what to do, what tools and equipment to use, and how to employ them. Therefore, they waste no time in completing a job satisfactorily. In this unit, we will provide you the knowledge you need for successful painting and marking. In addition, we will present some valuable information on corrosion control procedures. We will also show you how the information in this volume can be used in the first step of auto repair: Estimating collision damage.

5–1. Refinishing Materials and Equipment

As a vehicle management Airman, you need to learn the fundamentals of painting. Your proficiency is determined by your knowledge of the composition of paints, their types, and the methods used to apply them. In addition, as with all manual skills, proficiency in painting can only be achieved with practice. In this section, we will discuss the composition of paints, the types you will use most on auto bodies, and some paint job defects and their causes.

637. Paints and related materials

The more you know about the painter's "tricks of the trade," the more proficient your work will be. One of these tricks of the trade is knowing as much as possible about the paint itself. The basis of understanding each paint is to look at its composition.

Paint composition

The word "paint" is a broad term covering almost any material you use to apply color to a surface. Artists' colors and the simple watercolors you remember from primary school are both paints. In vehicle body refinishing, you will be working with synthetic or acrylic enamels. For our purposes, these are the types of paint. We will discuss each in later paragraphs.

Paint has two parts—the vehicle (liquid) and the pigment (coloring material). In addition, these parts have certain properties. The paint vehicle has two important properties, essentially liquid binder and liquid reducer.

Binders

Binders are a resinous, film-forming ingredient that bond the pigment to the surface you paint. They determine the physical and chemical characteristics of paint, but do not contribute significantly to the color.

Solvents

Solvents are used to thin the pigment-carrying binder to the consistency necessary for easy application (lowers viscosity). The solvent must be highly volatile so it can evaporate quickly, leaving the paint film entirely dry.

Pigments

The pigments in paint provide the desirable color and hide the surface you paint. They are grouped according to how they are made: natural, organic, or synthetic.

Paint materials

To be proficient in automotive body refinishing, you should know about the materials most commonly used in Air Force paint shops. This information may be found in the applicable technical orders that list the paint materials authorized and the supply information you need to acquire them.

Store paint materials where they are protected from the weather and extreme temperature changes. Further, the age of the paint is important; always store paint so you use the oldest first. Directions for storage of paint materials are normally mandated by Department of Defense (DOD) and Air Force directives as well as local and state legislative directives under Environmental Protection Agency (EPA) guidelines.

Paints

The Air Force uses synthetic enamel, acrylic enamel, acrylic urethane enamel, and polyurethane for refinishing vehicles and equipment. When refinishing an automotive body, you will mostly use acrylic urethane enamel (better known as “basecoat clearcoat” or acrylic enamel). Acrylic urethane enamels give a harder finish that is more durable; with the addition of a hardener or catalyst, they require less drying time than most other paints. Acrylic enamels are more likely to be used on larger vehicles due to lower material cost. Whichever paint you use, always follow the manufacturer’s directions.

Reducers

As you prepare paint for use in spray equipment, a reducer is required to give the paint a spraying consistency. In other words, you need to reduce the paint to the correct viscosity for sprayer application. The type of paint will dictate whether to use a reducer or a thinner to attain the proper spraying viscosity. We mention thinners here to familiarize you with lacquer paints, which are not being used in most AF body shops. However, you need to be aware of their availability to ensure you *do not use a thinner in place of a reducer*. The following is a helpful guideline.

- Enamel paints require a “reducer.”
- Lacquer paints require a “thinner.”

Reducers may or may not be necessary for brush painting, depending on the paint used and the surface on which it is applied. Most automotive paints are synthetic compositions and require a special reducer. An important fact to remember: *Thinners and reducers are not interchangeable!*

NOTE: Most paint containers have directions printed on the side for the type and amount of reducer to use for spraying—READ THESE DIRECTIONS! The amount of reducer varies with climatic conditions and type of reducer you use.

If you have to reduce the paint's viscosity, use a small amount of the prescribed reducer. Because of its volatility, reducer evaporates from the paint film, leaving approximately the same amount of pigment per square foot of surface.

There are three types of reducers as described in the following table.

Reducer Types	
Type	**Description**
Slow-drying	Used with acrylic paints, slow-drying solvents produce a slow evaporation rate of approximately 3 1/2 to 5 minutes.
Medium-drying	Used for applying primer-surfacer and solid colors, the evaporation rate of medium-drying solvent is approximately 2 minutes at 65° F and higher.
Fast-drying	This type of reducer is used when applying primer-surfacer below 60° F temperatures. If you use a fast-drying solvent with a primer-surfacer in temperatures above 65° F, you will end up with a rough or spongy surface.

As the temperature decreases, the evaporation rate of a solvent slows down. The following are a couple of ways you can increase the evaporation rate:

1. You can mix a medium-drying solvent with a slow-drying solvent to speed up the slow-drying solvent when the temperature decreases.
2. You can also mix the medium-drying solvent with a fast-drying solvent to slow the fast-drying solvent's evaporation rate.

If you are painting in hot, humid weather, you may want to use a retarder, which has an evaporation rate of about 30 minutes. You would use a retarder with acrylic enamel paints to prevent blushing, a milky appearance on the surface of the paint caused by moisture entering the paint during spraying. In addition, the retarder also allows smoother application of paint during hot and humid weather.

Internal temperature of the paint itself plays a part in how viscosity is varied. If you bring paint in from a cold area, its viscosity is typically higher that when it has been warmed to room temperature. Therefore, always store paint in temperatures around 70° F or allow paint to warm to room temperature before adding reducer and applying the paint to a body surface.

To size up painting automotive body surfaces according to temperature, use a fast-drying reducer for cold temperatures and a slow-drying reducer or retarder for hot temperatures. Select the reducer according to the temperature and humidity conditions in your area; experience is the true teacher in selecting the right reducer.

Additives

Several additives can be used to help in the painting process, including the types described in the following table:

Paint Additives	
Type	**Description**
Hardeners	Catalyzing agents used in some paints to activate the paint hardening process.
Accelerators	These help speed up dry time between coats; especially helpful when the temperature is below 70° F.
Fisheye Preventers	Prevent the effects of silicone contaminants. Use only if absolutely necessary.
Flattening	Agents that can be used to flatten or reduce the gloss of the paint. They can also be

Paint Additives	
Type	**Description**
Agents	used to help blending.
Flexitives	As the name implies, these are additives used on flexible panels (hence the name flexitives). They allow the paint to flex when the panel flexes, preventing the paint from cracking. Flexible agents are normally used in primers and clearcoats.
Retarders	As previously explained, retarder additives are used to slow down dry time and help improve paint flow. This is especially helpful when the temperature is hot.
Static Electricity Eliminators	Cut down the amount of static electricity on the paint surface to help reduce dirt attraction.

Polishing compounds

Polishing compounds, which contain fine abrasives for polishing, can be used for most types of paint. The compounds vary in the abrasive content. Compounds with heavier abrasives are used for removing coarse scratches or major defects in the paint. Lighter abrasive compounds are used for polishing the paint finish. This can include removing minor scratches or imperfections.

Abrasives

A standard abrasive rating system is essential when discussing auto body paint repair procedures. The United States uses the American National Standards Institute (ANSI) system for rating sandpaper grit. Europe uses another rating system, differing greatly from the US ANSI system. However, you may find yourself using this type. There is an easy way to determine which type you have:

- European sandpaper has the letter “P” in front of the grit number.
- The US ANSI system does not have a letter before the grit number.

Figure 5–1 provides a good comparison between the two rating systems. Notice the European grade P1000 is roughly equivalent to the ANSI grade 500. However, the references to sandpaper grit used in this text reflect the US ANSI standards. Note that there is no ANSI standard for grits beyond 600. This means there may be differences in grits between manufacturers. Therefore, it is important to refer to the manufacturer’s published information when using sandpaper finer than 600 grit. This will help ensure the appropriate grit for the specific application, producing a quality repair.

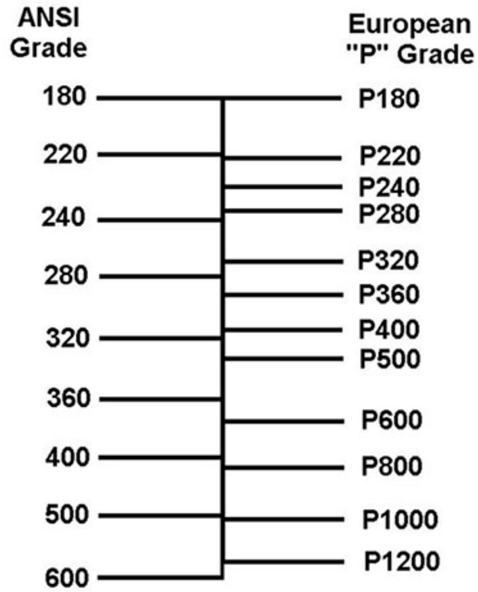


Figure 5–1. Sandpaper grit comparison.

Other additives and characteristics

In addition to the preceding discussion of paints and related materials, there are three other additives and/or characteristics that we need to consider: primers, undercoating, and film thickness.

Other Additives and Characteristics	
Type	**Description**
Primers	Metal primers are designed to provide a coating on bare metal to prevent corrosion. Primers also provide a base for the paint and serve as filler for small sanding scratches.
Undercoating	Undercoating is an acid-proof coating compound with an asphalt base and a solvent. This compound is available in two types: • Type 1 is for spraying operations only. • Type 2, which is a little heavier, is for spraying or brushing.
Film Thickness	Understanding film thickness is important when you are confronted with a repair situation. Film thickness, or film build as it is sometimes called, is the measurement of the paint thickness in thousandths of an inch or mils. All paint films can be measured in this manner.

Volatile organic compounds

Previously we explained that reducers are a necessary part of a successful paint system. Unfortunately, reducers are volatile organic compounds (VOC) and can be harmful to the human body. Reducers are organic chemicals and organic chemicals contain the element carbon (C). Organic chemicals are the basic chemicals found in living organisms and in products derived from living organisms. This also includes such things as coal, petroleum, and refined petroleum products. Many of the organic chemicals (or compounds) we use do not occur naturally; instead, they are synthesized (created) by chemists in laboratories. Not only are they organic but they are considered “volatile.” This simply means that they readily produce vapors at room temperature and normal atmospheric pressure. Under these conditions, vapors escape easily from volatile liquid chemicals. Volatile organic chemicals/compounds include the following:

- Gasoline.
- Industrial chemicals, such as benzene.
- Solvents, such as toluene and xylene, and tetrachloroethylene (perchloroethylene, the principal dry-cleaning solvent).

Toluene and xylene are components you will see in paint thinner. Many of the VOCs are also hazardous air pollutants; for example, benzene causes cancer.

Always ensure your paints and solvents are securely covered. The use of high-volume low-pressure (HVLP) or low-volume low-pressure (LVLP) paint equipment will also significantly reduce your shop’s VOC signature.

Due to the nature of VOCs, most areas of the United States have environmental laws regarding the handling and tracking of these emissions. You will have to observe the law’s requirements and you may even be tasked to track your VOC output. VOCs are tracked by pounds per gallon (lbs/gal) of liquid material. Information regarding these laws and complying with them is given as part of the shop orientation.

Low volatile organic compounds paints

While equipment manufacturers are designing spray guns that lower emissions, paint manufacturers are also developing low VOC paints. The down side is that low VOC paints are thick and difficult to atomize. Thicker paint results in the disadvantage of higher cap (nozzle) pressures necessary to get the paint to the target. Before ordering or using the low VOC paints, make sure you have the proper equipment needed to apply it. The problem that usually arises is that the guns cannot maintain sufficient cap pressure to atomize the paint properly.

For example if your shop is only equipped with HVLP spray guns, the low-operating pressure may not be enough to apply the paint. The following lesson will help you in determining equipment types.

638. Automotive painting equipment

There is no set standard for vehicle paint shop equipment. This means that the equipment varies from base to base, and you will use various types of equipment as you transfer during your career. While each shop may or may not have the particular type of equipment we will discuss, most shops have equivalent equipment. If you have a general idea of the operation of one type, you should have a general understanding of similar types. We will start our discussion with the larger items.

Paint booth

A small painting booth is shown in figure 5–2. It is a room or compartment that is open at one end so you can bring vehicle body components inside the booth for painting. Note that the exhaust fan is installed in the roof to remove volatile paint fumes. The automotive spray booth (fig. 5–3) is large enough to drive a vehicle inside and paint. Here, the exhaust fan is installed at the rear of the booth with a deflector plate covering the opening. The fan must exhaust enough air to remove the harmful and volatile fumes during painting operations. Air coming in to the paint booth (due to the exhaust fan taking air out of the booth) is normally filtered to prevent any dust particles from entering the paint booth. The public health and bioenvironmental engineering office on your base can assist you in ensuring the booth meets ventilation requirements.

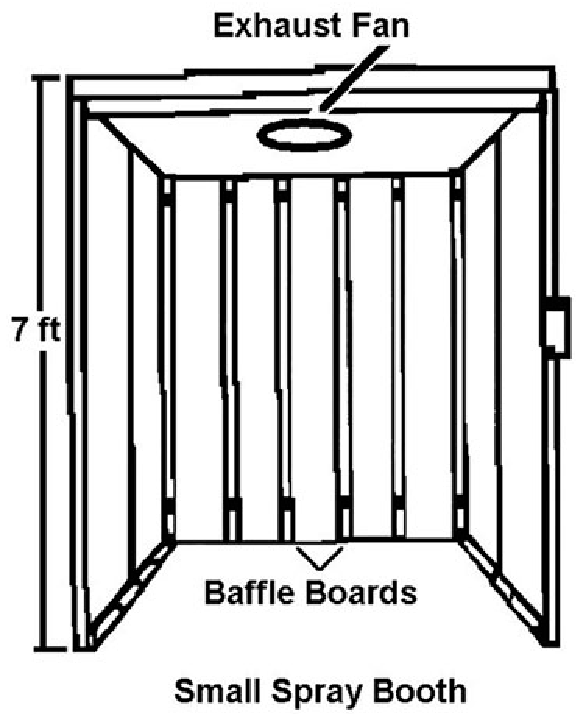


Figure 5–2. Small paint booth.

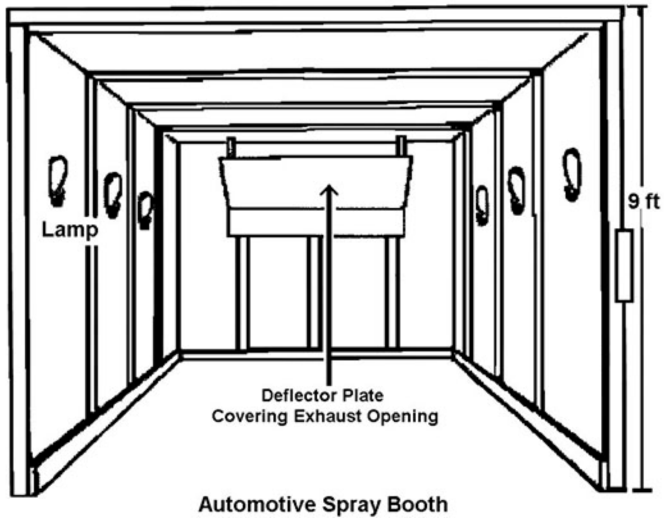


Figure 5–3. Auto spray booth.

NOTE: It is important to understand that *certain types of paints react if they are exposed to each other*. For this reason, it is a good idea to change the paint booth filters before you start painting with a different type of paint.

Filters must also be changed once they become contaminated with dust, dirt, or paint residue. Otherwise, excess dust, which the filters cannot handle, settles on wet paint and ruins the appearance and quality of a freshly painted body surface. If your paint booth contains more than one filter, change all of them at the same time, even if only one needs changing. Air Force Manual (AFMAN) 91–203, *Air Force Occupational Safety, Fire, and Health Standards*, Chapter 28, *Interior Spray Finishing,* provides additional guidance about spray-booth filters.

Vapor-proof lamps are installed along the walls and ceiling of the booth (fig. 5–3). As you would expect, these lamps should provide adequate illumination. To do this, the lighting inside the paint booth must be adequate to eliminate shadows while painting is in progress. Some Air Force installations do not have paint booths. At these installations, major paint operations are likely accomplished by contract maintenance, and you will probably be limited to minor paint operations. Whatever the case, you must comply with appropriate Air Force publication requirements when painting.

Air compressors

Air compressors provide the air pressure for spray painting equipment. These compressors are normally electric-motor driven; however, field operations may dictate the use of an internal-combustion-engine-driven compressor.

On the electric-motor-driven compressor (fig. 5–4), a pressure switch starts or stops the electric motor automatically. It does this according to the amount of pressure within the storage tank. An air strainer attached to the compressor filters the air entering the compressor. In addition to the filter, most air compressors have a safety valve, an outlet valve, and a pressure gauge. If the pressure switch malfunctions while the compressor is building up pressure, the electric motor may not shut off. In this case, the pressure continues to build up until the safety valve opens and releases the excessive air pressure. Normally, the safety valve opens up if the compressor *exceeds its maximum pressure by 10 pounds*. The outlet valve is a manual off-and-on valve that allows you to release or shut off pressure to the air lines carrying pressure to the pneumatic equipment. The pressure gauge shows the pressure in the storage tank at all times.

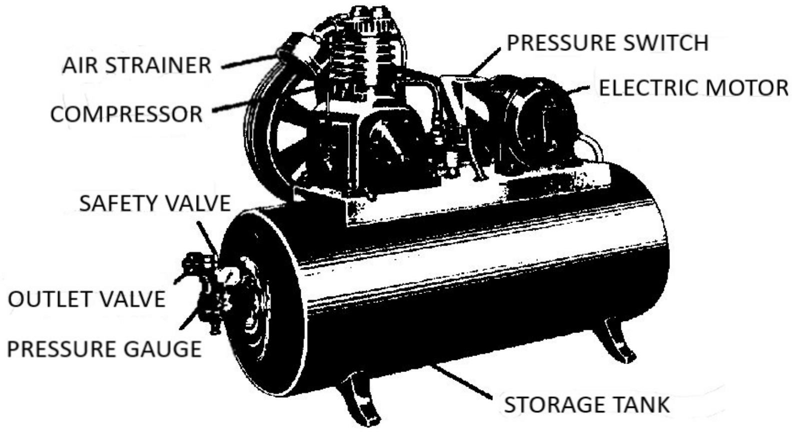


Figure 5–4. Air compressor.

Air transformer (regulator)

Normal air contains water vapor. The air transformer (fig. 5–5) removes oil and water from the air and regulates the air pressure to the spray gun. The air transformer needs to be located as close as possible to the air compressor. This reduces the amount of air line needed, which in turn, reduces the amount of condensation that could accumulate in the air line and thus potentially mar your paint job. Figure 5–5 shows the two main air line pressure control valves. The pressure control regulator controls the pressure entering the air transformer from the main air line. You use the regulator pressure valve controls to regulate the pressure to the spray guns:

- The lower gauge indicates pressure within the lines to the spray guns.
- The upper gauge indicates the pressure to the air transformer from the air compressor or air supply line.

The drain petcock drains the oil and water that collects in the air system. Open this petcock at the beginning of each duty day you paint. Doing so helps keep moisture from entering your spray gun and causing a malfunction.

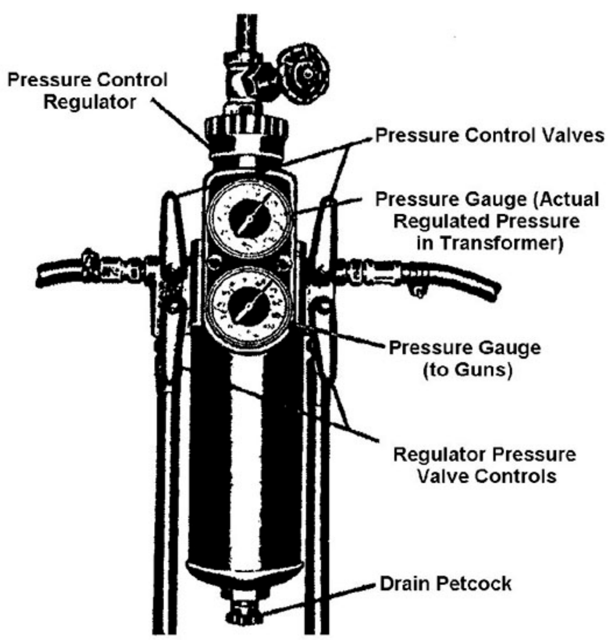


Figure 5–5. Air transformer.

