MOTORBOOKS WORKSHOP

- Cutting, shaping, and joining metal for any project
- Fabrication from simple patch panels to complex body parts
- Detailed instruction for welding, grinding, hammering, and shaping processes

PROFESSIONAL SHEET METAL FABRICATION

"THE MOTORBOOKS WORKSHOP SERIES gives readers a wealth of knowledge on a variety of very specific subjects, and it's always on the shelf for reference in years to come."

TOM VOGELE, EDITOR, *STREETSCENE* MAGAZINE

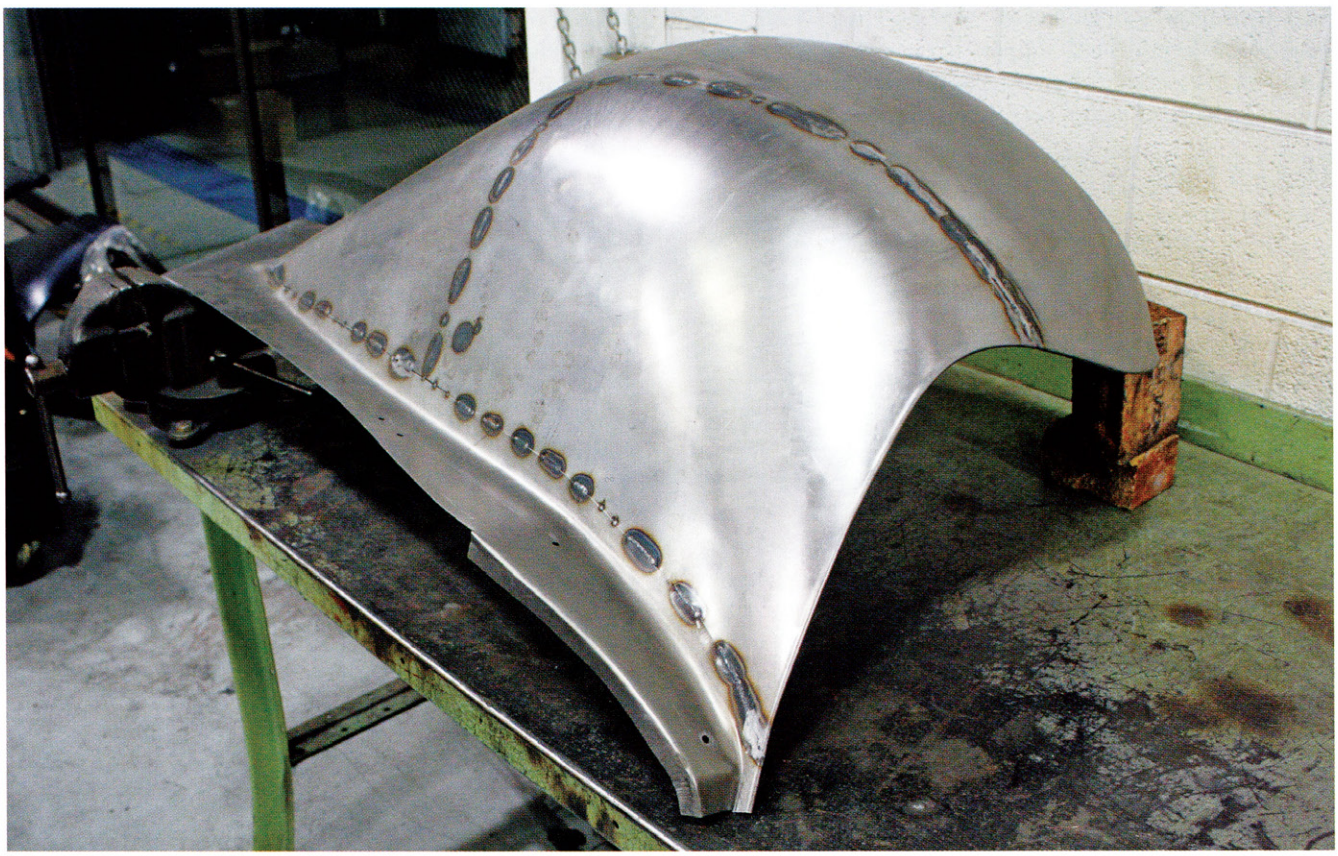
Ed Barr

Chapter 1
Getting Started

SAFETY AND FASHION SENSE

Although I have reached a point in life where fashion for the sake of being fashionable is no longer a concern, I still make careful wardrobe choices before I enter the shop. Working with sheet metal can be dangerous, but not if you pay attention to the potential hazards involved before you go to work. Minimize welding and grinding hazards by protecting yourself from head to toe. First, wear safety glasses, either with or without corrective lenses as needed. In total defiance of all conventions of coolness, I wear eyeglasses with the little plastic shields on the sides. These glasses embarrass my children when I wear them in public, but most debris enters your eyes from the sides, so taking precautions is essential. Furthermore, if your incredible good looks make leaving your house a nuisance, these eyeglasses insure that members of the opposite sex will go out of their way to avoid you; you'll have more time for working with metal. If you work in a shop with other people, some of the greatest hazards will be debris generated by co-workers, especially if they will be grinding. In addition, wear long-sleeve shirts, long pants, and leather shoes or boots to block UV rays generated during welding. Use common sense. Espadrille sandals may have worked for Crockett and Tubbs on *Miami Vice*, but they have no place in an area where you'll be welding and cutting. Spiked heels tend to sever the cord to the TIG welder amperage control, so leave those deep in the closet behind the espadrilles. Every sheet metal edge is a potential cutting edge, so keep sheet metal stored away in a rack when not in use. Wear leather gloves when handling new or freshly cut sheet metal.