Drying oven

Figure 5–6 shows a vehicle "baking" in a drying oven. Most drying ovens have heated air flowing through to produce the specified heat to dry the paint. Some drying ovens use banks of infrared lights for the drying or baking process. You may install these lights in sections to cover small areas or in large banks to cover the complete vehicle. The drying oven needs to have adequate ventilation regardless of whether it uses hot air or infrared lights.

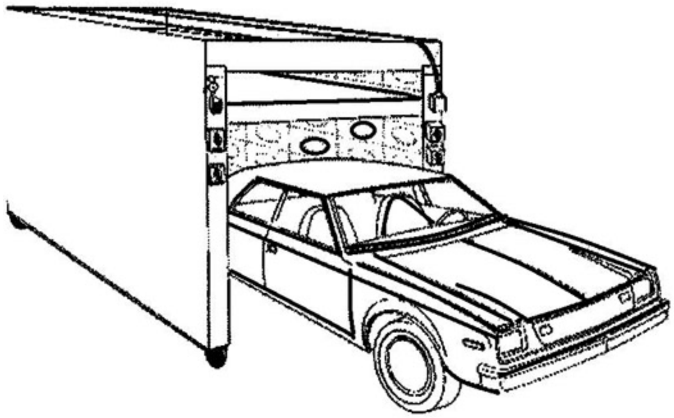


Figure 5–6. Drying oven.

Enamel paints dry in two ways: oxidation and polymerization.

Oxidation

Enamel paint oxidation is simply the enamel's absorbing oxygen from the air and drying.

Polymerization

Polymerization is actually solidifying the synthetic resins in the enamel paint when heat is applied (much as an egg solidifies when you heat it). The process speeds up drying beyond the oxidation process, makes the paint harder, improves water and chemical resistance, as well as its durability and gloss.

The higher the temperature you apply, the quicker the oxidation and polymerization processes occur. The ideal temperature for both oxidation and polymerization to occur without causing damage to the paint depends on the manufacturer (on average it is about 158 °F). Keep in mind that darker colors absorb more heat, which means using a lower baking temperature. Leave the side windows partly open to equalize the heat between the inside and outside of the vehicle.

NOTE: Never use the spray booth as a drying oven. There is the possibility of spontaneous combustion of volatile paint vapors. In addition, all major vehicle manufacturers recommend disconnecting all onboard microprocessors, such as supplemental inflatable restraint (SIR), ABS, or power train modules. Make sure you follow procedures set forth in the appropriate technical manuals.

Respirator

The respirator is a mask worn to prevent you from inhaling harmful dust and toxic vapors from various types of paints. There are many types of respirators; however, the two main types you will be more likely to encounter in your work area are the cartridge and air supplied (fig. 5–7).

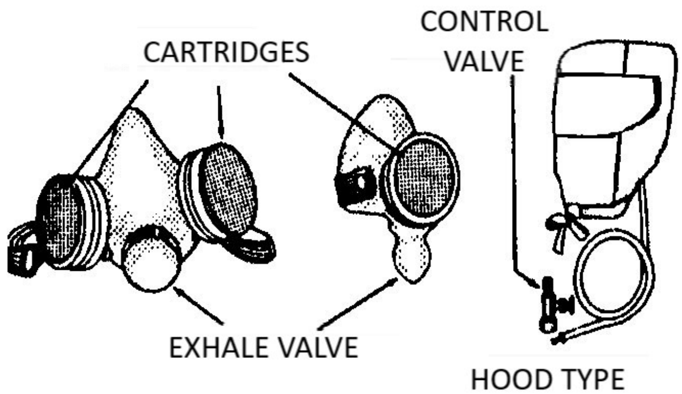


Figure 5–7. Respirators.

Air Force Instruction (AFI) 48–137, *Respiratory Protection Program,* contains information about respirators. It lists the types of respirators for both general painting purposes and painting automotive components. It also provides the federal stock numbers (FSN) for these respirators. The AFI further provides recommended ways of cleaning a respirator. One way is to use warm water with liquid detergent added. Always clean the respirator after you have used it during painting, grinding, sanding, mixing, and so forth.

NOTE: Never use your biological/chemical warfare respirator when painting. As with other equipment and tools, use respirators only for their designated purposes.

Cartridge

This respirator can be used in well-ventilated areas such as paint booths and open-bay areas. It protects against vapors and spray mist of nonactivated enamels (no hardener added), lacquers, and other nonisocyanate materials. (Isocyanate is very hazardous and is used as an accelerant or hardener for paints). The cartridge respirator consists of a rubber face piece designed to conform to the face for an airtight seal. As a result, *it must be fit tested.*

The cartridge respirator includes replaceable prefilters and cartridges that remove the harmful fumes from the air as you breathe. It is very easy to maintain. For example, simply remove the filters and clean the respirator in warm water and liquid detergent, rinse the respirator in clean warm water several times, and hang it up to dry. After the respirator dries, always store it inside a container (plastic bag, small cardboard box, or self-made container) to keep it away from dust, sunlight, heat, extreme cold, excessive moisture, or from coming in contact with any chemicals. Change the cartridges at manufacturer-recommended intervals or whenever breathing becomes difficult from heavy contamination of spray mist or dust.

Air supplied

The air-supplied respirator is used when you are spraying in areas of poor ventilation, such as the inside of panel trucks or van-type semi-trailers. Special paints like urethane paint finishes, or any paint products containing isocyanates, also require using special respirators of the air-supplied type. This respirator can be a half-mask, full-face, hood, or helmet type. A hose attaches to the facemask and a fresh air source pump. This source pump must be located in a clean air area. You can use compressed air from the shop; however, it must be filtered with a trap and carbon dioxide/monoxide filter. Oil, water, and scale must be removed from the air supply. The mask will also be fitted with an airflow control valve to regulate the airflow to the respirator specifications. The respirator is comfortable to wear.

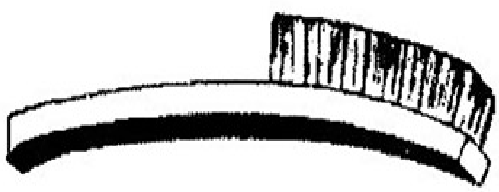
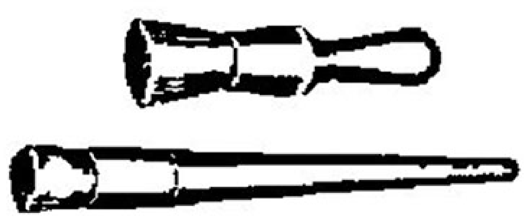
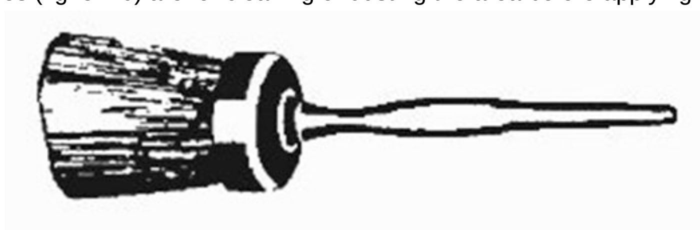
NOTE: *Fit testing is not required for hood or helmet types*. *Any respirator with a tight-fitting seal must be fit tested.* Always consult AFI 48–137 and your public health and bioenvironmental engineering office for guidance in what training, medical clearance, protective equipment, and respirators you will need.

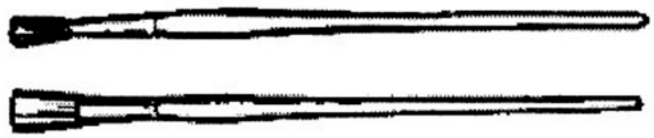
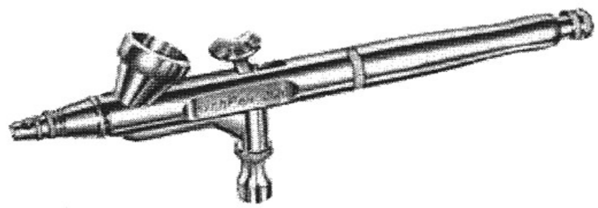
639. Brushes and hand-held paint spray guns

When most people think of painting, they visualize a bucket of paint and a brush. Although you will use the spray gun for most of your painting tasks, there will be times when a bucket and brush is appropriate to the job at hand. For this reason, we will begin this lesson by briefly touching on the subject of paintbrushes. As the lesson progresses, we will discuss the spray gun and its use in detail. We will conclude the lesson with a discussion on how you care for your equipment.

Brushes

You need brushes for small touch-up jobs or automotive body refinishing, as well as for various other jobs in the paint shop. Some of these brushes are shown and discussed more fully in the following table.

Brushes	
Type	**Use**
Wire Brush	The wire brush (fig. 5–8) is for cleaning and scouring vehicle body surfaces or automotive components.  **Figure 5–8. Wire brush.**
Stencil	The stencil brush (fig. 5–9) is for stenciling numbers or letters on Air Force equipment.  **Figure 5–9. Stencil brush.**
Dusting	Dusting brushes (fig. 5–10) are for cleaning or dusting the area before applying paint.  **Figure 5–10. Dusting brush.**

Brushes	
Type	**Use**
Artist	These brushes (fig. 5–11) are for repairing damaged or faded vehicle markings. Sometimes, a touch-up is more economical than stenciling a complete set of numbers or letters.  **Figure 5–11. Artist brush.**
Air Brush	This is a small spray gun about the size of a pencil (fig. 5–12). It is air operated and may be used to touch up work on letters, numbers, or hard-to-get-to body surfaces.  **Figure 5–12. Air brush.**

Spray guns

The purpose of the spray gun is to take paint from a paint container and atomize it (break the paint up into small particles) at the air cap or fluid tip by air pressure for application to the body surface. Depending on the specific task, you can equip the spray gun with various types of heads and nozzles. Spray guns are ruggedly constructed and are normally made of aluminum. Like all precision tools, they require maintenance and care. You should become knowledgeable about spray gun construction, maintenance, and operation to ensure satisfactory results.

NOTE: A special point to keep in mind is to be careful and not over-torque any threaded component of the spray gun body. Otherwise, you might damage the threads.

The Air Force uses the following two types of spray painting systems:

1. Self-feed—Has a small container attached to the gun (siphon or gravity).
2. Pressure feed—Supplies paint from a larger container through a hose to the spray gun.

No matter which painting system you are using, the components for the spray gun (fig. 5–13) are the same. The gun is equipped with an air valve controlled with the two-finger trigger. The control screw adjusts spring tension on the material needle valve that controls the flow of paint. By removing this screw, you can remove the needle valve for cleaning. There’s also an adjustable air control screw used to control the width of the spray pattern. On the front of the gun, the air nozzle directs air into the paint stream. The air atomizes (breaks up) the paint in the stream from the material nozzle. In other words, as the air and paint streams meet, they form a mist of spray. If you correctly adjust the various controls on the gun, you can develop the proper spray pattern you need. Look again at figure 5–13. Paint under pressure enters the gun through the hose connection and travels to the material nozzle. Compressed air enters the spray gun handle through the air hose connection (air inlet). As you pull back on the two-finger trigger, the air valve opens. This allows air to reach the air nozzle through an orifice. The air control screw determines the size of the orifice.

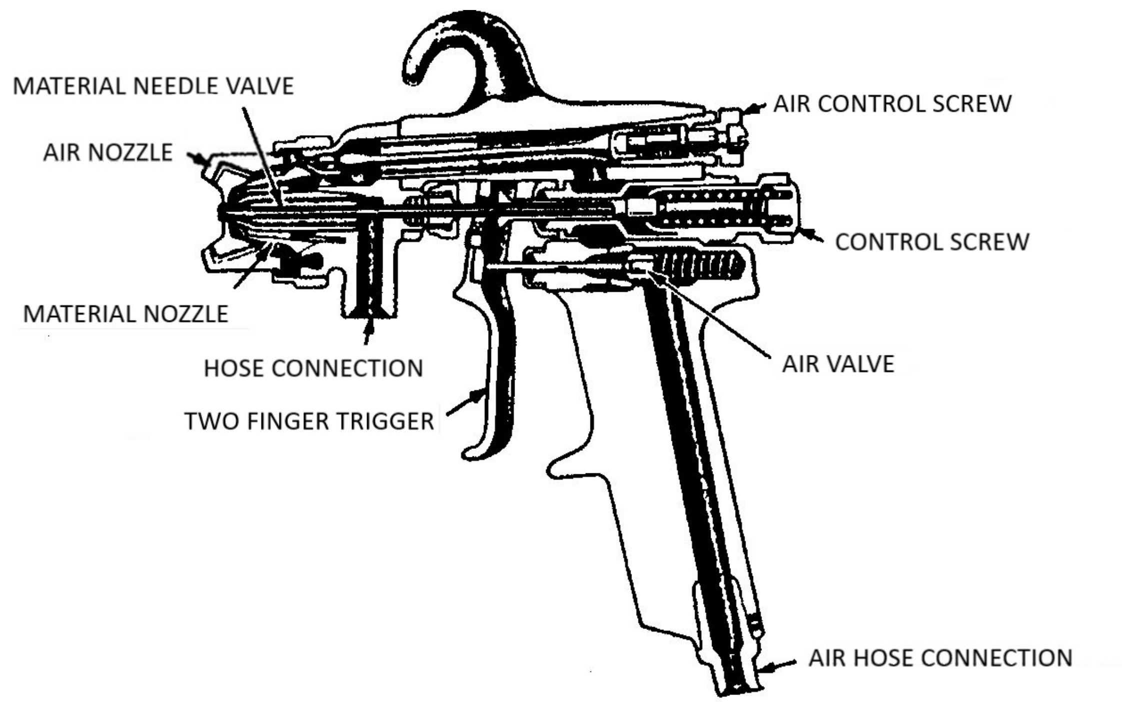


Figure 5–13. Spray gun.

Figure 5–14 provides a closer view of the spray nozzle and cap. You can easily see how the nozzle and cap form the paint spray.
The two-horn air jets (fig. 5–14, View A) provide a small half-enclosed mixing area directly in front of the paint orifice. Each horn air jet sends an air stream directly across the paint stream. If one of the orifices of the horn air jet becomes obstructed, the paint spray pattern will be deflected to that side of the horn air jet. Two auxiliary air jets on each side of the paint orifice help form the spray and provide better control of the pattern.

Figure 5–14, View B, shows a cross-sectional view of the nozzle in operation. Notice the air from the auxiliary jets keeps the paint in a smooth stream. Air from the horn jets strikes the paint stream at a sharp angle, *atomizing* the liquid into a spray. You can control the spray pattern by controlling the force of the horn jet air streams. You can see it is extremely important to keep all of the jets and orifices free of obstructions.

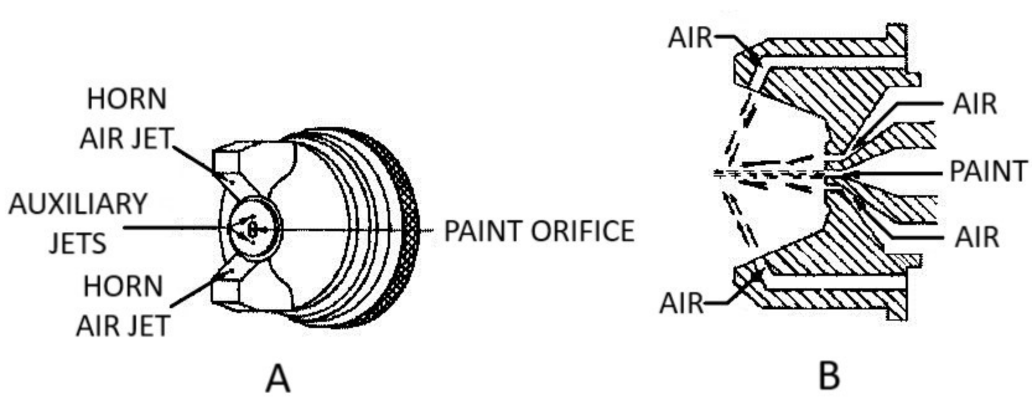


Figure 5–14. Spray nozzle (air cap).

Siphon-feed spray guns

The siphon-feed spray gun operates on the principles of siphoning the paint from a container attached to the underside of a spray gun (fig. 5–15). The container is not pressurized; instead, the lid vents to atmospheric pressure. As you start to pull back on the two-finger trigger, air pressure alone exits the nozzle. As you pull back further on the trigger, the passageway to the container holding the paint uncovers and the movement of more air flowing out the nozzle creates a vacuum past this passageway, drawing the paint from the container through the siphon tube. The vent on the cap of the container holding the paint vents atmospheric pressure into the container so paint flows up and out the spray gun nozzle. Some of the drawtubes extending down into the container attached to the spray gun have a certain angle to them. If your spray gun has this configuration, point the tube towards the front of the container when attaching the container. This will help to eliminate "paint spitting" by keeping the siphon immersed in the paint as much as possible.

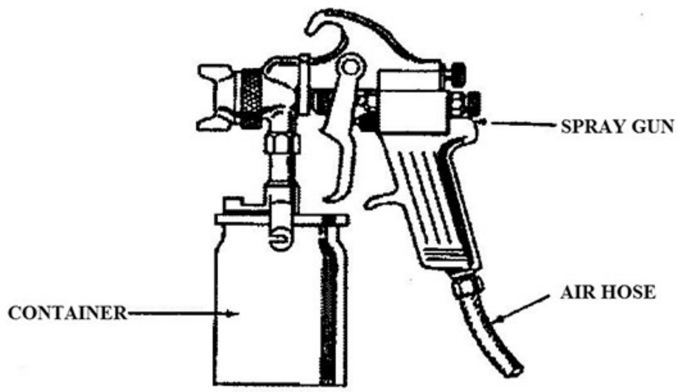


Figure 5–15. Attached container spray gear.

The following are three disadvantages to this type of spray gun.

1. The entire spray gear is heavier. Even though each container possesses 1-quart capacity, the weight of a container with paint inside adds to the weight of the gun.
2. If you tilt the gun too far, paint will run out of the container's vent.
3. If the siphon tube becomes uncovered, "paint spitting" will occur.

As you tighten the container lid, make sure you have the vent hole towards the spray gun handle to minimize paint spillage when tilting the spray gun forwards.

Gravity-feed spray guns

This type of spray gun is distinctive in its appearance. It has a nonpressurized paint container mounted on the top of the gun assembly. This enables the painter to use gravity to feed the paint into the air cap. This design also helps eliminate the problem of "paint spitting." Due to the gravity-feed design, the paint feed hole is always covered with the material in most painting positions. This provides a continuous flow of the material without tubes becoming open due to tilting the gun.
The operating principles are the same as the siphon feed with the difference of instantaneous paint expulsion because less air has to be moved to get the paint to the air cup. This is a very common gun type used with the high-spray-efficiency painting systems in today's paint shops.

Pressure-feed spray guns

These spray guns use pressurized metal containers to provide a constant flow of paint at uniform pressure to the paint spray gun. You connect the spray gun to the tank with two hoses: one for air and the other for paint.

Air hose

The air hose connects to the spray gun at the handle (refer to figure 5–13). The other end connects to the air transformer mounted on the top of the tank.

Paint hose

The paint hose carries paint from the pressure-feed paint tank to the spray gun (refer to figure 5–13). This hose connects to the spray gun just behind and below the spray nozzle.

Pressure-feed tanks

Pressure-feed tanks vary in capacity from 2 to 60 gallons. The tank (fig. 5–16) consists of a container with a cover secured by clamps. Compressed air reaches the tank through the air intake valve. The tank pressure regulator controls tank pressure. A pressure gauge indicates the internal pressure, and a safety valve will unseat to protect the tank from serious damage. To reach the spray gun, paint is pumped under pressure through the material outlet valve and the paint hose. Air pressure forces paint through the fluid delivery tube to the material outlet valve. A screen keeps any solid matter from entering the delivery tube and prevents small orifices in the tank and gun valves from becoming obstructed. An agitator, operated by a detachable crank, thoroughly mixes the paint. This type of pressure tank is normally used to paint large buses, vans, refueling vehicles, trailers, and so forth.

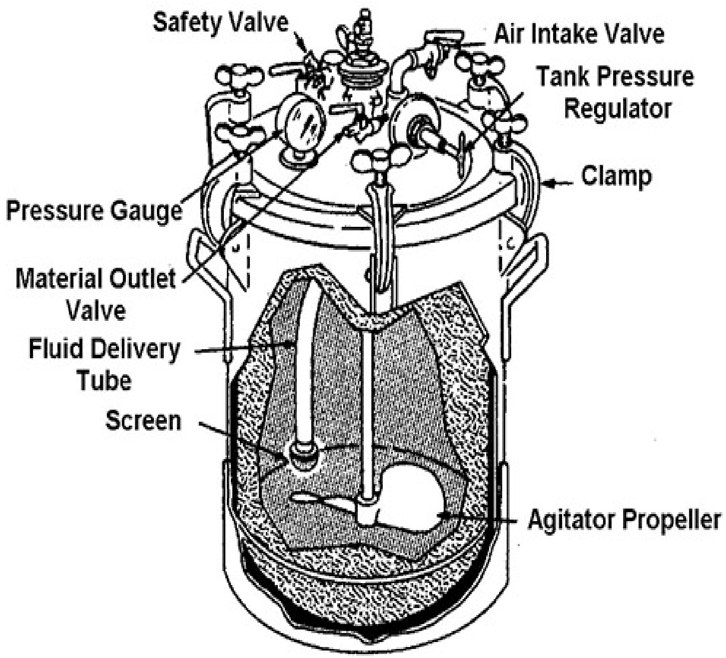


Figure 5–16. Pressure feed tank.

High-volume, low-pressure spray guns

With the move towards a cleaner environment and the passage of more stringent legislation, much emphasis is being placed on cleaner paint facilities. As a large user of automotive paints, the Air Force is complying with federal regulations. Part of this effort entails the use of HVLP sprayers.

Industries that want efficient painting or finishing of their products use HVLP sprayers. Increased use of high-solid paints, whose viscosity (thickness) make them more effectively applied, has helped to popularize HVLP. This is due to the ability of HVLP sprayers to apply high-solid paints quite well.

Numerous industries successfully using HVLP systems in paint and coating operations include the following:

- Furniture finishing.
- Painting of manufactured goods.
- Auto body repair.

Prior to the HVLP systems, the accepted method of increasing the rate of paint/coatings application was to increase the pressure output of the sprayer. However, as the spray pressure increased, an increased amount of material overshot the target or rebounded off the surface. This situation increased the amount of solid or hazardous waste produced and contributed to air pollution problems. A breakthrough came with the development of HVLP spray systems. These systems use innovative nozzle and gun designs, as well as pressure regulators, to transfer large volumes of paint/coatings at pressures as low as 0.1 psi.

NOTE: Pressures below 10 psi are now required to comply with some air quality rules relating to VOCs. The most frequently quoted standards are those of the South Coast Air Quality Management District (SCAQMD) around Los Angeles, California. *The SCAQMD standards are considered the most stringent in the United States.*

HVLP spray systems have fewer emissions because they have a high transfer efficiency (TE). The term *TE* describes the amount of paint a spray gun is capable of depositing on a surface. TE is expressed as a percentage. *The higher the TE of the spray gun, the lower the amount of paint wasted in the form of mist and overspray*. As a result, less paint is used and less VOC emissions are produced. The conventional high-pressure spray gun with a siphon cup has a lower TE and does not meet new regulations for VOC emissions.

Three basic types of HVLP systems are marketed today, including turbine, air conversion units, and step-down guns. These three types vary in the method used to supply air to the gun.

HVLP Systems	
Type	**Description**
Turbine	This system uses an electrically powered turbine to compress air; the spray gun is then supplied this compressed air through a large $^3/_4$-inch hose. The air to the gun may be over 200 ° F due to the heat of compression. The air is oil free and dry. The *maximum pressure* normally delivered is usually between 3 and 10 psi. Turbine units can be portable or stationary (which can operate several spray guns). Self-contained or portable turbines are convenient to use since you can move the unit to the painting location; simply plug the unit into a 110-volt outlet and start painting. The heated air produced by the system can benefit painting because warming the paint helps to reduce its viscosity, which improves atomization. However, the heat also evaporates the solvents in the droplets faster than conventional cold air. Depending on the paint, reducer, and painting conditions, a drier spray and a lower quality appearance may result. The air temperature depends on the turbine design, turbine distance from the gun, ambient air temperature, and how well the air line is insulated. Note that the temperature is difficult, if not impossible, to control. Turbine units are often used for applying primers and other applications where appearance and finish are not as important. A typical turbine system spray gun uses a pressure cup, the opposite of the vented cup previously discussed. A small hose directs air pressure from the air cap to the top of the cup. This design does not allow for separate adjustments of air cap and cup pressure. The cup pressure is always the same as air cap pressure. Due to cup pressure coming from the air cap, the cup does not pressurize until the trigger is pulled. Fluid control is achieved by adjusting a needle to the fluid tip opening.

HVLP Systems	
Type	**Description**
Air Conversion Unit	These units use an adjustable pressure regulator to reduce (step-down) standard shop compressed air to 10 psi or less. A large $^3/_4$-inch hose carries the HVLP air to the spray gun. There are several different air conversion variations—while some have a large adjustable electric heater that warms the air to simulate the heat of a turbine system, others can be carried on your belt. In essence, an air conversion unit is simply a pressure regulator that reduces standard shop compressed air to 10 psi or less. It is adjustable up to a maximum of 10 psi to qualify as an HVLP system and to conform to emission regulations. It is also designed to deliver the required amount of air volume in cubic feet per minute (cfm) to the gun at all pressure settings. The large hose fitting at the gun air inlet allows unrestricted HVLP air to enter the gun. During operation, the air pressure at the inlet of the gun is the same as the pressure at the air cap. Similar to other HVLP guns, air cap (nozzle) pressure is used to pressurize the cup. Fluid flow is adjusted by the position of the needle to the fluid tip. Air volume is controlled by adjusting the pressure on the air conversion unit.
Step-down Gun	This type of system uses standard shop compressed air (40 to 100 psi) at the air inlet. A venturi, or special orifice, inside the gun is used to reduce (step-down) air pressure in the air nozzle to 10 psi or less. The advantage of this system is that it allows use of an existing high-pressure shop air system. Since the air is reduced from high-pressure to low-pressure inside the gun, these systems do not require a large $^3/_4$-inch hose to carry the air from the source to the gun. Step-down guns have an adjustment for controlling air volume to the air cap. Since the cup receives its pressure from the air cap, the pressure in the cup is always the same as the pressure in the air cap. Condensation can occur when air pressure is reduced from high-pressure to low-pressure, making step-down guns especially susceptible to water condensation. To avoid condensation problems, the shop air system must have proper air dryers and filters.

Spray gun operation

Most spray guns are capable of an operating speed beyond the operator's skill in using them. Consequently, you should adjust the gun to operate at the maximum speed consistent with the type of paint, flow rate, vehicle body surface, and your individual skill. Hold the gun perpendicular to the work at all times, 8 to 10 inches from the surface. If you hold the spray gun too close to the body surface, you will normally experience paint runs or color changes. If you hold the spray gun too far from the body surface, you will normally experience excessive dry spray, overspray, or color change. Experience will help you in the judging the proper speed for moving the spray gun from side to side while applying different types of paint under various working conditions. One way of estimating distance is by spreading your fingers out. With the spray nozzle touching the end of your thumb, move the spray gun and your hand towards the body surface until your little finger touches the body surface. This distance normally equals between 8 to 10 inches. With each side-to-side stroke you make, you should overlap each layer of paint you spray on the body surface by 50 percent. If you aim the nozzle of the spray gun at the bottom of the last layer of paint you apply, you normally create the 50 percent overlap.

As you spray paint, hold the spray gun in the upright position. Normally, the air cap is adjustable for the vertical or horizontal patterns. The vertical pattern is the most popular and easier to work with. Using the vertical spray pattern assures maximum coverage as you move the gun from side to side parallel to the auto body surface. Make the stroke with a free-arm motion, keeping the face of the air nozzle parallel with the body surface at all points of the stroke. The correct and incorrect procedures are illustrated on figure 5–17.

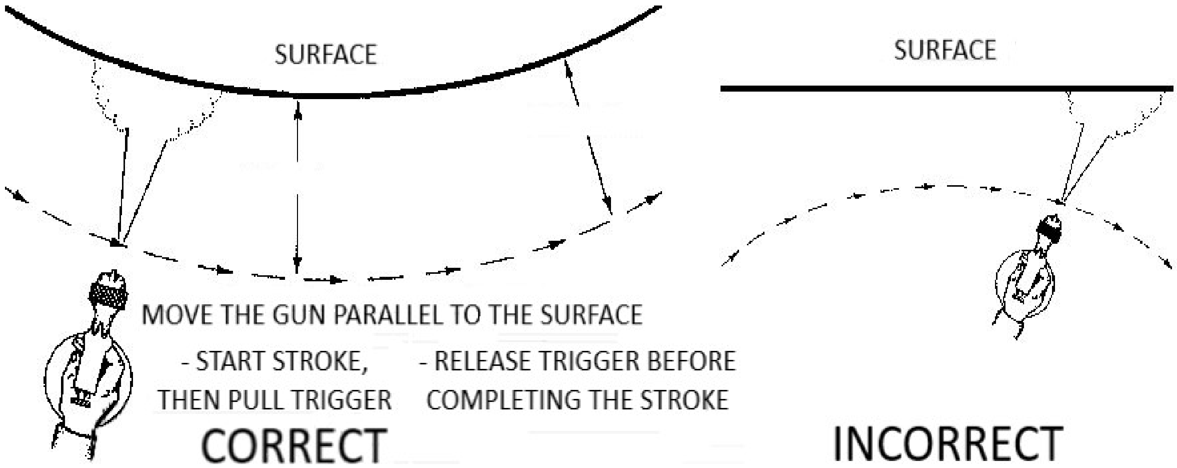


Figure 5–17. Spray gun operation.

Feather the ends of the side-to-side stroke by “triggering” the spray gun. In other words, when you begin the stroke across the body surface slightly pull the trigger back so only air will come out of the nozzle. As your stroke progresses, pull the trigger all the way back so paint starts coming out of the spray gun nozzle. Towards the end of the stroke, release the trigger enough to shut off paint flow but continue airflow through the spray gun nozzle. For best results, make 18 to 36-inch side-to-side strokes. If the panel you are painting is longer than 36 inches, paint the panel in two or three sections, overlapping the end and start of each section you spray paint.

NOTE: You can practice feathering with a rectangular or square piece of paper no larger than 36 inches. Make a giant “X” on the paper from corner to corner, then paint in the areas at the center of the “X” without crossing over the lines.

Some examples of improper spray gun operation or malfunctions and the reasons for them are shown in figure 5–18. Some painting defects might be the result of the spray gun operator’s lack of skill or the spray gun itself. For example, an air leak can occur at the front of the spray gun if the air valve is not seating properly. Foreign matter on the valve or valve seat, worn or damaged valve seat, or a broken air-valve spring can prevent proper seating of this valve. You can correct these defects by loosening or tightening nuts or screws, cleaning and lubricating, or replacing components as necessary. This brings us to our next subject, taking care of the equipment you will be using.

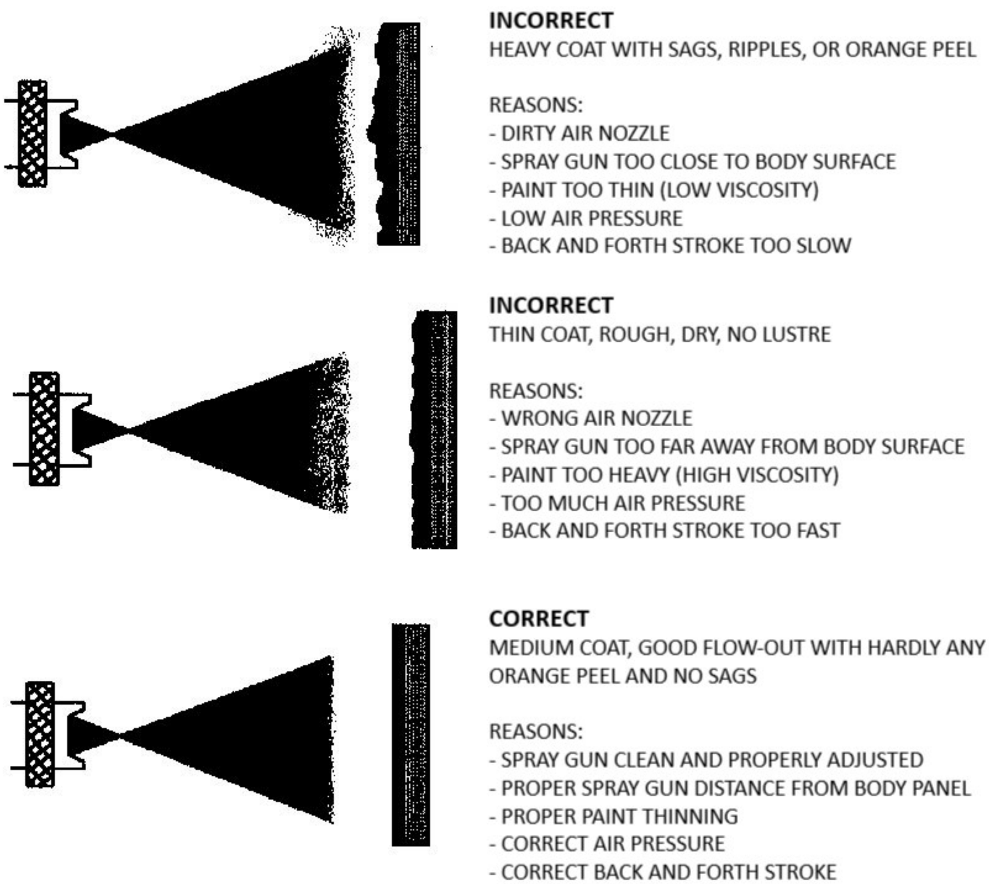


Figure 5–18. Spray pattern imperfections.

Equipment care

Spray guns and related equipment require cleaning immediately after use. Paint that hardens in the gun or hose is extremely difficult to remove and invariably will cause trouble in the spraying operation. If you have sprayed lacquer, clean the gun with an approved solvent. After spraying with synthetic enamel, clean the gun with synthetic solvent.

The following instructions are general in nature. Ensure you observe local policy when cleaning your equipment, including any environmental guidance. Some installations may have specialized cleaning equipment that must be used to clean painting equipment and meet legal requirements.

Cleaning the attached-container spray gun

Never immerse the entire gun in solvent because it will remove the lubrication and dry out the packing. Instead, observe the procedure listed in the following table as you complete a spraying operation with an attached-container spray gun.

Cleaning the Attached-Container Spray Gun	
Step	**Action You Take**
1	Loosen the container from the spray gun, leaving the drawtube within the container.
2	• Loosen the air cap two revolutions. • Hold a cloth over the air nozzle. • Trigger the gun to blow any remaining paint back into the container.

Cleaning the Attached-Container Spray Gun	
Step	**Action You Take**
3	• Empty the container. • Rinse it thoroughly with the proper cleaning agent. As mentioned earlier, this depends on the type of paint you have used.
4	• After you rinse out the attached container, put a small amount of cleaning agent in the container. • Spray it through the gun as if you were painting. • Repeat until the cleaning agent at the end of the fluid stream is clear.
5	• Remove the nozzle or air cap. • Immerse the nozzle or air cap in the cleaning agent. • Clean thoroughly.

Use a stiff-bristled nonmetallic cleaning brush to remove any remaining paint from the air cap or nozzle after cleaning them in the solvent. Do not use any sharp-pointed metal object to do this because you can ruin the tiny holes in the air cap or nozzle.

Cleaning pressure-feed spray equipment

To clean the pressure-feed spray equipment, observe the steps described in the following table.

Cleaning Pressure-Feed Spray Equipment	
Step	**Action You Take**
1	Release the pressure on the container. Blow the fluid back through the system in the same manner as you do for the attached-container type gun.
2	With cleaning tank: This is a small container for cleaning purposes. • Fill this container with the cleaning agent. • Disconnect the hose the paint flows through from the tank to the spray gun. • Attach this hose to the container with the cleaning agent. • Run the fluid through the gun. This will clean all the paint from the system. No cleaning Tank: When the smaller container is not available. • Empty the paint from the tank. • Add the cleaning agent to the tank. To determine how much and what type of cleaning agent to add to the tank, follow the directions that come with the equipment you are using.
3	After you clean the spray gun components, use compressed air to blow-dry them.
4	Lubricate all moving parts with the petroleum product recommended in the operating instructions.
5	Clean the inside and outside of the pressure-feed spray tank with the cleaning product recommended in the operating instructions. Use a nonmetallic stiff-bristled brush to remove paint that is hard to remove.
6	Use compressed air to blow dry all of the tank components.

Brushes

Clean paintbrushes immediately after use. If you allow paint to dry and harden, the brushes are hard to properly clean. When you clean a paintbrush, use the same type solvent you used in mixing the paint. Correct and incorrect methods for storing paintbrushes short term are shown in figure 5–19.

The three small glasses on the left show incorrect methods of storing paintbrushes. From left to right, the first glass does not contain enough solvent; the middle glass is not tall enough for the brush; and the last glass is not holding the bristles off the bottom of the glass. The single glass in the right-side illustration on figure 5–19 shows the correct storing method. Notice the bristles do not touch the bottom of the glass and that the solvent comes up to the band of the brush. This method is for short-term use only, such as an all-day project requiring repeated use of the brush. You should not store brushes in an open container of solvent. Ensure you follow local environmental guidance for solvent use and disposal. It may be against the law to have an open container of solvent in the shop.

If you are going to store paintbrushes for any length of time, use the following procedures:

1. Clean them.
2. Wipe them dry as possible.
3. Wrap them in stiff paper to hold the bristles straight.
4. Store them in a dry place.

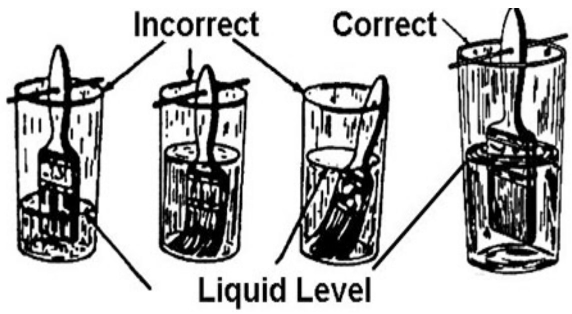


Figure 5–19. Storing paintbrushes.

Using aerosols

Aerosols are simply pressurized cans of paint used for small repair jobs and touch up (spot painting) of a vehicle panel. Many of the concepts you have just read about regarding spray guns apply to aerosols as well, especially operation and resulting paint defects. Two procedures for successful spot painting using aerosol cans are provided in the following two paragraphs.

Keep the route the paint travels as clean as possible

This includes the spray tip and the intake tube that extends into the paint inside the pressurized can. Do this by simply turning the can upside down and pressing the spray tip. By turning the can upside down, you have essentially placed the end of the intake tube above the level of the paint. Pressure inside the can forces the remaining paint that is inside the intake tube out of the can. Now, paint cannot coagulate inside the intake tube. You can also clean the spray tip by wiping it with a bit of reducer or thinner dabbed on a cloth.