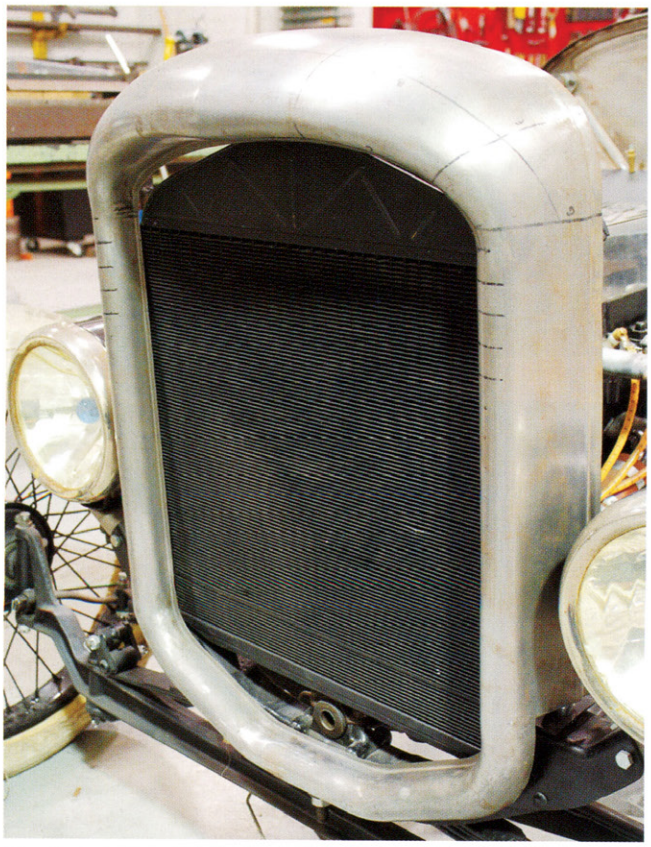
When working around old cars, be mindful of the threat they pose as falling objects, as containers for flammable liquids like fuel and brake fluid, and as electrocution hazards. Disconnect the car's battery or remove it altogether. Eliminate



This fender seems complicated, but it is made up of eight individually shaped panels that were less intimidating when conquered one at a time following John Glover's classic video on the subject.

Chapter 2
Special Techniques for Welding Sheet Metal

Because of its thinness, sheet metal can be difficult to weld—too little heat results in an incomplete weld, whereas too much heat burns a hole in the metal with alarming speed. In addition, sheet metal moves as it is heated and as it cools, thereby creating stresses and strains that can further frustrate your fabrication efforts. With a little guidance and a lot of practice, however, you will start to understand how the metal behaves and how to achieve the results you want. This chapter covers the three welding processes most commonly used for joining sheet metal: the oxyacetylene torch, MIG, and TIG welding. Although this chapter is not a substitute for more comprehensive welding books, such as Motorbooks' excellent *How to Weld*, by Todd Bridigum, it does cover the use of the torch, MIG, and TIG to solve the special problems inherent to welding thin metals. I encourage readers to follow along in the order that the material is presented. Students new to welding will find that each new technique builds on previous techniques. I hope that readers with prior welding experience will rekindle an interest in, or appreciation for, techniques that they may have fallen out of the habit of using. MIG, TIG, and torch-welding all have definite strengths and weaknesses. Getting thoroughly acquainted, or reacquainted, with them, as the case may be, is a lifelong process that can lead you to new levels of satisfaction and metal crafting merriment.



Adam Banks fashioned this Ford Model T steel radiator surround from several hand-shaped pieces that he TIG welded together. TIG was a good choice because it doesn't heat up the work excessively and the welds can be finished to the point that they are imperceivable.