Keep the paint well mixed

When an aerosol can sits for extended periods, the heavier material collects at the bottom of the can. Shake the can well! Manufacturers place a small marble inside the pressurized can to break up this collected sediment. As a minimum, you should shake the can until the marble rattles freely inside. Another trick of the trade is to place cold aerosol paint cans in WARM water. This helps bring the cold sluggish paint to a tolerable viscosity for traveling through the typically small intake tubes. Be careful with this though! Use WARM WATER ONLY and follow the cautions on the label. Extremely hot water could help burst the pressurized paint can. It will also introduce you to a common term for aerosols—the spray BOMB.

If you adhere to these two tips, your attempts to spot paint enamel paints will have better results.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

637. Paints and related materials

1. What are the two parts of paint?

2. What determines the physical and chemical characteristics of paint without contributing to the color?

3. How is paint consistency varied?

4. What are the two purposes of the pigment in paint?

5. Which type of paint is most commonly used on Air Force automotive vehicles?

6. List the three types of reducers.

7. What paint defect does using a retarder prevent?

8. Match the paint additive in column B with its use/effect in column A. The functions in column B may be used once or more than once.

Column A	*Column B*
____ (1) Used to help reduce dirt attraction.	a. Hardeners.
____ (2) Normally used in primers and clearcoats.	b. Accelerators.
____ (3) Especially helpful when the temperature is hot.	c. Fisheye preventers.
____ (4) Prevent the effects of silicone contaminants.	d. Flattening agents.
____ (5) Should only be used if absolutely necessary.	e. Flexitives.
____ (6) Help to speed up dry time between coats.	f. Retarders.
____ (7) Catalyzing agents are used in some paints.	g. Static electricity eliminators.

____ (8) Used to slow down dry time and help improve paint flow.
____ (9) Allow the paint finish to flex with the panel without cracking.
____ (10) Can be used to reduce the gloss of the paint.

9. What ANSI grade sandpaper provides a rough equivalent to European “P800” grade sandpaper?

10. What material provides a base for paint and serves as filler for small sanding scratches?

11. Describe the composition of undercoating.

12. What is film build?

13. What component of a paint system is a volatile organic compound?

638. Automotive painting equipment

1. Which office on base would you consult for information about paint booth ventilation?

2. Before you start painting with another type of paint in the paint booth, what should you do?

3. What type of lights do you need inside the paint booth?

4. What is the source of air pressure for spray painting?

5. What valve opens to relieve excessive pressure if the pressure switch does not shut down the electric motor that drives the air compressor?

6. What is the function of the air transformer (regulator)?

7. How often should you open the drain petcock on the air transformer (regulator)?

8. What is polymerization?

9. What is the purpose of the respirator mask?

10. Which Air Force publication lists the kinds of respirators you should use for painting purposes?

11. What are the storage requirements for respirators?

12. When should you use an air-supplied respirator?

639. Brushes and hand-held paint spray guns

1. What do you use brushes for in body refinishing?

2. What two types of spray guns are used for painting body surfaces?

3. What component controls the air valve in the spray gun?

4. What component determines the size of the orifice air passes through?

5. How do you control the spray pattern of a spray gun?

6. What are three disadvantages with using the siphon-feed spray gun?

7. Under what circumstances would you use a pressure-feed paint tank?

8. What types of paints have popularized HVLP paint systems?

9. Prior to the HVLP systems, what was the accepted method for increasing the rate of paint/coatings application?

10. What air pressure is required to comply with some VOC-related air quality rules?

11. Explain "transfer efficiency."

12. What are the three types of HVLP paint systems marketed today?

13. Which type(s) of HVLP paint gun use a standard shop compressed air source?

14. What is an air conversion unit?

15. What component inside the step-down HVLP paint gun reduces the standard shop compressed air?

16. How many inches should you hold the spray gun away from the vehicle body surface for effective spray painting?

17. What are some factors that could prevent the spray gun's air valve from seating completely?

18. Why should you not immerse a spray gun in solvent during the cleaning process?

19. What can you use to remove any remaining paint on the air cap or nozzle after you have cleaned them using the appropriate cleaning agent?

20. What should you do with the spray gun components after you run solvent or thinner through the system to clean it?

21. How should you care for and store paintbrushes after use?

5–2. Preparation and Application

Up to this point, our discussion has covered painting equipment and materials. We will now turn our attention to preparing the vehicle and applying paint. Some people think vehicle painting is merely picking up a spray gun and spray painting the vehicle. However, it is not quite that easy. Instead, you must spend many hours preparing the body surface before spray painting begins. To prepare the vehicle, you must cover the parts you do not want to paint (such as lights, glass, bumpers, etc.) with masking tape or some other suitable material. In this section, we will first provide the information you need to successfully prepare a metal surface to be painted. We will then discuss mixing and applying coatings; including basecoats, clearcoats, and paint. Finally, we will consider cleaning and rustproofing.

640. Preparation of metal surfaces for painting

Preparing a vehicle for painting means preparing the vehicle's body surfaces so the paint will stick. In many cases, you do not have to remove the old paint. However, if you do not remove the old paint, the new paint adheres to it and not to the body surface. If the old paint should peel or free itself from the metal surface, the new paint will come with it. You need to determine the condition of the old paint before removing it. If the old paint is faded and chalked or chipped in spots, it is not necessary to remove the entire coat. Instead, a good sanding of the faded parts and a feather edging of the chipped spots is all you need to do.

Cleaning

Before beginning preparation for a painting operation, you must be certain the vehicle is thoroughly clean. Remove any wax, grease, oil, or silicones a sanding operation could force into the metal. Sanding without removing these materials could result in embedding them in the metal. If this happens, the paint will not stick. The best way to remove wax or other foreign material is by using a specially blended wax and grease remover. After you remove the wax and grease, do the following:

1. Wash the vehicle with soap and water.
2. Rinse thoroughly with clean water.
3. Use compressed air to dry the body surface.

You are now ready to begin sanding.

NOTE: Different surface preparation procedures are required for polyurethane paints. Always refer to the appropriate technical order when using them.

Surface evaluation

You must check the body surface you are refinishing and determine whether it has good adhesion and rust is not present under the paint. To test for good adhesion, do the following:

1. Sand through the finish.
2. Featheredge a small area.

3. If the featheredge *does not* crumble or break apart, the new paint will adhere with sanding preparation only.
4. If the featheredge crumbles and breaks apart, you must remove the old paint down to the bare metal.

NOTE: Featheredging is gradually sanding from the metal surface outwards towards the paint finish. This does not leave an abrupt edge where the metal and the paint finish meet. If the thin edge does not break or crumble, you can assume the old paint will stay on after you refinish the body surface.

You can detect rust development by pitting, roughness, or bubbling of the body surface. However, sometimes the rust may not have reached a deteriorated stage. Experience will allow you to become proficient in spotting areas that may require examining for rust. Ask your supervisor or other experienced personnel to aid you in identifying areas that may conceal rust such as fender wells, trunks, and cowling panels.

Surface areas with rust or poor adhesion must be stripped to the bare metal. You can use any one of several different paint removal methods. The method you select is determined by the requirements of the individual task and the available equipment. Most shops you will work in have power grinders or disc sanders.

- Power grinders have quite abrasive wheels and, very quickly, can eat through paint and metal if you are not careful.
- Power disc sanders are usually the most convenient tools available for removing paint from an auto body surface. Because you normally have so many different grits (abrasiveness of sandpaper) available, it is more practical to use a disc sander in place of a grinder. Since we covered disc sander operation in an earlier lesson, we will not repeat the information here.

NOTE: Never operate the power disc sander without wearing a respirator, hearing protection, and the proper eye protection. A respirator will protect you from the small fine particles of pollutants that, if inhaled, remain in your lungs and can cause emphysema or other maladies later in life. Even though some sanding equipment comes with vacuum-type attachments that help to remove pollutants before they become airborne, you should still wear protective respirators.

If your shop has the proper equipment, sand or media blasting is one of the easiest and most economical methods of paint removal. This system combines forced air with an abrasive material and concentrates the combined materials to rapidly chip the paint away. This method is particularly well suited for completely removing paint from large surfaces that are not prone to warping. Newer equipment may contain vacuum and filtration systems that capture and recycle the abrasive for future use.

NOTE: Sandblasting can warp thin steel metals, aluminum, plastics, and other flexible materials.

On occasion, it may be necessary to use a paint-stripping compound (paint remover). Directions for using a specific remover are printed on the container. Due to state or local EPA laws that may forbid the use of certain paint strippers, always consult your local environmental experts or bioenvironmental engineering before using any paint stripper. Follow these procedures when using paint stripper:

1. Brush the compound on and allow it to set a predetermined time.
2. Remove the softened paint with a scraper, wire brush, or possibly even a shop towel.
3. Do not allow the paint stripper to come in contact with aluminum components or with rubber seals.

Once you have removed the paint, you must treat bare metal areas with a metal conditioner to neutralize rusting action. Before painting, you will need to etch the metal for better adhesion of new paint. This assists with preventing paint from peeling. There are chemicals you can use to etch the metal.

Sanding preparation

After all collision damage has been repaired, all new and fabricated components are in place, and the paint and rust removal have been accomplished, it is time to sand. Sanding is one of the most important steps in vehicle surface preparation. If not done correctly, the new paint will not adhere to the prepared surface, resulting in having to complete the entire job again. As with all things, practice and experience will be your best teachers.

As previously mentioned, grit relates to abrasiveness. On the backside of sandpaper, you will find a number. The higher numbers indicate *less abrasive* sandpaper (leaves smooth surface), while the lower numbers indicate *more abrasive* sandpaper (leaves rougher surface).

There are three types of sand paper available for use, including aluminum oxide, silicon carbide, and Zirconia Alumina.

- Aluminum oxide and silicon carbide are the two most popular abrasives. Aluminum oxide is harder than silicon carbide and is used primarily with disc sanders to sand metal surfaces.
- Silicon carbide, in contrast, is good sandpaper for sanding paint finishes.
- Zirconia Alumina is the most limited in grit variances

The following table will help you choose the right grit for the right job.

Sand Paper Grit Sizes				
Grit	**Aluminum Oxide**	**Silicon Carbide**	**Zirconia Alumina**	**Primary use for collision repair**
Micro-fine	_	2000 1500 1250	_	Basecoat-clearcoat paint systems.
Ultra-fine	_	800	_	Color sanding.
Very-fine	_	600	600	Color sanding and sanding paint before polishing.
	400 420 280 240	400 420 280 240	400 280 240	Sanding primer-surfacer and paint prior to painting.
	220	220	_	Sanding of top coat.
Fine	180 150	180 150	180 150	Sanding of bare metal and smoothing old paint.
Medium	120 100 80	120 100 80	100 80	Smoothing old paint and plastic filler.
Coarse	60 50 40 36	60 50 40 36	60 40	Rough sanding plastic filler.

There are power tools to help in heavy sanding requirements for surface preparation. Delicate and final sanding preparations are usually performed by hand. The two types of methods used are block sanding and wet sanding.

Block sanding

Block sanding is a simple back and forth action with the sand paper mounted on a sanding block. It is often used on large flat surfaces. It helps to level the surface or make it flat depending on the panel contour.

Wet sanding

Wet sanding can be accomplished by hand or by using a sanding block. It is used when finer grit of sand paper is required for a smoother finish. The addition of water helps to keep the sand paper from clogging up. In essence, the water flushes out the sanded particles from the paper.

- Never apply too much pressure to the wet sandpaper.
- Never sand an area more than 1-square-foot at a time.

Keep dipping the sandpaper in water to rinse the paint from the sandpaper. Further, periodically squeeze water from a sponge on the body surface you are sanding.

After you have completed the sanding process, do not be in too big a hurry to cover the body surface with paint. There is one more step. Remember, paint will adhere only to a body surface that is both physically and chemically clean.

- Wash the vehicle again with soap and water.
- Be sure to rinse thoroughly with clean water.
- Dry the body surface with compressed air.

NOTE: When using compressed air, ensure that all the protective gear is being worn and the area is clear of unprotected personnel.

The force of the compressed air against the body surface will remove any foreign material or water from its small scratches and crevices. You will probably be tempted to rub your hand over the clean metal to check for smoothness. Do not! Once you have cleaned the body surface, the natural oil from your skin can keep the paint from sticking wherever you touch. Be extra careful not to touch the surface you are going to paint.

Masking

Masking is the process of covering and protecting surfaces you do not want painted. Your shop should have a large roll of masking paper. Use this paper to cover large areas; masking tape holds it in place. Cut the paper slightly smaller than the area you are covering. The masking tape you use to hold the paper in place overlaps the edges of the paper, ensuring the entire area is covered. For example, if you have to cover an area 27 × 18 inches, cut the masking paper 26 ½ × 17 ½ inches. The masking tape is wide enough to overlap the paper and cover the exposed ½-inch area around the paper's edge. If you use two pieces of masking paper to cover a large area (windshield), start at the bottom and lap the next piece of paper over the bottom one. This permits water and other foreign debris to flow over the paper edges and not run inside. When covering a large area, apply masking tape over the edges where two or more pieces of masking paper overlap, sealing the edges together.

Cover small areas or irregularly shaped items such as data plates, gauges, door handles, marker lights, etc., entirely with masking tape. Select the tape width most suitable for the particular job you are doing. Use a masking tape that will not come loose if small quantities of water contact the adhesive holding the tape to the vehicle components. Never attempt to apply or remove any masking tape when the temperature is below 50° F, as adhesion transfer is greater below this temperature. Additionally, never try to remove masking tape while the paint is wet or tacky. Instead, be patient; wait until the paint is completely dry and dust free before removing the tape. Always store masking tape away from heat, but never store it in a cold place.

NOTE: Never use newspaper to mask over a painted body surface. The solvents in the paint you are applying can dissolve the newspaper ink and carry it to the paint on the body surface.

As a last resort, you can use paste-like materials, such as grease or high viscosity oil, to cover gauges, lights, etc. This is a last-resort practice because some of the additives in these petroleum products can cause discoloration of certain paints. Once the paint dries, wipe all of this material off with a soft cloth. Using a soft cloth prevents scratching the paint surface.

Mask radiator cores to protect them from overspray. If you do not, engine overheating may result from paint adhering to and insulating the radiator core. Take the little extra time to cut the masking paper to cover the radiator core. Use masking paper and masking tape to completely mask off the tires of the vehicle. Pleat the edges of the masking paper so it conforms to the circular shape of the wheel rim. Use masking tape to secure the masking paper. Your shop may make wheel coverings from flexible material (canvas or vinyl) to protect the wheels and tires from overspray and to speed up the masking process. If they are available, use them.

To save time when you are spraying engines, use “bandages” and “socks” instead of masking tape to protect rubber hoses, the ignition system, and flexible tubing. Bandages are pieces of cloth with drawstrings at each end or around the center. Tuck the bandages around the parts you are protecting and tie the drawstrings to secure the bandages. Socks are cloth bags, which fit over the unit and are tied at the bottom.

641. Mixing and applying coatings and paint defects

You must exercise great care when mixing the paint materials you are going to apply to a vehicle. All paint manufacturers publish manuals and bulletins explaining how you should use their products. Due to space limitations, we will not attempt to go into detail on each product. However, we will discuss the materials that are essential to the mixing process—the solvent or reducer used to gain the proper paint consistency. No discussion of the mixing process can take place without a firm understanding of the characteristics and use of these materials.

Solvents

Solvent selection is very important in the mixing process; solvents are used to reduce (reducer) or thin (thinner) the paint to the correct viscosity for spray painting.

- *Reducers* are used for synthetic-base products.
- *Thinners* are used for acrylic-base products.

The types of solvent used controls paint flow and drying time. Solvents are available in several evaporating rates.

Reducers and thinners are not interchangeable except for solvents designated as “all purpose” solvents or retarders. The table that follows gives a general idea of mixing ratios when the label directions indicate percentages for mixing. You decide what the “part” measurement will be (pint, quart, etc.).

Percent Reduction	Mixing Ratio	Paint Material	Solvent Material
12 ½	8:1	8 Parts	1 Part
25	4:1	4 Parts	1 Part
33	3:1	3 Parts	1 Part
50	2:1	2 Parts	1 Part
75	4:3	4 Parts	3 Parts
100	1:1	1 Part	1 Part
125	4:5	4 Parts	5 Parts
150	2:3	2 Parts	3 Parts
175	4:7	4 Parts	7 Parts
200	1:2	1 Part	2 Parts
225	4:9	4 Parts	9 Parts
250	4:10	4 Parts	10 Parts
275	4:11	4 Parts	11 Parts
300	1:3	1 Part	3 Parts

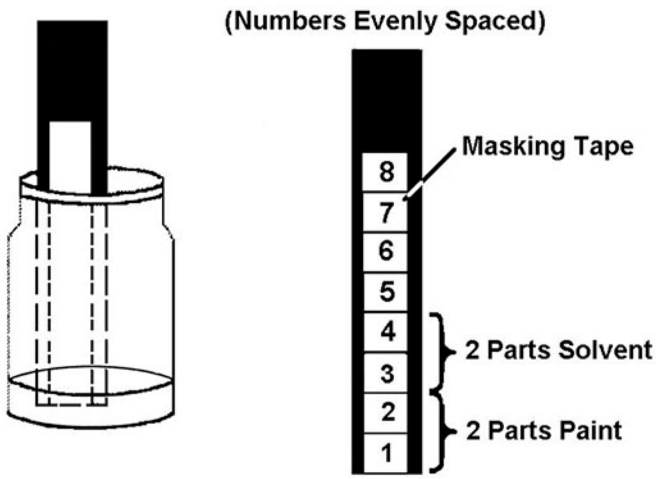


Figure 5–20. Mixing paint and solvent with marker.

You can make a homemade rule for measuring the "parts," illustrated in figure 5–20.

- Use a wooden paddle.
- Cover it with masking tape.
- Mark the amount of "parts" evenly apart on the paddle.

This is a quick method and you will not have to pour the contents into the spray gun container from two different measuring containers. Add the solvent or reducer to the paint slowly and stir the paint at the same time. If you add the solvent or reducer to the paint too fast, you will end up with a seedy-looking paint finish.

Mixing procedures

Now that you have a better understanding of solvent or reducer characteristics, let us look at paint mixing procedures.

Primers

Normally, these products have mixing instructions on the containers. It is imperative that you follow these instructions for the best results. It is advisable to use a synthetic based primer-surfacer to fill in slight imperfections in the body surface. Depending upon the severity of the imperfections in the body surface, you can increase or decrease the viscosity of the primer-surfacer.

- Increase the viscosity (make it thicker) for filling in larger imperfections.
- Decrease the viscosity of the primer-surfacer (make it thinner) for very light imperfections, like small scratches.

NOTE: If you increase the viscosity too much, you will apply a too thick primer-surfacer coating.

This results in cracking. The primer-surfacer, like the primer, adheres to the metal surface very well and permits a good bond for the paint to adhere properly. If the imperfection is too large for the primer-surfacer to fill in, use putty between the primer-surfacer and paint. Apply a thin coat of primer-surfacer or a sealer over the putty before you apply paint over the primer-surfacer and repaired imperfection.

Use a regular primer for adhesion to special surfaces such as aluminum, galvanized metal, etc. Do not use a regular primer for filling in small imperfections in the body surface.

Sealers

The purpose of sealers is to prevent the following:

- Solvent penetration from a new coat of paint into the previous coat of paint.
- Adverse reaction between the new coat and the old.

You do not mix sealers with other materials, and you apply them in their natural state. Different types of paint require a separate type of sealer.

Paints

Just as it is important to use the correct solvent for the type of paint you are applying, you must also mix it into the paint using the proper proportions and procedures. Failure to do so may result in a paint that does not spray or atomize correctly, an inaccurate pigment color, or a poor finish quality. In the following table, you will find general information for mixing polyurethane, and synthetic and acrylic enamel paints. As a reminder, always follow any instructions included with the product with which you are working.