OXYACETYLENE OR GAS WELDING

Chances are, if you have ever taken a welding class or looked through a book on welding, you have noticed that oxyacetylene welding is almost universally the first welding process taught to new students. This is true for several reasons: first, mastering the oxyacetylene torch builds manual skills and welding knowledge helpful for learning other welding processes; second, the torch is extremely versatile—some readers may never wish for anything else; and third, the torch is hard to beat in terms of value for your money. There is a dark side to the torch, however, because you are also getting a tremendously dangerous instrument if it is used improperly. Therefore, treat it like you would your neighbor's pit bull, your in-laws, or your local mob boss—with the utmost respect. Fortunately, the welding industry has developed many safeguards to protect users of their equipment, which I will discuss momentarily, but the responsibility for practicing shop safety is *yours*. Review the following precautions until they become second nature to you. For sheet metal welding, the torch is probably the most difficult technique to master, but the finished torch-weld is soft and easy to form, and it behaves like the rest of the panel.

Gas welding uses a mixture of oxygen and a fuel gas to create a flame hot enough to fuse metals by melting them together. Although many fuel gases are used with the torch for a variety of purposes, we will discuss acetylene because it produces a lot of heat, it has a wide variety of uses, and it is readily available. For welding to take place, compressed oxygen and acetylene are supplied from two specially prepared cylinders, each dedicated to one type of gas. The gas in each cylinder is controlled by a dedicated regulator, and

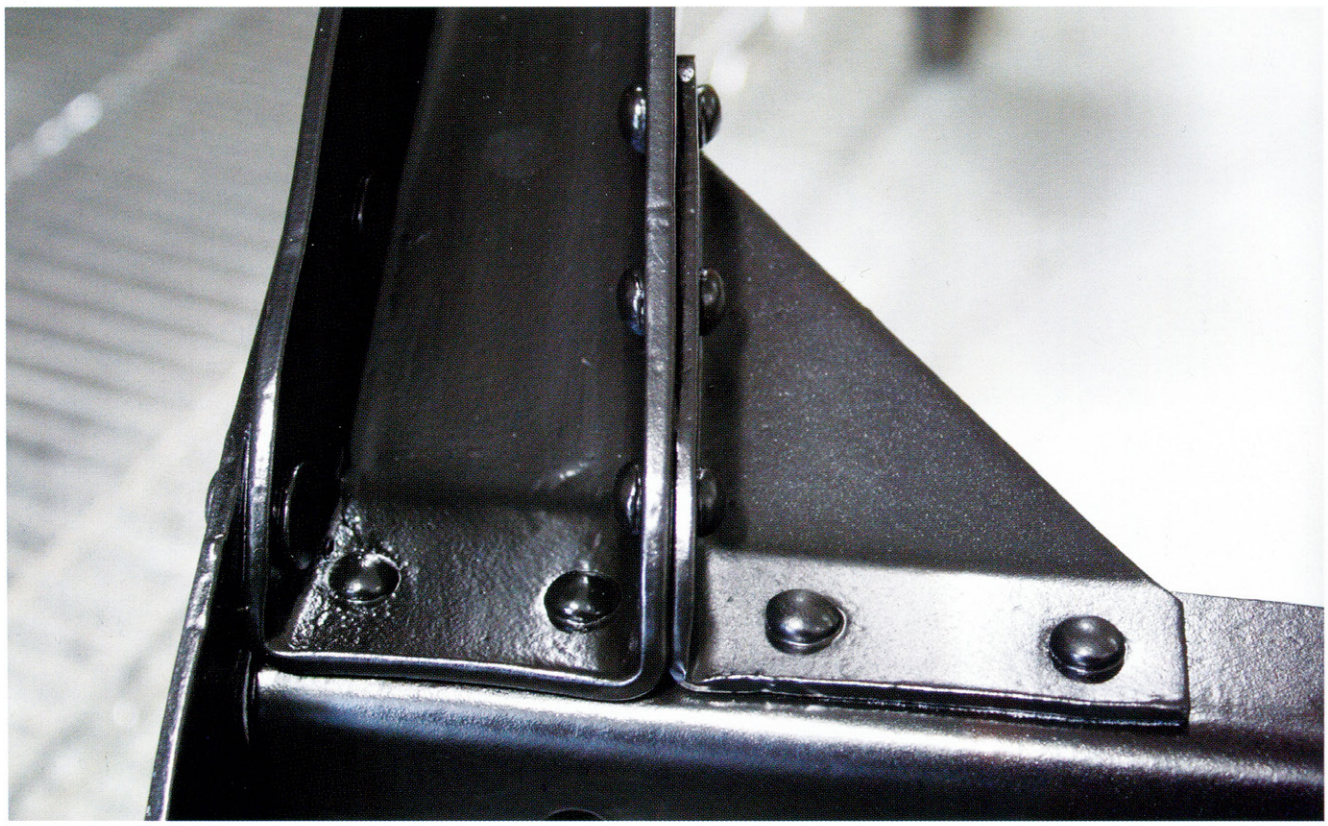
Chapter 3
Brazing, Soldering, and Riveting

In this chapter I will discuss three nonwelding fastening processes that are commonly used in the restoration of antique automobiles. Brazing and soldering rely on heat, of course, but they are different from welding in that the base metal is not melted and fused together. Instead, a filler metal forms a bond between two metals through surface adhesion. Riveting, on the other hand, is typically done cold, but you need to bring in a torch to install steel rivets successfully.