Mixing Paint

Type	What To Do
Polyurethane	Before mixing, thoroughly agitate each component (preferably with a mechanical shaker) in a paint booth. 1. Make sure there is adequate exhaust ventilation. 2. After agitation, pour the components into separate containers. 3. Then combine the resin and catalyst in the proportions recommended by the manufacturer. Use only resin and catalyst from the same manufacturer. 4. Mix only the amount of paint you will use within a 2-hour period. **WARNING:** When mixing polyurethane materials, avoid breathing in any of the vapor, or making skin contact with either liquid or vapor. Consult the local base bioenvironmental engineer for protective clothing guidance before mixing or painting. You must meet bioenvironmental engineer requirements for respiratory protection.
Synthetic and acrylic enamel	For synthetic enamel, the mixture is normally 1-quart reducer per gallon of enamel or ½-pint reducer per quart. Mix acrylic enamels at the rate of 1-quart reducer to 2 or 3 quarts of acrylic enamel, depending on shop conditions. Since enamels dry from the inside-out, you do not have to use a rubbing compound or polishing agent with acrylic enamels.

Applying coatings

Once you prepare the body surface for refinishing, you must apply the primer and finish coats of paint. To do this successfully, consider the following factors:

- Type of vehicle you are going to paint.
- Correct primer-to-paint relationship.
- Selection of the right type and amount of paint.
- Proper paint mixture.
- Correct air pressure for spraying the paint.

Primers

Primers are very tough materials that withstand hot and cold temperatures. They are water-resistant and are chip-resistant from sand and gravel. Lacquers, acrylic lacquers, polyurethane, and enamels all require a primer-surfacer before they are applied to bare metals. Synthetic primers have replaced old-type oil-base primers. These synthetic primers have been made especially for synthetic and acrylic enamels.

As you apply primer, it penetrates into the valleys and cavities of sanding scratches and surface irregularities. Good adhesion between the primer and metal is very important. First, it protects the bare metal surface. Secondly, the primer is the basecoat for the finish coat.

Apply the primer with a spray gun once you have cleaned and prepared the body surface (preferably within 24 hours, if possible). When applying a heavy coat of primer, one-pass results in poor adhesion. Further, too heavy of a primer coat will not dry properly. Instead of a heavy coat, always apply primer in several wet applications. Wait between the applications for the solvent to flash dry (tacky). Once the primer dries thoroughly, wet sand it with 320–400 grit wet sandpaper. Do not apply too much pressure during your sanding operation; instead, let the abrasiveness of the paper do the work for you. If you sand the primer to the metal surface, you will have to apply another coat of primer. After successfully sanding the primer, you are ready to apply the first coat of paint.

Sealers

If you use acrylic enamel, it is best to use a sealer. The proper sealer presents an even, thin surface that will prevent the solvents of the new finish from penetrating into the old finish. You also apply sealers to give the topcoats greater gloss. Apply sealers in their natural state with a spray gun. Do not sand a sealer because this removes a great part of its effectiveness.

Enamels

After you sand, clean, and prime the body surface you are going to paint, using the procedure in the following table:

<table>
<tr><th colspan="2">Applying Enamels</th></tr>
<tr><th>Step</th><th>What To Do</th></tr>
<tr><td>1</td><td>Use a clean tack rag to remove dust and lint.
A tack rag is a piece of cheesecloth dipped in a thin nondrying varnish and rung out.
Keep this cloth in a container so the varnish will not harden, but remains tacky.</td></tr>
<tr><td>2</td><td>For the first coat, use a thin mixture of enamel that will dry quickly. Apply a thin coat and let it dry just enough to provide a tacky surface—that is why it is called a tack coat.</td></tr>
<tr><td>3</td><td>Apply the second coat.
Mix the enamel for the second coat to the specifications provided by the manufacturer.
Apply the second coat to produce a smooth, even surface—free from runs, sags, and overspray.</td></tr>
<tr><td>4</td><td>If paint drying equipment is not available, allow the new paint to dry in a dust-free area for at least 12 hours.</td></tr>
</table>

Acrylic

After you sand, clean, and prime the body surface you are going to paint, use the procedures in the following table:

<table>
<tr><th colspan="2">Applying Acrylics</th></tr>
<tr><th>Step</th><th>What To Do</th></tr>
<tr><td>1</td><td>Use 55 to 60 psi air pressure. Spray one full wet coat or one even double-coat.</td></tr>
</table>

Applying Acrylics	
Step	**What To Do**
2	Allow sufficient drying time (normally 20 minutes) for this coat to set and form a good color seal (flash-off).
3	Apply a second coat in the same manner. Apply a third coat if necessary.
4	Air dry (normally 10 to 15 minutes) and force dry for a maximum of 30 minutes at 180°F, or simply air dry overnight.

NOTE: If you don't have a gauge to check the air pressure at the spray gun, take a plain piece of white paper and attach it to a larger object you do not mind getting paint on. Set the air pressure rather low and make a fast sweep with the spray gun across the plain paper. Look at the small paint particles landing on the paper. If they are not uniform in size, increase the air pressure approximately 5 psi and repeat the sweep across another piece of plain white paper. Inspect the paint particles once again and repeat if necessary until you get uniform paint particles on the paper. You will know you have the correct air pressure when the paint particles are uniform in size.

Polyurethane

As you apply polyurethane, be sure to use an approved respirator and protective clothing and use the procedures in the following table.

Applying Polyurethane	
Step	**What To Do**
1	When applying more than one coat of polyurethane, allow a *minimum* of 30 minutes and a *maximum* of 4 to 6 hours *between applications*.
2	To keep a uniform dispersion of the pigment, intermittently agitate or stir the mixture during the application process.
3	Avoid heavy application of each coat.
4	Curing time varies according to temperature and humidity. Under normal conditions with temperatures of 60 ° F or higher, allow 6 hours before removing masking paper or applying decals.
5	Allow 24 hours curing time before using the vehicle.

Paint defects

There is a cause for every paint failure, and in most instances, you can prevent the failure by observing specific precautions and instructions. The main cause of paint failure is poor preparation of the body surface. The failures you will see most often (fig. 5–21) are discussed in the following table.

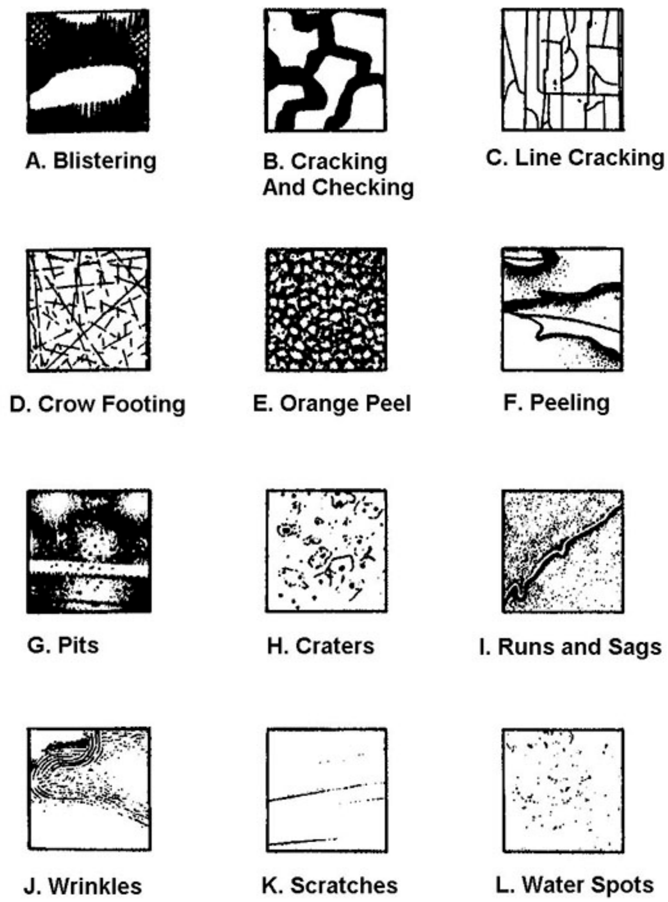


Figure 5–21. Paint failures and defects.

Paint Failures & Defects	
Defect	**Cause**
Bleeding	Occurs when old coat colors mix with those of the new coat, creating discoloration or seeping into the new coat.
Blistering	This condition (fig. 5–21, View A) is very hard to identify without the aid of a magnifying glass. In some instances, you may confuse blistering with dirt in the paint. Accomplish the following to verify blistering has occurred: 1. Prick the suspected areas. 2. Note if holes exist under the bubble.
Bruising and chipping	Gravel, stones, and other material striking the painted surface cause this condition. A fault in the finish is not a cause.
Cracking and checking	This may develop the appearance of cracking, checking (fig. 5–21, View B), or line cracking (fig. 5–21, View C). Cracks in the undercoat normally cause cracking, and appear as depressions in the paint film. Temperature stress, flexing of body panels, second-coat application before the first coat is dry, or improperly mixed paint can cause simple line checks.
Crowsfooting	These are small lines branching off in all directions and giving the appearance of a crow's foot (fig. 5–21, View D). It is normally caused by either of the following: • Spraying the second coat before the first coat is dry. • Spraying too thick a coat. • Using solvents that evaporate too rapidly.

Paint Failures & Defects	
Defect	**Cause**
Orange peeling	The orange peel defect (fig. 5–21, View E) is caused by either of the following: • Improper thinning of the paint. • Using improper air pressure at the spray gun. • Selecting an incorrect solvent that dries too quickly.
Peeling	Peeling (fig. 5–21, View F) occurs when large areas of the enamel or the primer coat separate from the primer coat or metal. This is usually caused by moisture, wax, grease, rust, or oil under the paint. Do not confuse this with orange peel.
Running, sagging, and wrinkling	Running or sagging may appear in the form of teardrops or sagging lines (fig. 5–21, View I). Normally these lines are quite soft and sometimes appear wrinkled (fig. 5–21, View J). Applying too much paint or hesitation in the stroke of the spray gun causes any of these three defects.
Scratches	Thin marks or tears may partially or completely penetrate the surface of the finish coat of paint (fig. 5–21, View K). Correction of scratches depends on their depth. You can normally remove a very light scratch by using a rubbing compound. If the penetration of the scratch is deep, you will have to remove the paint from the body surface's surrounding area and apply a new finish.
Pits and craters	You can identify this (fig. 5–21, View G and H) by the appearance of small round depressions in the paint. These are caused by the following: • Applying the second coat before the first coat is dry. • Failing to remove silicone polishes before repainting.
Water spotting	This appears as a milky pattern where water drops (fig. 5–21, View L) have fallen. You should try polishing first to correct spot discoloration. It may be necessary to refinish the affected area.

There are numerous other defects such as blushing, chalking, dulling, flaking, etc. Most of the defects damage the vehicle's appearance so much you must remove the finish down to the metal base. Naturally, this means you will have to refinish the body surface.

642. Applying basecoat/clearcoat products

As you can probably tell from its name, a basecoat/clearcoat is nothing more than a combination of two types of coatings to produce a vehicle finish. At this point, it is critical to our discussion to emphasize rule number one: ***Do not mix brands of products!***

This rule applies from the primer to the final clearcoat. It also applies to solvents and reducers. Different brands may not have compatible ingredients in subsequent coatings. Following this rule will help to prevent numerous defects and having to strip each coating down to the bare metal to begin again. You will save yourself from headaches in the end!

This paint system was developed to provide a better and more durable paint finish. The first step in the system (after preparing the surface) is an application of a basecoat or "color" coat, followed by a clearcoat. The basecoat provides the paint color. Alone, the basecoat has no shine and is susceptible to the ultra-violet (UV) rays of the sun. The clearcoat gives the paint finish its shine and protects the basecoat from UV rays. Without the clearcoat, the basecoat would deteriorate quickly (several weeks to months). Together, the basecoat/clearcoat system protects the entire car finish from the environment and provides added depth and luster.

The following are the four basic repair methods for basecoat/clearcoat finishes:

- Spot/partial repair.
- Full panel repair.
- Exterior flexible part painting.
- Repair without painting.

NOTE: Any necessary body repairs are assumed to be completed.

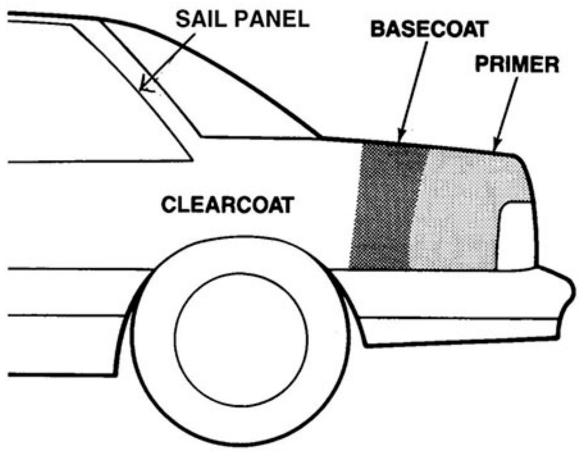


Figure 5–22. Spot/partial repair.

Spot/partial repair

A spot/partial repair is required on panels that do not have a good break line, such as some quarter panels. The repair requires the spotting in (spot painting) of the basecoat and a clearcoat over the entire panel. In this example (fig. 5–22), blending of the clear is required where the sail panel meets the roof. If the area to be blended will not hide well, the adjacent panels should be clearcoated.

In addition, a panel with clear break lines can be a partial repair when the clearcoat is only painted to that line. An example is part of a door panel with a body side molding.

This type of repair can be divided into three actions: preparation, application of the basecoat, and application of the clearcoat. It will be very helpful in this section if you closely view the text and graphics together.

Applying Basecoat/Clearcoat	
Preparation	
Step	**What To Do**
1	Wash the entire repair panel with water and a mild detergent. Rinse it thoroughly.
2	Clean the entire panel with a wax and grease remover.
3	Sand the repair area. Feather out damaged areas.
4	If the paint has been sanded through to bare metal, prepare the bare metal surface with a metal cleaner/conditioner. Self-etching primers already contain metal conditioning properties.
5	Clean the entire panel again to remove any sanding residue. You can use compressed air as well as wipe the panel clean with the appropriate cloth.
6	Prime the repair area in three coats (fig. 5–23).

Applying Basecoat/Clearcoat

7 — Sand the primed repair panel.

- Use 360–400 dry grit or wet sand with 500–600 grit sandpaper.
- Scuff sand with 1200 grit or finer sandpaper the panel areas that only require clearcoat. Scuff the clearcoat blend area (figure 5–24) with 1200 grit or finer sandpaper.
- Hand compound the area.
- Sand the blend area 4 to 6 inches past where you will be blending your clearcoat.

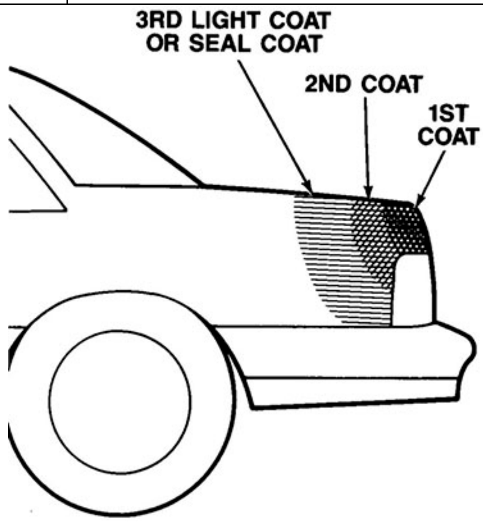


Figure 5–23. Priming the panel.

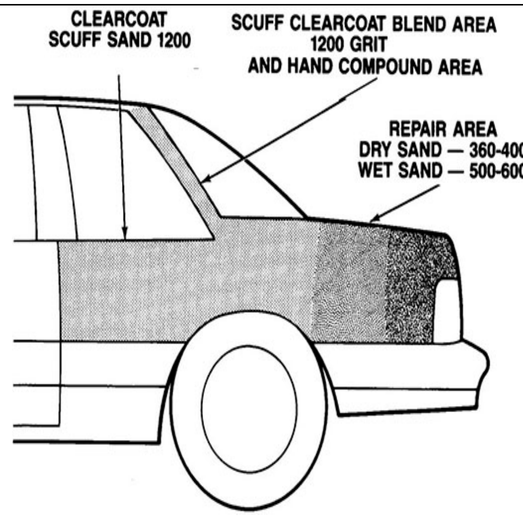


Figure 5–24. Sanded panel for basecoat/clearcoat.

Basecoat Application

1	Check paint manufacturer’s basecoat label and mix the basecoat to the recommended manufacturer’s specifications.

2 — Apply the first coat of color to the repair area only (fig. 5–25).

- For best results, avoid sanding the basecoat at any point in the application process.
- Use 30 to 40 psi of air pressure at the paint gun.
- Allow 5 to 10 minutes flash time between each coat of basecoat color. (Flash time is the time needed for solvents in the paint to evaporate.)

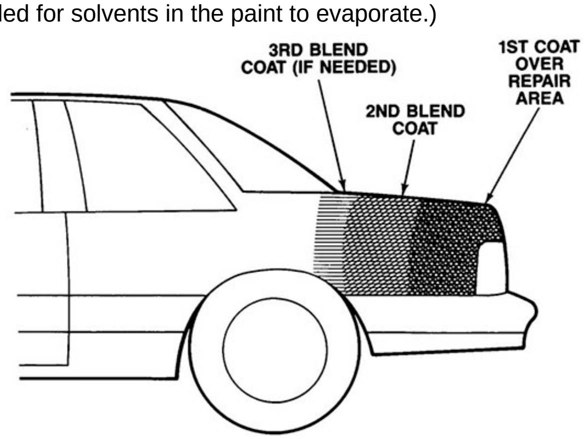


Figure 5–25. Applying the basecoat.

3	Apply a second coat of basecoat color to the repair area. Blend approximately 4 to 6 inches beyond the repair area.

Applying Basecoat/Clearcoat	
4	If two coats aren't enough to hide repairs or color match, perform the following: • Apply a third coat. Blend an additional 4 to 6 inches beyond the previous coat that is already covering the repair. • Do not try to melt-in or sand the dry overspray after you have correctly blended the color. It is not necessary because the clearcoat will accomplish the desired gloss. • If you notice minor defects in the basecoat, you can remove them and reapply the basecoat prior to applying the clearcoat.
Clearcoat Application	
When applying clearcoat on a spot paint operation (if you have a good line break), the job is simplified because you can mask off the remainder of the panel and apply the clearcoat. However, if there is no line break, you need to apply and blend the clearcoat into the panel. Refer to figure 5–26 as we discuss the procedures in the following steps.	

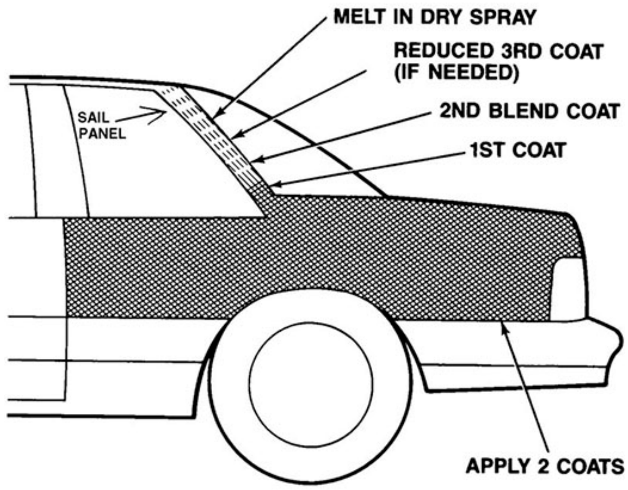


Figure 5–26. Applying and blending the clearcoat.

1	Before spraying the clearcoat, allow the basecoat color to flash between 15 and 20 minutes.
2	Mix the clear coating with any required hardener and reducer to the manufacturer's recommended specifications.
3	Clean the entire repair panel with a clean tack rag.
4	Apply the clearcoat using 50 to 60 psi of air pressure at the gun. • Allow 5 to 10 minutes of flash time between coats. • If the panel you are painting does not have a break line, such as a quarter panel, you will have to blend the clearcoat.
5	Apply the first coat of clearcoat over the entire repair area and approximately 3 to 4 inches before the blend area.
6	Apply the second coat of clearcoat over the entire repair area and into the blend area—approximately 4 to 6 inches past the previous coat. The last (third) coat of clear can be over-reduced to lessen the amount of dry spray. Reduce per the paint manufacturer's recommendations. Allow the last coat of the clearcoat to flash for 5 minutes before melting in the dry spray, if necessary (see next step).
7	Spray light coats of pure reducer to the blend area to melt the dry spray into the existing clearcoat. Use 25 to 35 psi of air pressure at the gun for best results.

Full panel repair

A full panel repair is the blending of the basecoat and clearcoating on the full panel. A fender is good example. Like a partial repair, full panel repair can be divided into the same three actions: preparation, application of the basecoat, and application of the clearcoat.
The actions in the preparation and basecoat application step are identical to the actions needed in spot/partial repairs. The only difference lies in the clearcoat step. Instead of blending the clearcoat, coating you will simply apply it to the entire panel. As you apply the clearcoat, you will need to perform the following:

- Apply two medium wet coats over the entire repair panel using 50 to 60 psi of air pressure at the gun.
- Allow 5 to 10 minutes of flash time between coats.

Exterior flexible part painting

To help avoid cracking, flexible parts require different paint additives and slightly different procedures than nonflexible parts. If the replacement part is a plastic panel, it comes factory-primed with an *elastomeric enamel-based primer*. If you are repairing the panel, prime the damaged area with flexible primer. In either instance, the entire panel needs to be painted according to the procedure in the following table.

Painting Flexible Exterior Parts	
Step	**What To Do**
1	Wash the entire panel with water and a mild detergent.
2	Clean the entire panel with a suitable wax and grease remover.
3	Feather out the repair area. Sand the panel with 240–320 grit sandpaper.
4	Clean the entire panel again to remove any sanding residue. Use compressed air and wipe the panel clean.
5	Prime the panel with a flexible primer. It is essential to use the correct flexible primer on the flexible panel being painted. Improper primer can result in poor adhesion. Check the appropriate technical order for related information. Allow the panel to dry per the manufacturer's recommendations before painting.
6	Sand the primed panel with 400-grit sandpaper.
7	Clean the entire panel again to remove any sanding residue. Wipe it clean with a tack rag.
8	Check the paint manufacturer's basecoat label. Mix the basecoat to the recommended manufacturer's specifications.
9	Apply two to three coats of basecoat to the plastic panel. Apply only enough coats to gain complete hiding and color match. Allow the basecoat to dry to the recommended manufacturer's specifications before applying the clearcoat.
10	Mix the clear with the required hardener, flexible additive, and reducer to the manufacturer's recommended specifications.
11	Wipe the entire repair panel with a clean tack rag.
12	Apply two coats of clearcoat to the plastic panel. Allow 5 to 10 minutes of flash time between coats.

Repair without repainting

Repair without painting is repairing damage to the clearcoat only. This is accomplished through various detailing procedures. If the damage to the paint finish is deeper than the clearcoat or the repair will not leave enough clearcoat to provide adequate basecoat protection, painting is required. As we previously stated, repairing clearcoat imperfections without painting is often called paint detailing. This generally involves some form of light sanding and polishing. While this concept is not new to the industry, the use of clearcoats has created slightly different techniques and products for repair.

When sanding and/or polishing the clearcoat, make sure to leave enough clearcoat to provide adequate UV protection. Before attempting a paint detail, see if the damage has broken through the clearcoat or if sanding may cause you to break through the clearcoat. If so, you will need to prepare to recoat the panel with clearcoat. A mil is defined as a thousandth of an inch (1 mil = .001 in.), which is the minimum thickness that you need for adequate UV protection for the basecoat. To give you some perspective here, the clearcoat is typically only 1.5 mils; the entire coating thickness for domestic vehicles is 3 to 5 mils. Therefore, you can see paint detailing for basecoat/clearcoat paints is really dealing with removing the whisker from a gnat, so to speak. There are electromagnetic thickness gauges in addition to mechanical gauges that you can use for measuring a coating's thickness. If you are unsure of the amount of clearcoat remaining, prepare the repair panel and apply new clearcoat over the entire panel. Further, if you require a grit coarser than 600 to remove a defect, recoat the clearcoat over the entire panel.

Identifying the paint damage

Some paint damage can be repaired without painting (fig. 5–27). Inspect the damage carefully before starting a repair to avoid unnecessary painting.

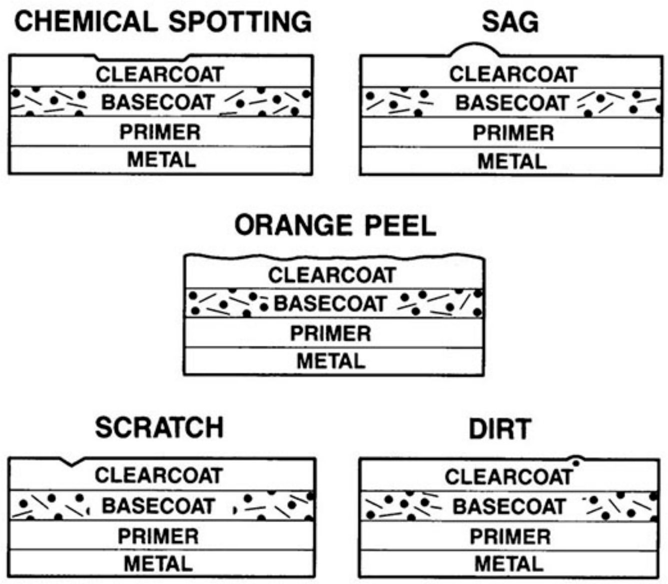


Figure 5–27. Repairable defects in a clearcoat.

Repair methods

All repair methods require thorough cleaning before starting the repair. Always wash the area with mild detergent and water; afterwards, clean with wax and grease remover. There are several tools available for repairing clearcoat defects. These include the dirt-nib file, sanding blocks, orbital sanders, foam backing pads, terry cloth bonnets, and numerous polishing compounds.

Clearcoat Defect Repair	
Method	**What To Do**
Dirt-Nib File	A fast and easy way to remove dirt spot or paint sag without sanding is by using a small dull file called a dirt-nib file. Figure 5–28 illustrates how to fabricate one from an unserviceable vixen file. The dirt nib file will level the spot even with the level of the clearcoat. Then all that is needed is minor polishing to return the original shine to the repair area. To use a custom dirt-nib file as just described, preform the following: 1. File the dirt spot or minor sag. 2. Apply a straight short stroke in one direction directly over the repair area. One

<table>
<tr><th colspan="2">Clearcoat Defect Repair</th></tr>
<tr><th>Method</th><th>What To Do</th></tr>
<tr><td></td><td>
or two strokes should be enough to remove the defect.

3. Polish the repair area.

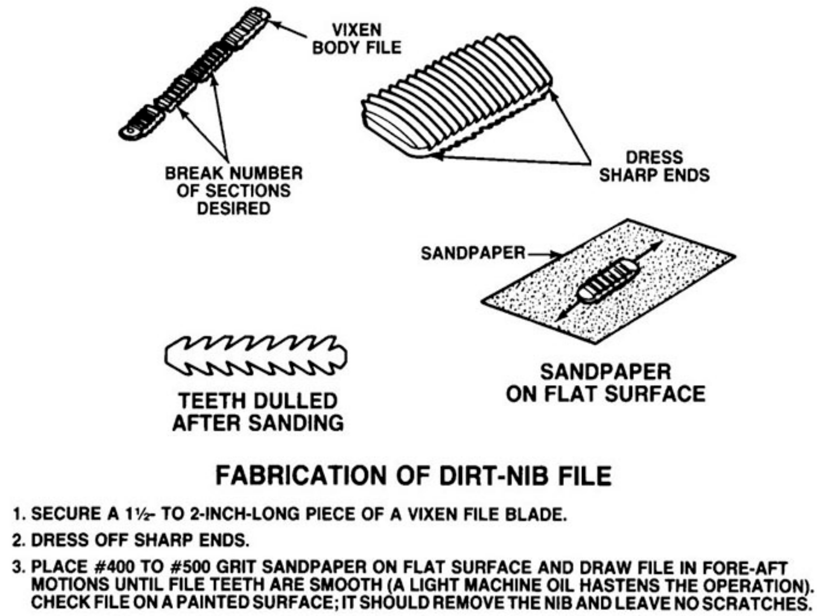


Figure 5–28. Dirt nib file.
</td></tr>
<tr><td>Sanding Blocks/ Pads</td><td>
Many types of sanding pads, blocks, and sponges are available. Choose the size pad that is most appropriate for your repair damage. To remove a small defect with a sanding block, perform the following:

1. Wet sand the defect with a small sanding pad and fine sandpaper.
2. Keep the area wet with water while sanding to keep the surface smooth and clean.
3. The sandpaper grit used will vary with the amount of damage, but it should be between 800 and 1500. Again, damage requiring the use of 600 or coarser sandpaper will require clearcoating.
4. After the defect has been removed, polish the repair area.
</td></tr>
<tr><td>Machine Polishing</td><td>
These polishing tools include an orbital sander, foam backing pad, and terry cloth bonnet.

The orbital sander and terry cloth bonnet will remove small, localized defects without leaving swirl marks.
</td></tr>
</table>

Paint detailing compounds and procedure

There are various paint detailing products. The following table illustrates some polishes and their uses. On the right, you can identify the paint defect; on the left, you can determine the most effective detail product.

Type polish	Used for
A non-wax, non-silicone polishing glaze	A swirl free paint finish.
Light machine polish	Light spotting. Minor scratches.
Wet sanding and/or machine polish	Orange peel. Deep scratches.

The following is a basic paint detailing procedure. Always follow the product manufacturer's recommended procedure.

1. Thoroughly wash the area with a mild detergent.
2. Clean the repair area with wax and grease remover.
3. Decide if the imperfection can be repaired by polishing only, or if sanding is required.
4. Wet sand the imperfection with 800 or finer grit as needed (depending on severity of imperfection).
5. Polish the imperfection area and blend into the rest of the panel. Keep the polishing pad flat to the panel and apply light pressure; otherwise, you could burn the coating. Panel edges and moldings are especially susceptible to burn through. Fresh paint will burn easier than old paint. Some light imperfections may only need hand polishing.

We have stated many times up to this point that experience is the best teacher. Basecoat/clearcoat is no exception. Once you get the experience, you will undoubtedly find this paint system is simple and easy to use in making repairs.

643. Cleaning and rustproofing

The environment is the single most important cause of rust development on vehicles. Industrial pollution, along with acid rain, contributes to vehicle corrosion. Another contributing corrosion factor occurs in states receiving large amounts of snow—the salt spread on the roads to keep ice from forming. Vehicles operating on these roads pick up the salt, which sticks to the undercarriage and paint finish of the sides of the vehicle. If left unchecked, these will rapidly deteriorate into rusted surfaces.

As you learned in volume one of this course, TO 36–1–191, *Technical and Managerial Reference for Motor Vehicle Maintenance*, contains systematic procedures for applying rustproofing materials. Always refer to this technical order when treating vehicles. Some of the following material you may remember from volume one. Since performing body maintenance is part of your duties as a mission generation vehicular equipment maintenance journeyman, you are especially subject to performing these duties. As a result, a little review and additional information is appropriate. Let us look at some of the most common steps.

Cleaning

The first step in treating any vehicle is to clean all areas. Accomplish this by placing the vehicle on a lift and raising it to a good working level. The best method is to begin at the front and work toward the rear, in this sequence: front splash panel, headlight area, front fenders, panels and supporting members, fender beads, floor pan, rocker panels, quarter panels, gas tank, taillight area, and the rear splash panel. Remove heavy deposits of rust, loose undercoating, mud, and other foreign material by using a wire brush, putty knife, or chisel. Pay particular attention to seams, welds, and corners.

Coating materials are designed to adhere to moist or wet surfaces and to displace water. There may be times when you have to use high-pressure water and soap solutions to clean an extremely dirty underbody. After washing the underbody, you can apply rustproofing materials to the underbody surface.

CAUTION: ***DO NOT use steam*** for cleaning. Hot steam could loosen or remove some of the existing undercoating material.

Application

Spraying is by far the best method for applying the material. Figure 5–29 shows a typical airless-type spray apparatus. Its basic operation is similar to pressure-type lubricators used in lubricating vehicles.

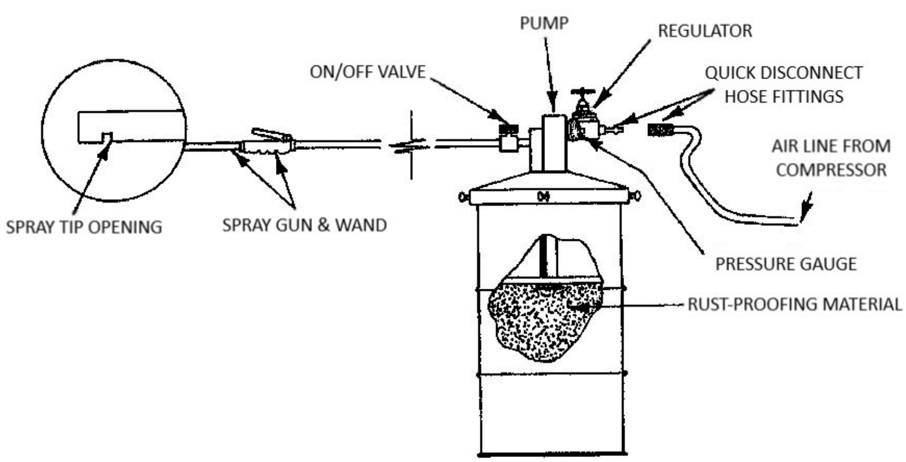


Figure 5–29. Airless sprayer.

CAUTION: Exercise extreme caution when operating these sprayers. Undercoating material discharges from the spray tip opening at extremely high pressure and can easily penetrate the skin. To avoid serious injury, keep your fingers away from the spray tip opening. Additionally, wear gloves and goggles or face shield.

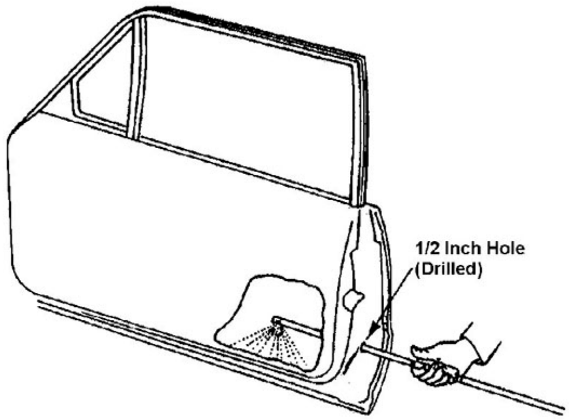


Figure 5–30. Treating the interior of a door.

Most sprayers have various tips and wands for spraying hard to reach areas. However, if there are no existing holes through which you can insert the wand or tip, you will probably have to drill holes in some components to ensure these enclosed places become treated. This normally requires a ½-inch drilled hole (fig. 5–30). Figure 5–30 illustrates a spraying operation inside a door panel. After applying the undercoating, you can cap the hole with a plastic plug made especially for this purpose.

After you complete the spraying operation, check all drain holes (under doors, rocker panels, etc.). Make sure none of the excess material accumulates in the drain area, restricting the drain hole.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

640. Preparation of metal surfaces for painting

1. How can grease, oil, or silicones embedded in the metal affect the refinishing process?

2. What must you do to the body surface prior to the sanding process?

3. How can you detect rusted areas?

4. What is the most economical and easiest method of removing paint from large metal surfaces?

5. What is the purpose of using compressed air to dry the body surface after sanding and washing the vehicle prior to painting?

6. Why should you cut the masking paper 1/2-inch smaller than the area you are going to mask off?

7. If you have to use two pieces of masking paper to cover a large area, how should you position the paper?

8. What should you use to cover irregular shaped components, data plates, gauges, door handles, marker lights, and so forth?

9. What materials can you use (other than paper or tape) in the masking process, but only as a last resort?

10. Why must you protect radiator cores to protect them from overspray?

641. Mixing and applying coatings and paint defects

1. What type of solvent do you use with acrylic-based products?

2. Why is the selection of thinner or reducer so important to the paint mixture?

3. Why would you want to use a primer-surfacer in painting an auto body surface?

4. What would you use to ensure proper adhesion of paint to an aluminum body surface?

5. How much polyurethane paint should you mix at one time?

6. How do enamels dry?

7. What is the purpose of a sealer?

8. What is the minimum drying time for enamel paint when paint drying equipment is not available?

9. How much curing time should you allow before applying decals to polyurethane?

10. What term describes a discoloration caused by old coat colors mixing or seeping into the new coat?

11. What paint defect can be caused by improper air pressure at the spray gun, selecting the incorrect solvent, or improperly thinning the paint?

12. What defect occurs from over application of paint or hesitation in the stroke of the spray gun?

642. Applying basecoat/clearcoat products

1. What is basecoat/clearcoat?

2. What does the basecoat provide to the entire coating in the basecoat/clearcoat paint system?

3. What is the basecoat's weakness?

4. What does the clearcoat provide to the entire coating in the basecoat/clearcoat paint system?

5. What type of body panels require a spot/partial repair?

6. How many coats of primer are applied when priming a repair in the basecoat/clearcoat paint system?

7. How long should you allow for flash time between each coat of basecoat color.

8. As you apply a second coat of basecoat color to a repair area, how far beyond the repair area should you blend the color?

9. When you are removing a defect from a clearcoat, what grit sandpaper will *require* recoating the clearcoat?

10. What is a fast and easy way to remove a dirt spot or paint sag without sanding a clearcoat?

11. When repairing a defect in the clearcoat, what grit sandpaper is appropriate?

12. How should you polish imperfections in a clearcoat surface to avoid burning the coating?

643. Cleaning and rustproofing

1. How can you remove heavy deposits of rust or mud?

2. What should you use to clean an extremely dirty vehicle underbody?

3. Why should you not use a steam when cleaning a vehicle?

4. State an important safety precaution to observe when using an airless sprayer. Why?

5. What is the procedure for rustproofing enclosed areas or hard-to-reach places (such as inside a door panel)?

5–3. Assessing Damage

Accurately assessing collision damage is a very important task you may be asked to accomplish. The major reason is that repair costs for vehicle accidents are generally reimbursable to the vehicle maintenance flight's budget.

644. Fundamentals of damage estimating

Many decisions will ride on your professional skill in estimating repairs. The following are the two most important considerations you will face to help make these estimates.