BRAZING AND SOLDERING

Brazing is useful for repairing cast iron, for joining dissimilar metals, and for building up worn gear teeth and other surfaces. One of the purported benefits for brazing is less heat distortion due to the lower temperatures involved compared with torch-welding. Although there is no disputing the temperature difference involved between torch-welding and brazing, I am dubious of the distortion claim. The metal still must be brought to a red heat to braze and the metal is heated more slowly than in torch-welding. In addition, brazing requires an overlapped joint, so there are two thicknesses of metal to heat. As a result, I believe that more total heat ends up in the panel than with welding. Also, an overlapped joint is thick and hard to finish compared with a welded butt joint. I would never choose brazing over welding when dealing with thin sheet metal, but brazing is still useful for the other purposes previously cited.

Brazing rods are made of brass, an alloy of zinc and copper, and must be used with a flux, which facilitates the flow of the molten filler rod and promotes good adhesion by dissolving oxides and preventing atmospheric contamination.



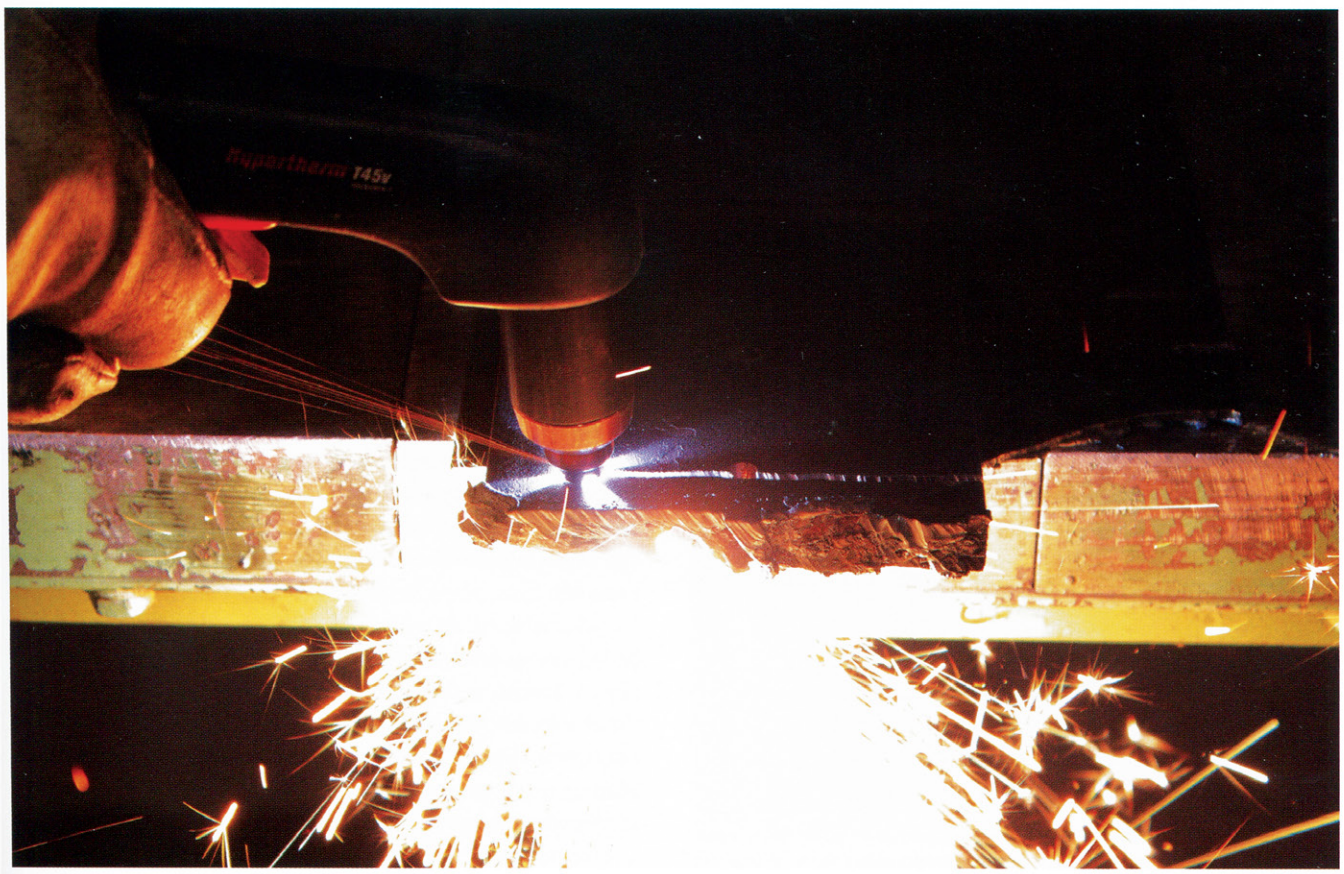
The rivets on this Ford Model T frame must have a certain appearance if they belong to a car that is being restored to like-new condition.

Chapter 4
Cutting Sheet Metal with the Oxyacetylene Torch and Plasma Cutter

Fortunately, the thinness that makes lighter-gauge sheet metal challenging to weld facilitates many cutting operations. Thin metal is easily cut by mechanical means, such as with tin snips, saws, cut-off wheels, shears, and various nibblers. As the thickness of the metal increases, however, the demands placed on your tools increase, and consequently, tool cost rises with increased capacity. If you enjoy being able to cut straight, curving, and freeform lines across metal as if it were paper, you need not spend a fortune, however. Luckily, the most basic oxyacetylene torch will cut carbon steels of up to ⅜ inch or more, assuming your acetylene cylinder and torch tip are sized appropriately. An entry-level plasma cutter, though more expensive than a torch, will easily cut ferrous and non-ferrous metals up to ⅛ or 3⁄16 inch. This chapter introduces you to oxyacetylene torch and plasma cutting, the processes you will most likely want to investigate to supplement mechanical cutting.

OXYACETYLENE CUTTING TORCH

As described in the previous chapter, most metal shaping enthusiasts acquire an oxyacetylene torch because of its versatility and low cost, and let's face it—wielding a 6,000



Plasma cutters are like a lightsaber in a box. They will cut, pierce, or gouge almost any metal with ease. They are also simple to operate.

Chapter 5
Beginning Sheet Metal Shaping

Learning to form sheet metal by hand is the critical first step in your education in metal shaping. Machines are labor savers, but using them properly requires knowledge. Otherwise, they can transform perfectly good sheet metal into scrap with astonishing speed and efficiency. Fortunately, once you understand the basics of shaping sheet metal, its responses to your input will be less mysterious, so progress will come quickly—you will not need an arduous seven-year apprenticeship to start seeing results and finding satisfaction in your work. Furthermore, craftsmen have been shaping metal by hand for centuries, so do not be intimidated by the existence of complex and expensive machines, which simply harness electrical and/or hydraulic power to shape metal according to the very same principles you will learn in this chapter. For the average person interested in repairing rust spots and making a few patch panels for a historic vehicle, for example, a few basic shaping exercises will endow most enthusiasts with the confidence to move ahead with their intended project.

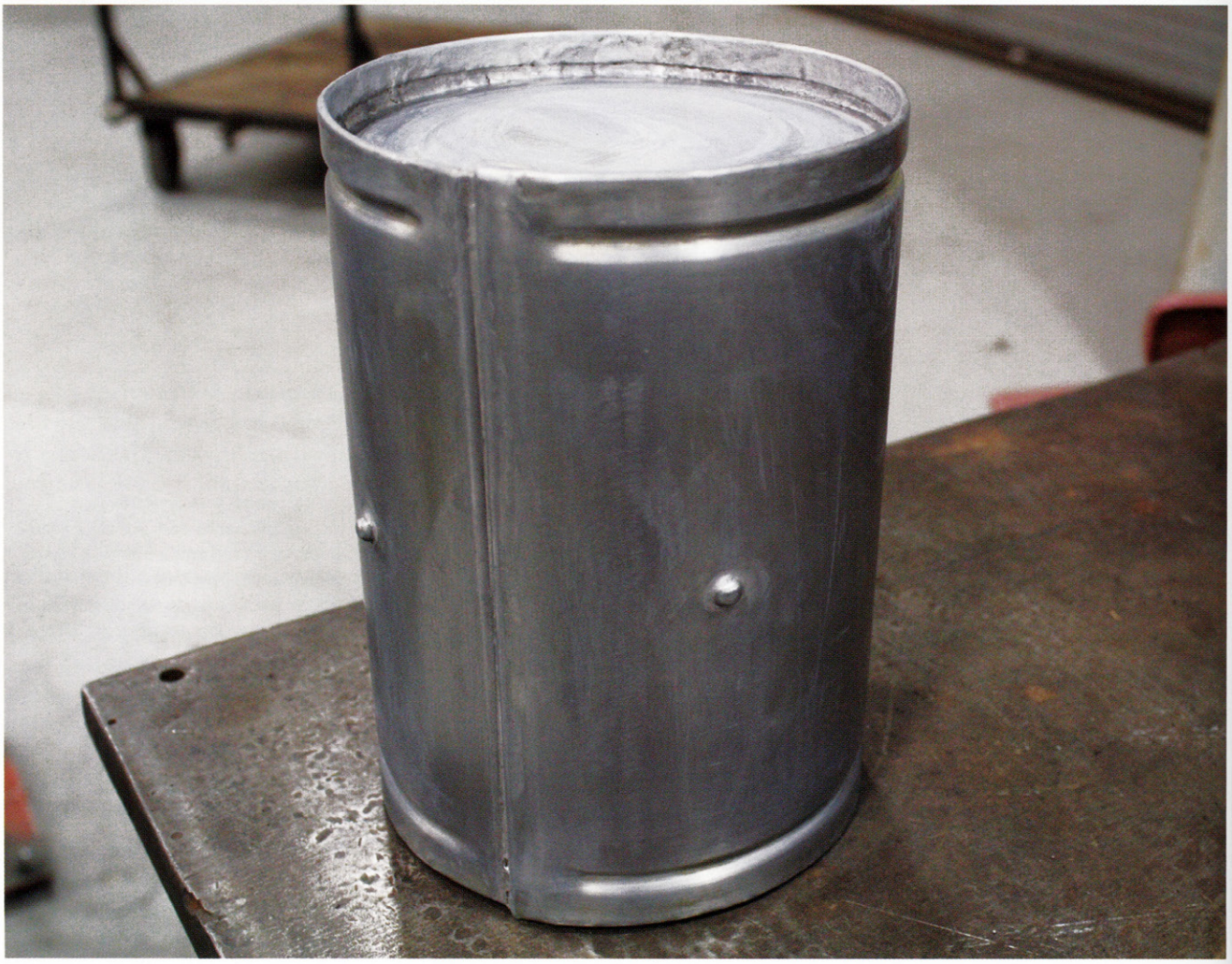
One overriding principle to keep in mind when working with sheet metal is that you often trade thickness for surface area as you shape the metal. Sometimes you increase the surface area, or stretch the metal, making it longer and thinner. Other times you will decrease the surface area, often called shrinking or upsetting, making the metal shorter and thicker. I tell students to think of their metal as a slab