1. How much the repair will cost?
2. Is this vehicle economically repairable (should an attempt be made to repair it)?

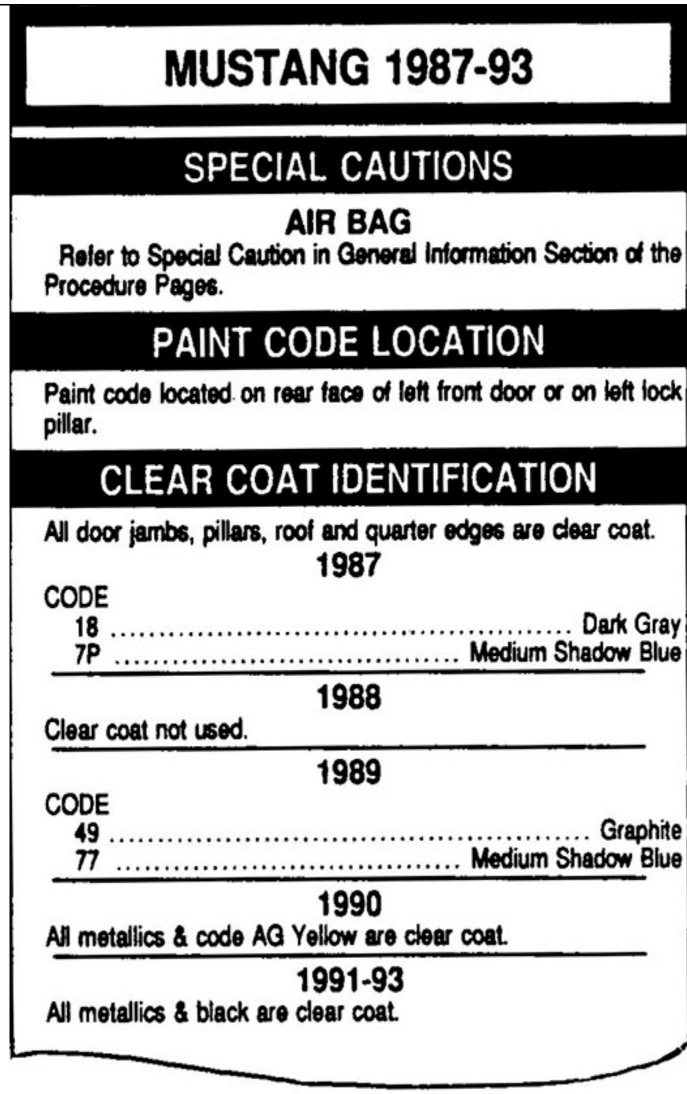
The second consideration is the most important. Therefore, an estimating guide will help you make a decision and is the best and most accurate way to estimate collision damage. Further, this guide will help you develop a system of estimating repair damage. A system not only enables you to perform quick and accurate estimates; it allows you to be quick and accurate every time.

Estimating guide

There are several different producers of collision estimating guides (referred to as the guide). By far, the one most commonly used is published by Mitchell International, a company specializing in repair and estimating manuals. There are also many computer-based collision estimation programs. The computer estimators are pretty straightforward. Plug the information into the program and presto, you have an estimate. Using a paper guide requires a bit more effort. We will focus on using paper guides in this lesson.

In the front of every edition of the guide are some extremely important pages. They are usually numbered P1 through P4. They describe the kind of parts and labor information contained in the guide. They also explain how to properly use the information. While we will not reproduce these pages from the guide, we will cover the basic organization and the information contained in it in the following paragraphs and accompanying tables.

Organization of The Guide	
Section	**Description**
Index	The beginning of each guide has an index listing each model described in the guide. This listing shows the following: • The manufacturer. • Models and years covered. • Body code identification where applicable. To begin estimating, simply locate the model you wish to estimate in the index. Turn to the page number listed. All parts and labor information for the vehicle, beginning with “Front Bumper,” will start on that page.
General Arrangement	The guide is divided into “services.” These are groups of vehicles that are similar enough that all variations can be described more conveniently as a group rather than each one separately. A service normally constitutes the life cycle of a particular body style. For example, a service for the 1987–1993 Ford Mustang is shown in figure 5–31. Information about all body styles, engines, trim, etc., is provided within each service. This means that all relevant collision information on that group of vehicles is in one place. All services within the guide have the major vehicle sections (front bumper, cooling, and engine, etc.) arranged in the same sequence throughout. Once you learn the order of component arrangement, you will be able to quickly locate the major section you desire.

<table>
<tr><th colspan="2">Organization of The Guide</th></tr>
<tr><th>Section</th><th>Description</th></tr>
<tr><td></td><td>


MUSTANG 1987-93

SPECIAL CAUTIONS

AIR BAG

Refer to Special Caution in General Information Section of the Procedure Pages.

PAINT CODE LOCATION

Paint code located on rear face of left front door or on left lock pillar.

CLEAR COAT IDENTIFICATION

All door jambs, pillars, roof and quarter edges are clear coat.

1987

CODE

18 .... Dark Gray

7P .... Medium Shadow Blue

1988

Clear coat not used.

1989

CODE

49 .... Graphite

77 .... Medium Shadow Blue

1990

All metallics & code AG Yellow are clear coat.

1991-93

All metallics & black are clear coat.

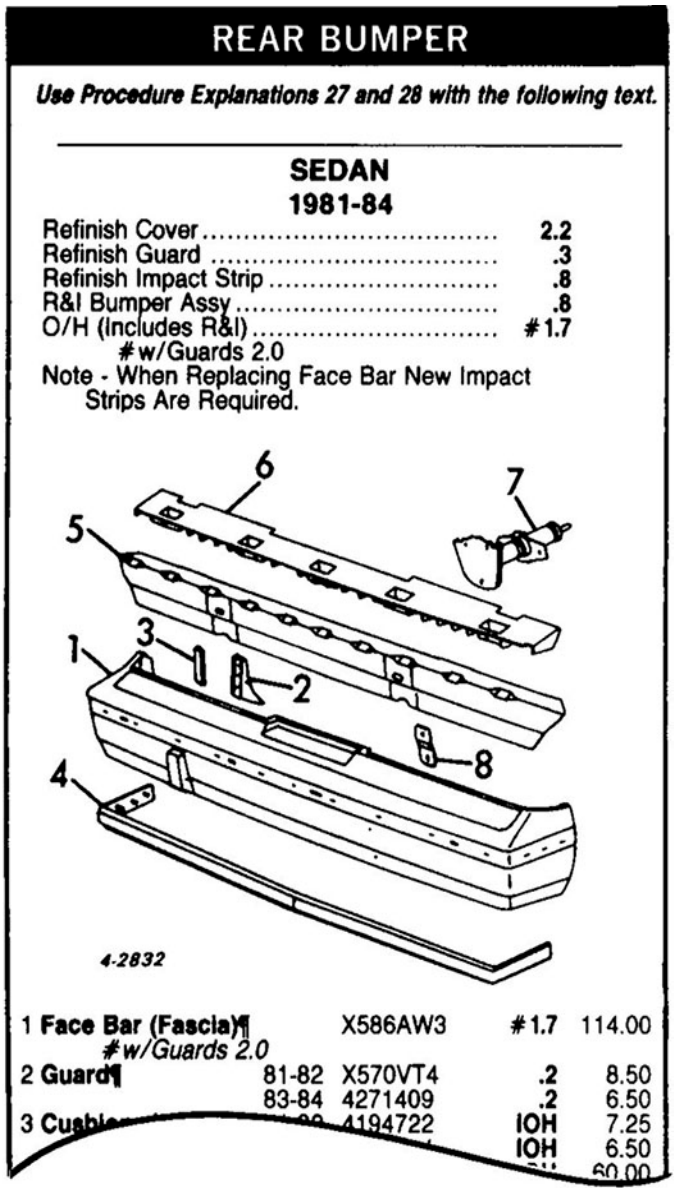
Figure 5–31. Typical “Service” heading.
</td></tr>
</table>

Parts arrangement

Parts information entries detail all collision repair components. Each replacement parts listing is arranged in a logical order within each model section. All parts are keyed (through appropriate part or model numbers) to the respective vehicle. In relation to the vehicle, the parts are listed from front-to-back and from outside-to-inside. Parts listed from each manufacturer’s parts catalog are arranged in an easy-to-use style and are fully supported with illustrations.

The individual part prices are generated from electronic information received directly from the manufacturer. This assures you of accurate, complete, and current prices, as well as listing superseded or discontinued parts information in each issue.

When the electronic information is received from the manufacturer, the guide's database is completely updated and considered accurate as of the time of printing of each issue.

The Guide Parts Section	
Section	**Description**
Parts Illustrations	Parts are illustrated in the guide in exploded view displays (fig. 5–32). Parts most likely to be damaged together are shown together. These exploded views show individual components and their relationship to the complete parts assembly. All parts are numbered with "key numbers." These numbers directly relate each part to the parts listing information contained in the column of text below each illustration. Linking these detailed illustrations to the text on each assembly will help you note parts that you might otherwise have missed.  **Figure 5–32. Typical exploded view.**

<table>
<tr><th colspan="2">The Guide Parts Section</th></tr>
<tr><th>Section</th><th>Description</th></tr>
<tr><td>Part (reference) Numbers</td><td>All parts in the guide are numbered using the most up-to-date part numbers available. They assist the technician by allowing for greater accuracy and time savings when estimating. Parts listed are often noninterchangeable right-hand and left-hand pieces. These normally will have the same price. Where practical, the guide combines the right- and left-hand part numbers into a single line, always listing the right-hand part first (fig. 5–33).

“Left” and “right” are always defined as if you are sitting in the driver’s seat. For example, take part number 4016406–7.

• The right-hand part is 4016406.
• The left-hand part is 4016407.

As stated previously, the right-hand number is always listed first. This applies regardless of whether the right-hand part number is lower or higher than the left-hand side. If the right- and left-side part numbers differ widely, or if a difference in price exists, each will be listed on a separate line and specified. For example:

R - 4016406
L - 7205954</td></tr>
<tr><td colspan="2">

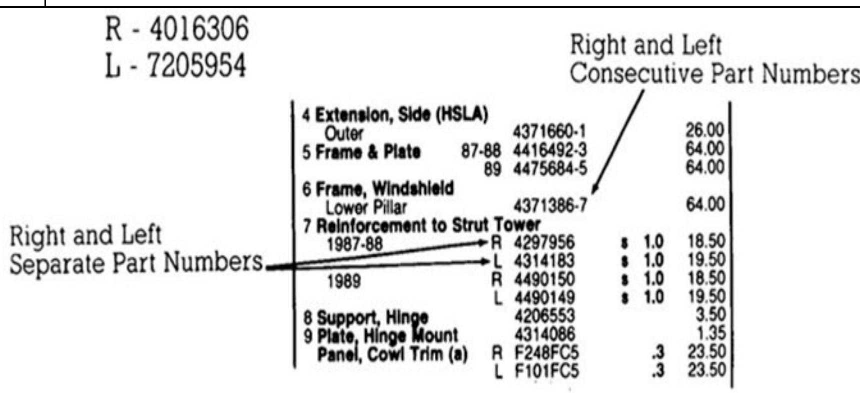


Figure 5–33. Right and left-hand part numbers.

</td></tr>
<tr><td>Interchangeable Parts</td><td>To determine interchangeability, refer to the similar body styles of other models produced by the same manufacturer. Determine if a similar vehicle uses the same part number required for the model being repaired. If so, you have greater flexibility in obtaining the part. For example, you might cannibalize the part from Air Force vehicles being disposed of or from a vehicle on non-mission capable supply (NMCS) status. Therefore, accomplish the following two items to determine interchangeability:

1. Determine the part number of the part in question.
2. Review the sections on similar type body styles to determine if that same part number is used on the respective vehicle.</td></tr>
<tr><td>Parts Prices</td><td>Each issue of the estimating guide carries the latest part numbers and prices available at the time of printing. The prices shown are the manufacturer’s suggested retail price. The price you are actually quoted could vary depending on your parts supply source.

Note that manufacturers sometimes do not provide replacement parts for vehicle glass and you will not see prices for them. However, when the manufacturer does not provide a price, the guide lists all available parts. In this case, a replacement glass price based on the National Auto Glass Specifications, Incorporated (NAGS) is typically listed.</td></tr>
</table>

Labor

The guide has labor procedure explanation pages that explain what IS and IS NOT included in labor operations. This section is an integral part of the guide and should be referred to whenever a damage report is written.

The Guide Labor Section	
Section	**Description**
Labor Times	Labor times shown in the guide are stated in hours and tenths of an hour (six minutes). These labor times are for replacement with *NEW, UNDAMAGED PARTS FROM THE VEHICLE MANUFACTURER ON NEW, UNDAMAGED VEHICLES* using the sequences and procedures listed in each guide. When calculating labor hour estimates, you will have to make extra time allowance for the following additional factors: • Damage requiring additional time to access parts. • Alignment pulls. • Nonoriginal equipment. • Used parts. Exceptional circumstances, including sub-operations or extra operations, are indicated as notes throughout the text or are explained in the procedure explanations. The actual time an individual shop takes to replace collision-damaged parts will vary due to vehicle condition, equipment used, etc. The key point is that the labor times listed serve as a ***starting point*** *for correctly and accurately estimating repair times and labor cost.*
Time Conversions	Labor conversion tables are included in the back of each guide. These charts allow you to convert labor time to dollars. Using the conversion charts, you can quickly and accurately determine your labor charges and more precise repair estimates. The actual hourly rate you use is provided by Fleet Management and Analysis (FM&A).

645. Identifying damages and estimating repairs

When writing a damage report using the guide, list all damaged parts and the labor times in the following manner:

- The front of the vehicle to the rear.
- The outside to the inside.

All parts in the guide are listed in this order. Following this sequence is the best way to track all the damage and reduce the possibility of missing anything. The following paragraphs describe a general procedure for working through the guide and producing an accident report.

Identify the vehicle

When writing a damage report, always record the vehicle identification number (VIN) and production date onto the report. This information facilitates parts ordering because it gives the year and month the vehicle was built, the model, and the engine size. Most VINs are located on a plate attached to the driver's side of the instrument panel, and is visible through the windshield. VIN decoding information is in the VIN Interpretation section located near the front of each guide.

In addition, record the trim and paint color code of the vehicle; this information is required for ordering parts that come in different colors. Paint and trim code plate locations vary from manufacturer to manufacturer, and the easiest way to locate them is by using the Paint Code Location Chart near the front of each guide. Current services also list paint code locations in the Paint Code Location or Clear Coat Identification section near the beginning of the service. Using these sources will save time when estimating.

Use the layout as a guide

The guide's format makes estimating collision damage easier because parts likely to be damaged together are placed together. Sections and sub-sections in the guide are arranged from front-to-rear and outside-to-inside the vehicle for each model. These sections contain the exploded-view illustrations identifying the components and include part numbers, prices, and labor times. The descriptions are carefully laid out to depict the most frequent repairs. By working your way through the sections as you do the damage report, you will be less likely to overlook anything.

The following table is the sequence of sections and sub-sections used in the exploded views and text descriptions in the guide. The major headings SPECIAL CAUTIONS, PAINT CODE LOCATION, and CLEAR COAT IDENTIFICATION correspond with figure 5–31. The sequence shown in the table can also be very helpful as a worksheet when you are actually inspecting an accident. It is somewhat generic and can be used for any type vehicle. You will see that the table follows the front-to-back and outside-to-inside scheme of a good accident estimate. Simply ignore items that do not apply.

Collision Estimating Sequence		
SPECIAL CAUTIONS	STEERING LINKAGE/GEAR	ROOF
PAINT CODE LOCATION	• Manual	• Overhead Console
CLEAR COAT IDENTIFICATION	• Power	• Luggage Rack
INFORMATION LABELS	STEERING PUMP	SUNROOF
FRONT BUMPER	STEERING WHEEL/COLUMN	CONVERTIBLE TOP
BUMPER AND GRILLE	• Standard	PICKUP CAB PANELS
GRILLE	• Tilt	BACK PANEL
FRONT LAMPS	• ENGINE	BACK WINDOW
• Combination Lamp	• Engine Mounts	QUARTER PANEL
• Headlamp	• Engine Oil Cooler	• Sheet Metal
• Headlamp Wiper/Washer	• Air Cleaner	• Exterior Trim
• Signal Lamp	• Exhaust	• Interior Trim
• Driving Lamp	• Intercooler/Supercharger	PICKUP BED
• Parklamp Park/ • Side Marker Lamp	EMISSION SYSTEM	VAN/UTILITY VEHICLE SIDE PANEL
• Side Marker Lamp	ELECTRICAL	QUARTER GLASS
• Fog Lamp	WINDSHIELD	REAR SUSPENSION
HOOD	COWL & DASH	• Level Control
COOLING	INSTRUMENT PANEL	REAR STEERING LINKAGE/ GEAR
AIR CONDITIONING/HEATING	CENTER CONSOLE	REAR DRIVE AXLE
GROUND EFFECTS	ROCKER/PILLARS/FLOOR	LUGGAGE LID
STRIPE TAPE	• Interior Trim	• Luggage Rack
FRONT FENDER	UNISIDE ASSEMBLY	REAR/LIFT GATE
• Exterior Trim	SEAT	• Sheet Metal
• Electrical Components	• Seat Belts	• Exterior Trim
UNDERHOOD DIMENSIONS	• Passive Restraint	• Glass & Hardware
FRONT INNER STRUCTURE	FRONT DOOR	REAR GATE
• Front	• Sheet Metal	• Sheet Metal
• Side	• Exterior Trim	• Exterior Trim
• Sub-Frame	• Interior Trim	• Glass & Hardware
• Electrical Components	• Hardware	FUEL TANK
• Antilock Brake System	• Glass & Parts	REAR BODY
FRAME	REAR DOOR	• Interior Trim
WHEEL	• Sheet Metal	REAR LAMPS
• Steel Wheel	• Exterior Trim	• Combination Lamp

Collision Estimating Sequence		
• Aluminum Wheel	• Interior Trim	• Back-Up Lamp
FRONT SUSPENSION	• Hardware	• License Lamp
FRONT DRIVE AXLE	• Glass & Parts	• Side Marker Lamp
		• High Mount Stop Lamp
		REAR BUMPER

Work through each section

Suppose you have a vehicle that was in a minor front-end collision. The collision crumpled the right front fender, the bumper, and the grille but did no damage to the engine compartment. Begin your damage report with the guide section labeled Front Bumper, after you have noted any special information in earlier sections. (Refer to the preceding table.)

Looking at the illustration of the bumper section (fig. 5–34), begin from the outside of the assembly and work inward. Relate the number next to the component illustrated to the number in the text column. Afterward, simply write down each part as it appears, noting each of the following:

- Part name.
- Part number.
- Labor time.
- Price.

Since the guide is arranged from front-to-rear, most of your estimating on this vehicle will take place within the first few sections (assuming most accidents occur from the front).

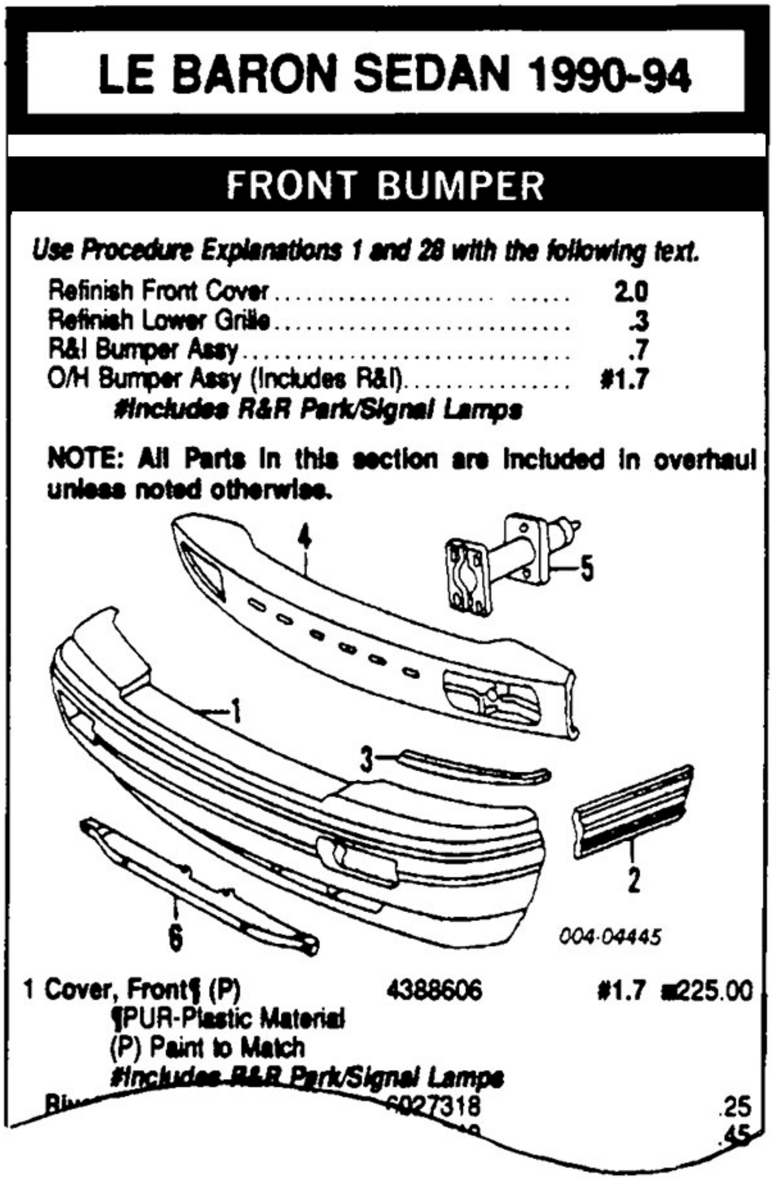
After completing the bumper assembly, move on to the grille section. Proceed in the same manner as you did with the front bumper. Continue throughout the sections until you reach the end. Since the damaged vehicle has only minor front-end damage, after the grille section you would go to front lamps. Notice that aiming the headlamps is not included in the removal and replacement of the headlamps; therefore, be sure to add extra time for aiming.