It's not automotive, but it's gorgeous. Ryan Brown made this handsome tail section for his Honda CB750 entirely with hand tools and the English wheel using principles you will learn in this chapter. Ryan's tail section boasts a subtle compound curve that both streamlines and enhances the otherwise chunky proportions of this motorcycle.

Chapter 6
The Small Gas Tank Project

This project gives you the opportunity to apply many of the skills that have been covered in previous chapters: planning, measuring, cutting, bending, beading, soldering, and riveting. Plus, you'll acquire a few more new techniques to add to your repertoire. Restorers of old cars occasionally need to fabricate containers such as gas and oil tanks and vacuum tanks. The small gas tank project shows you the typical steps involved in producing a functional vessel. If you choose to make a tank, please follow these instructions to the letter to avoid becoming frustrated, and measure everything at least twice. A sealed vessel relies on the absence of gaps at all of its seams, of course, so this is no place to work by eye or intuition alone. Keep the end product; maybe you'll have an engine-testing stand some day and you'll need it for your fuel supply.

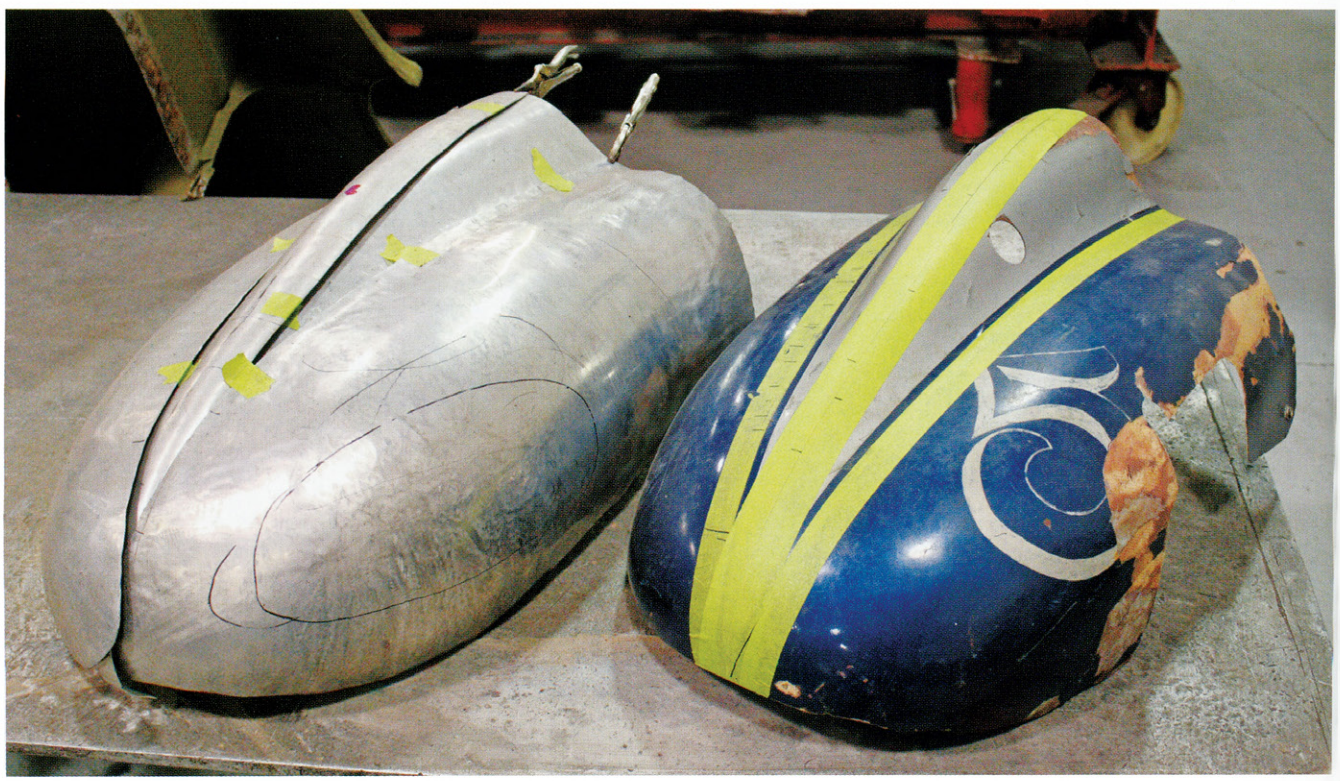
The length of our tank was chosen at random. The critical dimension is the diameter, which was chosen based on the diameter of two large sections of pipe—actually hollow steel cylinders—that we used to form the tank's endcaps. As we get further into the project, you will see how the cylinders come into play. You could easily use circular pieces of wood as long as you cut the edges very cleanly.



I made a gas tank similar to this for our engine dyno, but its construction is exactly as you might expect to find on an antique car. The skills needed to build it are a perfect culmination of material covered in this book thus far.

Chapter 7
Advanced Sheet Metal Shaping

As you begin to understand how sheet metal behaves, you will become anxious to get faster results. You may have seen or at least read about the staggering array of equipment now available to make your work easier and faster to produce, and you will know enough to understand how various new machines can help you. There is a mechanized tool for every metal-forming task it seems, and there is something for every budget. While a machine's price and capabilities often go hand in hand, it is possible to acquire a piece of equipment that will improve the comfort, speed, and quality of your work without spending a fortune, but don't be too hasty to start spending your money. The critical consideration is to determine exactly the kind of tasks you need to perform to create your work and shop accordingly. Before you buy anything, try to take a class or seminar from someone with equipment similar to what you are thinking of acquiring. Make sure that you can get an accurate appraisal of the tool as opposed to a blatant sales pitch. After trying out someone else's equipment, you will be much better informed when it comes time to purchase your machines. The tuition for your class will be well worth it if you save thousands on a significant tool purchase. Talk to people online in one of the metal-shaping forums. Do your research. I would not recommend getting carried away with acquisitions until you have acquired a feel for hand shaping, however. Unless you have some understanding how sheet metal moves, fancy equipment will only allow you to create scrap more quickly. I suspect that the best shapers could produce great work using only a brick, an old pipe wrench, and a sock filled with sand. The longer you extend your apprenticeship to that taskmaster Hand Work, the better prepared you will be when you move ahead into more advanced shaping.



Lance Butler decided to recreate this tattered Kurtis-Kraft quarter midget tail section in aluminum. It's still a work in progress, but it suggests that great potential shaping projects are out there if you look for them. Lance borrowed the original from a guy he met at a swap meet.

Chapter 8
Building a Fender From Concept to Completion

To demonstrate the use of the Dake hammer, planishing hammer, and other tools on an elaborate project, we built an aluminum fender based on the buck we completed in the last chapter. This description follows the construction in some detail, but that is the only way to follow the steps involved and have them make sense. Solving problems as they arise is a necessary part of learning to shape metal. Hopefully, watching us cope with different situations will offer ideas that you can apply to future projects. To get an idea of what would be involved in shaping the metal for this piece, we pinned some paper onto the buck with thumbtacks and folded and cut the paper as needed to get the paper to fit. The paper will serve as a very accurate plan for the project.