Next, move on to hood. Note all damage to the hood, especially in the latch and hinge areas. If the hood has a molding strip, note that also.

Follow this procedure through each section until you are fully satisfied that you have noted all the damage. For this type of vehicle damage, you would naturally pay close attention to critical areas like wheels, front suspension, steering linkage, and frame. On *unibody-type vehicles*, pay special attention to areas away from the actual damage point, as front-end accident impact could be transmitted transversely and laterally through the vehicle. Pay special attention to notes that apply to special situations. You will find that referring to the Procedure Explanation pages repeatedly is very helpful. Do this until you become thoroughly familiar with the approach used, which operations are included, and which are not included.

Have a final look

After completing the inspection following the guide, walk around the vehicle again to make sure you have not overlooked any sections or parts. If the vehicle was driven after the accident, did you or the driver notice any special conditions that have occurred since the accident? Take your time because these might not be readily apparent. Additionally, note any special circumstances that might affect the overall job (high-strength/low-alloy steel, accessory parts, excessive rust, etc.).



LE BARON SEDAN 1990-94

FRONT BUMPER

Use Procedure Explanations 1 and 28 with the following text.

Refinish Front Cover	2.0
Refinish Lower Grille	.3
R&I Bumper Assy	.7
O/H Bumper Assy (Includes R&I)	#1.7

#Includes R&R Park/Signal Lamps

NOTE: All Parts in this section are included in overhaul unless noted otherwise.

1 Cover, Front¶ (P)	4388606	#1.7	225.00

¶PUR-Plastic Material
(P) Paint to Match
#Includes R&R Park/Signal Lamps
Bi... 6027318 .25
.45

Figure 5–34. First major section, Front Bumper.

Add up all labor times

Calculate the total repair and/or replacement operation hours. To accurately convert labor times to a total dollar charge for labor, use the Labor Conversion Tables in the back of the guide. Again, be sure to include any special labor conditions that may affect the damage report (aligning parts, removing rustproofing, etc.). If there are different labor rates for body repair, mechanical, glass, frame, unibody structure, or refinishing work, be sure to take these rates into account and properly itemize them on your damage report.

In the Air Force, you will usually have only two shop labor hour rates: the *direct labor rate* and the *indirect labor rate*. Labor costs are calculated by separately multiplying the total repair hours determined in the accident estimate by each rate. The results give you both direct and indirect labor costs. For estimating purposes, they are added together to determine the entire labor cost.

Add up all part prices

Calculate the price for each part and add up the total. Make sure to note any differences in price between left- and right-side parts or between glass provided or not provided by the manufacturer if glass is being replaced.

Add the total of labor and parts

Calculate the total of the labor times and parts to arrive at a final completed damage report for the job. Present your *legible* report along with the *completed* vehicle work order to fleet management and analysis (FM&A) personnel. You may have to complete an Air Force Technical Order (AFTO) Form 91, Limited Technical Inspection–Motor Vehicles, along with your damage report (or in place of a damage report) for a repair decision.

What happens now?

FM&A personnel will review and determine feasibility of repairs. This normally results in a lapse between the time of your estimate and the time you may actually begin repairs. During this time, you may have to prepare the vehicle for a NMCS status or for some form of disposition status. If the vehicle is stored outside while awaiting a repair decision, ensure it is stored in a manner that reduces the possibility of sustaining further damage. For example, if a vehicle involved in an accident has damage that keeps the doors from closing, or has broken windows, ensure it is protected from the elements. You would not want to have to repair additional damage caused by improper storage.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

644. Fundamentals of damage estimating

1. What are the two most important considerations you will face to help estimate repairs?

2. What does the term *service* refer to in the index of the Collision Estimating Guide?

3. Due to collision estimating guides listing replacement parts in a specific and logical order, in what sequence is this data presented?

4. How are parts that are illustrated in a collision estimating guide grouped?

5. In addition to illustrations, what else does a collision estimating guide provide to assist the technician in ordering parts?

6. How are labor times shown in a collision estimating guide?

7. What additional factors must you consider when calculating labor hour estimates for collision damage repair?

8. What purpose does the time conversion chart serve the technician estimating collision damage?

645. Identifying damages and estimating repairs

1. Why should you always record the VIN and production date when writing a damage report?

2. What information is provided by the VIN?

3. Where are most VINs located on the vehicle?

4. Using the collision estimating sequence table, what should you inspect next after inspecting the front drive axle during an accident estimate?

5. What should be the next step after you have worked through each section of the guide?

6. What are the shop labor rates in an Air Force maintenance shop?

7. In addition to the repair estimate, what form may be required to assist in the decision to repair the vehicle?

Answers to Self-Test Questions

637

1. Vehicle (liquid) and the pigment (coloring material).
2. The binder used.
3. By the use of a liquid reducer.
4. To obtain the desired color and hide the surface being painted.
5. Acrylic enamel.
6. Slow-drying, medium-drying, and fast-drying.
7. Blushing.
8. (1) g.

(2) e.
(3) f.
(4) c.
(5) c.
(6) b.
(7) a.
(8) f.
(9) e.
(10) d.

9. 400 grit (ANSI grade).
10. Primer.
11. It is an acid-proof type of coating compound with an asphalt base and a solvent.
12. The measurement of the paint thickness in thousandths of an inch or mils.
13. Reducer.

638

1. The public health and bioenvironmental engineering office.
2. Change the paint booth filters.
3. Vapor-proof lights/lamps.
4. Air compressors.
5. Safety valve.
6. To remove oil and water from the air and to regulate air pressure to the spray gun.
7. At the beginning of each day you paint.
8. The solidifying of synthetic resins in enamel paint when heat is applied.
9. It is worn to prevent you from inhaling harmful dust and toxic vapors from various types of paints.
10. AFI 48–137.
11. Inside a container (plastic bag, small cardboard box, or self-made container) to keep the respirator away from dust, sunlight, heat, extreme moisture, and from coming in contact with chemicals.
12. When spraying in enclosed areas with poor ventilation.

639

1. Cleaning and scouring, cleaning or dusting prior to painting, stenciling, touchup jobs, and repairing damaged or faded vehicle markings.

2. (1) Self-feed possesses a small container attached to the gun.
   (2) Pressure feed supplies paint from a larger container through a hose to the spray gun.
3. The two-finger trigger.
4. Air control screw.
5. By controlling the force of the horn jet air streams.
6. (1) The entire spray gear is heavier, even with just a 1-quart capacity container.
   (2) When tilting the gun too far, paint will run out of the container’s vent.
   (3) If the siphon tube becomes uncovered, “paint spitting” will occur.
7. When painting large buses, vans, refueling vehicles, trailers, and so forth.
8. High solid paints.
9. Increase the pressure output of the sprayer.
10. Below 10 psi.

11. The term TE describes the amount of paint a spray gun is capable of depositing on a surface, and is expressed as a percentage. The higher the TE of the spray gun, the lower the amount of paint wasted in the form of mist and overspray.
12. Turbine, air conversion units, and step-down guns.
13. Step-down and air conversion.
14. A pressure regulator that reduces standard compressed air to 10 psi or less.
15. A special orifice or venturi reduces air pressure in the air nozzle.
16. Eight to 10 inches.
17. Foreign matter on the valve or valve seat, worn or damaged valve seat, or a broken air valve spring.
18. Solvent removes lubrication and dries out the packing.
19. Stiff-bristled nonmetallic brush.
20. Use compressed air to blow dry the spray gun components.
21. Clean them, wipe them as dry as possible, wrap them in stiff paper to hold the bristles straight, store them in a dry place.

640

1. The paint would not stick to these areas.
2. Remove any wax, grease, oil, or silicones with a specially blended wax and grease remover. You then wash the vehicle with soap and water, rinse thoroughly, and dry with compressed air.
3. By pitting, roughness, or bubbling of the body surface.
4. Sand/media blasting.
5. To remove any foreign material or water from the small scratches and crevices of the body surface.
6. The masking tape is wide enough to overlap the paper and cover the exposed ½-inch area around the paper’s edge.
7. Position the first piece of masking paper at the bottom of the area and lap the second piece over the first. This permits water and other foreign debris to flow over the paper edges and not run inside.
8. Masking tape.
9. Paste-like materials, such as grease or high-viscosity oil, to cover gauges and lights.
10. Overspray may cause engine overheating due to paint adhering to and insulating the radiator core.

641

1. Thinners.
2. It controls paint flow and drying time.
3. To fill in slight imperfections in the body surface.
4. A regular primer that adheres to special body surfaces like aluminum or galvanized metal.
5. Only the amount you will use within a 2-hour period.
6. From the inside-out.
7. To prevent solvents of the new finish from penetrating into the old finish.
8. Twelve hours.
9. Six hours.
10. Bleeding.
11. Orange peel.
12. Runs, sags, or wrinkles.

642

1. A combination of two types of coatings to produce a vehicle finish.
2. The basecoat provides the paint color.
3. The basecoat alone has no shine and is susceptible to the UV of the sun.
4. The clearcoat gives the paint finish its shine and protects the basecoat from UV rays.

5. Panels that do not have a good breakline, such as some quarter panels.
6. Three.
7. Between 5 to 10 minutes.
8. Blend approximately 4 to 6 inches beyond the repair area.
9. A grit coarser than 600.
10. Use a dirt-nib file.
11. The sandpaper grit used will vary with the amount of damage, but it should be between 800 and 1500.
12. Keep the polishing pad flat to the panel and apply light pressure.

643

1. By using either a wire brush, chisel, or a putty knife.
2. High-pressure water and soap solutions.
3. Because the hot steam could loosen or remove existing undercoating material.
4. Keep your fingers away from the nozzle; additionally, wear gloves and goggles or face shield. The undercoating material that discharges from the spay tip opening is highly pressurized and can easily penetrate the skin.
5. Drill a $^1/_2$-inch hole, apply the undercoating into the enclosed area, and plug the hole with plastic caps after spraying.

644

1. How much will the repair cost and should an attempt be made to repair the vehicle?
2. They are groups of vehicles that can be described more conveniently as a group rather than each one separately. A service normally constitutes (covers) the life cycle of a particular vehicle.
3. From vehicle front-to-back, outside-to-inside.
4. Parts that are most likely to be damaged together are shown together.
5. Part numbers.
6. In hours and tenths of an hour (six minutes).
7. Damage requiring additional time to access parts, alignment pulls, nonoriginal equipment, and used parts
8. It allows the technician to convert labor time to dollars. To determine quick and accurate labor charges and more precise repair estimates.

645

1. This information will facilitate parts ordering.
2. The year and month the vehicle was built, the model, and the engine size.
3. On a plate attached to the driver’s side of the instrument panel.
4. The manual or power steering linkage/gear.
5. Walk around the vehicle again to make sure you have not overlooked any sections or parts.
6. Direct labor rate and indirect labor rate.
7. An AFTO Form 91.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to AFCDA.

74. (637) What should be considered prior to using vehicle paint held in storage?
    a. Paint viscosity.
    b. Paint volatility.
    c. Age of the paint.
    d. Classification of the paint.

75. (637) What provides a coating on bare metal to prevent corrosion, provides a base for the paint, and serves as filler for small sanding scratches?
    a. Epoxy.
    b. Bondo.
    c. Primer.
    d. Thinner.

76. (637) What is a disadvantage of the greater thickness of low-volatile organic compound (VOC) paints?
    a. Higher cost.
    b. Availability.
    c. Storage requirements.
    d. Equipment requirements.

77. (638) If the pressure switch malfunctions on the electric motor air compressor, excessive air pressure is relieved by the
    a. manual pressure gauge valve.
    b. manual shutoff valve.
    c. safety valve.
    d. quick valve.

78. (638) For polymerization of automotive paint to occur, you must apply
    a. heat.
    b. cold air.
    c. ambient air.
    d. ultraviolet or sunlight.

79. (638) What types of respirators *must* be fit tested?
    a. All cartridge type and any air-supplied type with a tight-fitting seal.
    b. Only air-supplied type.
    c. All air-supplied type.
    d. Only cartridge type.

80. (639) How do you control the width of the paint spray pattern on a spray gun?
    a. Adjust the spring tension on the material nozzle.
    b. Turn the transformer (regulator) one turn.
    c. Adjust the air control screw.
    d. Loosen the cap.

81. (639) Which type of high-volume low-pressure (HVLP) paint system uses compression and generates oil free, dry air at temperatures that may be over 200 degrees Fahrenheit (° F)?
    a. Air conversion unit.
    b. Step-down unit.
    c. Electrostatic.
    d. Turbine.

82. (640) Before using a paint stripper to remove paint from a vehicle, you should consult with
    a. local environmental experts or bioenvironmental engineering.
    b. Fleet Management and Analysis.
    c. the vehicle control officer.
    d. the vehicle fleet manager.

83. (640) Which type of sandpaper is good for use on paint finishes?
    a. Aluminum oxide.
    b. Zirconia alumina.
    c. Silicon carbide.
    d. Pumice.

84. (640) To properly mask an area 31 inches by 27 inches, you should cut the masking paper to a dimension of
    a. 30 ½ inches by 26 ½ inches.
    b. 31 ½ inches by 27 ½ inches.
    c. 30 inches by 26 inches.
    d. 3 feet by 2 feet.

85. (641) For adhesion purposes, what should you use for the first coat on bare aluminum?
    a. Thinner.
    b. Lacquer.
    c. Regular primer.
    d. Primer-surfacer.

86. (641) What type of primer has replaced the old-type oil-base primer?
    a. Natural.
    b. Mineral.
    c. Synthetic.
    d. Penetrating.

87. (641) Within what time period should you apply a primer with a spray gun after you clean and prepare the body surface?
    a. 24 hours.
    b. 36 hours.
    c. 48 hours.
    d. 60 hours.

88. (641) What type of sanding should you perform after the primer thoroughly dries?
    a. Dry.
    b. Wet.
    c. Orbital.
    d. Circular disc.

89. (641) What is the *minimum* time limit between applications of polyurethane coats of paint?
    a. 10 minutes.
    b. 30 minutes.
    c. 60 minutes.
    d. 90 minutes.

90. (641) What is the paint defect that appears as small lines branching off in all directions and is caused by using solvents that evaporate too rapidly or spraying too thick a coat of paint?
    a. Crowsfooting.
    b. Orange peel.
    c. Peeling.
    d. Sags.

91. (642) The *clearcoat* in the basecoat/clearcoat paint system
    a. gives the paint its shine but makes the basecoat susceptible to the ultra-violet (UV) rays of the sun.
    b. gives the paint its shine and protects the basecoat from the UV rays of the sun.
    c. has no shine and makes the basecoat susceptible to the UV rays of the sun.
    d. has no shine but protects the basecoat from the UV rays of the sun.

92. (642) What action negates the need to apply a metal conditioner to bare metal?
    a. Clean the entire panel with a wax and grease remover.
    b. Featheredge the damaged areas.
    c. Wipe it clean with a tack rag.
    d. Apply a self-etching primer.

93. (642) To properly apply the clearcoat on a basecoat/clearcoat spot or full panel repair, you should have 50 to 60 pounds per square inch of air pressure at the
    a. air transformer and allow15 to 20 minutes flash time between coats.
    b. air transformer and allow 5 to 10 minutes flash time between coats.
    c. paint gun and allow 15 to 20 minutes flash time between coats.
    d. paint gun and allow 5 to 10 minutes flash time between coats.

94. (642) How much clearcoat (thickness) is considered enough to provide adequate ultra-violet protection for a basecoat?
    a. 10 mils (.0001).
    b. 1.0 mil (.0001).
    c. 10 mils (.001).
    d. 1.0 mil (.001).

95. (643) When cleaning the underbody of loose undercoating, do *not* use
    a. a six-inch putty knife.
    b. wire brushes.
    c. hot steam.
    d. chisels.

96. (643) You should be sure to keep your hands away from the nozzle of the airless spraying apparatus when applying undercoating because the material coming out of the nozzle
    a. has a high toxic acid base.
    b. has a low toxic acid base.
    c. is under high pressure.
    d. is under low pressure.

97. (644) Estimating guides list automobile parts and labor information beginning with the front
    a. interior components.
    b. and rear bumper.
    c. outer panels.
    d. bumper.

98. (644) In what order do collision estimating guides list vehicle parts?
    a. Left side to right side, right side to left side.
    b. Inside to outside, left to right side.
    c. Front to back, outside to inside.
    d. Right to left side, front to back.

99. (645) What type of vehicle construction requires paying special attention to areas away from the actual damage point, as the accident impact could be transmitted through the vehicle?
    a. Box beam.
    b. Unibody.
    c. Ladder.
    d. Frame.

100. (645) When storing a vehicle outside after performing an accident estimate and awaiting a decision, precautions should be taken to prevent
    a. personnel from touching vehicle until police investigate.
    b. the using organization from accessing vehicle.
    c. sustaining further damage from the elements.
    d. technicians from cannibalizing parts.

Student Notes

Glossary of Abbreviations and Acronyms

°	degree
° C	degrees Celsius
° F	degrees Fahrenheit
%	percent
ABS	antilock brake system
A/C	air conditioning
AC	alternating current
AFI	Air Force instruction
AFMAN	Air Force manual
AFTO	Air Force technical order
AISI	American Iron and Steel Institute
amps	amperage
ANSI	American National Standards Institute
Ar	argon
AWS	American Welding Society
BCM	body control module
BZP	benzoyl peroxide
C	carbon
CA	cyanoacrylate
cfh	cubic feet per hour
cfm	cubic feet per minute
CO_2	carbon dioxide
DC	direct current
DCEN	direct current electrode negative
DCRP	direct current reverse polarity
DOD	Department of Defense
E	electrode
ECM	electronic control module
EN	electrode negative
EPA	Environmental Protection Agency
FM&A	fleet management and analysis
FOD	foreign object damage
FSN	federal stock number
ft/lbs	foot/pounds
GMAW	gas metal arc welding
GPC	government purchase card
GTAW	gas tungsten arc welding

HAZ	heat-affected zone
He	helium
HSLA	high-strength, low-alloy
HSS	high-strength steels
HVAC	heating ventilation and air conditioning
HVLP	high-volume low-pressure
IPM	inches per minute
ISO	International Organization for Standardization
lbs/gal	pounds per gallon
LP	liquefied petroleum
LVLP	low-volume low-pressure
MEKP	methyl-ethyl ketone peroxide
MIG	metal inert gas
mm	millimeter
NAGS	National Auto Glass Specifications, Incorporated
NATO	North Atlantic Treaty Organization
NMCS	non-mission capable supply
O_2	oxygen
PAC	plasma-arc-cutting
PPE	personal protective equipment
psi	pounds per square inch
PVB	polyvinyl butyral
RP	reverse polarity
SAE	Society of Automotive Engineers
SCAQMD	South Coast Air Quality Management District
SIR	supplemental inflatable restraint
SMAW	shielded metal arc welding
SMC	sheet-molded compound
SP	straight polarity
TE	transfer efficiency
TIG	tungsten inert gas
TO	technical order
UV	ultra-violet
VAC	volts alternating current
VIN	vehicle identification number
VOC	volatile organic compounds

Student Notes

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