EARLY CONCEPT AND CONSTRUCTION

One feature I was determined to include in this fender was a crisp body line that travels down the center of piece, but fades into the sheet metal at its ends. As I pondered how best to approach the body line problem, I considered joining the two sides of the fender at the crease, but thought better of that option because I doubted that we would be able to finish out the weld bead satisfactorily. We could also have made one fender half a little longer and placed the bead near the edge of that half. This procedure would have required shrinking the short side flange that would have protruded next to the crisp body line, because the body line would be the highest point of the fender. This second option would

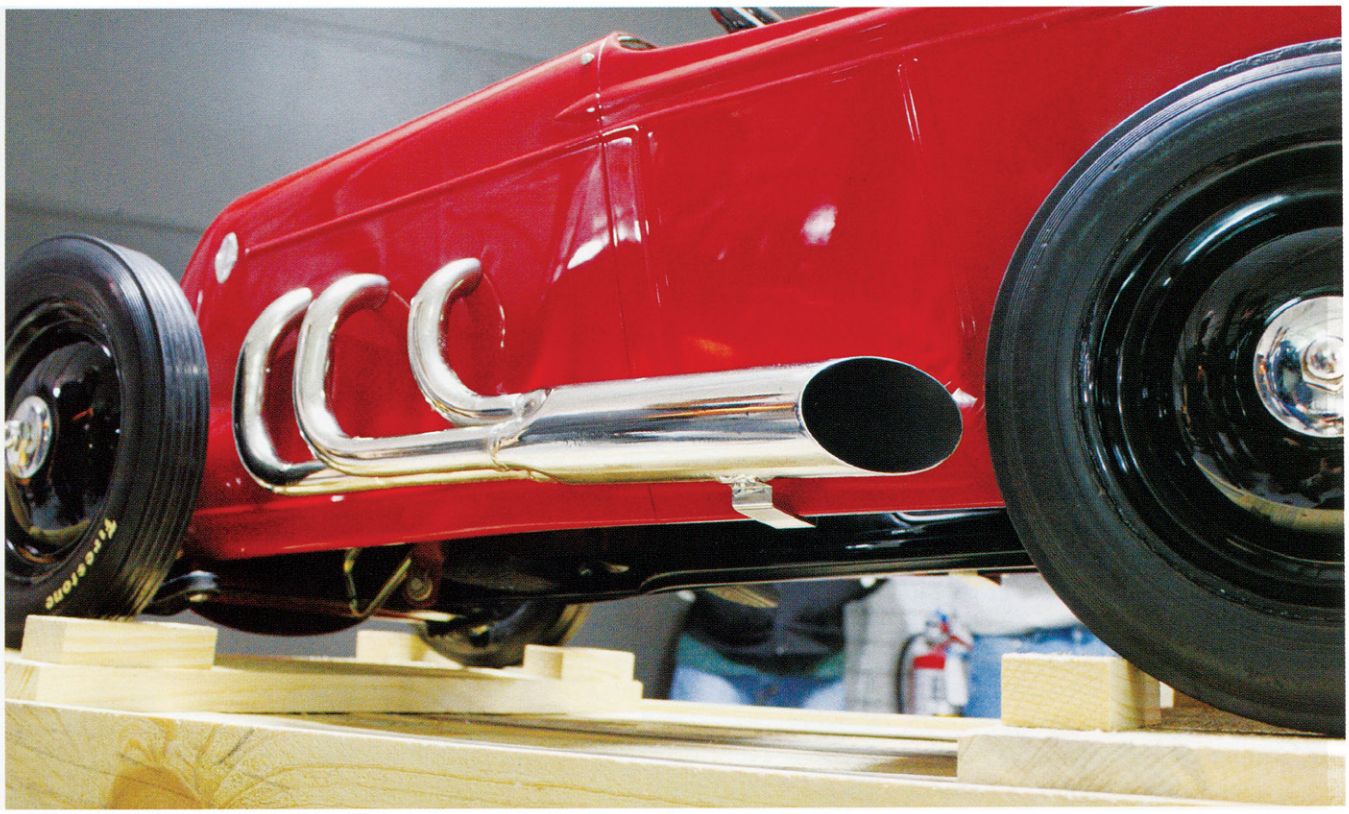
In this chapter we will go through the necessary steps to build this fender from start to finish.

Chapter 9
Making It Beautiful: Straightening, Grinding, and Surface Finishing

The process of beautifying a sheet metal object can be an arduous but rewarding task. If an object is corroded, dented, or incomplete, you have the opportunity to reverse the ravages of time and restore it to its former glory, but such miracle working seldom comes easily. In this chapter I will describe some techniques for removing old paint and oxidation, straightening sheet metal, and improving its surface finish to the level you desire.

REMOVING PAINT AND OXIDATION

Depending on the goal for your project, the presence of old paint and rust or corrosion may significantly affect the feasibility of your plans. Determine the true condition of what you have as early as possible. I have seen more than one vehicle purchased in an online auction that turned out to be a complete disaster beneath layers of carefully sculpted plastic filler. Unfortunately, after the owners had spent years amassing parts in preparation for the restoration of their dream car, the painful truth became known when the owners had their cars media-blasted or chemically stripped. Find out the condition of what you have and then find out if it is worthwhile to you to move forward. The time-tested means for removing old paint and oxidation are through sanding, the application of chemicals, and abrasive blasting.

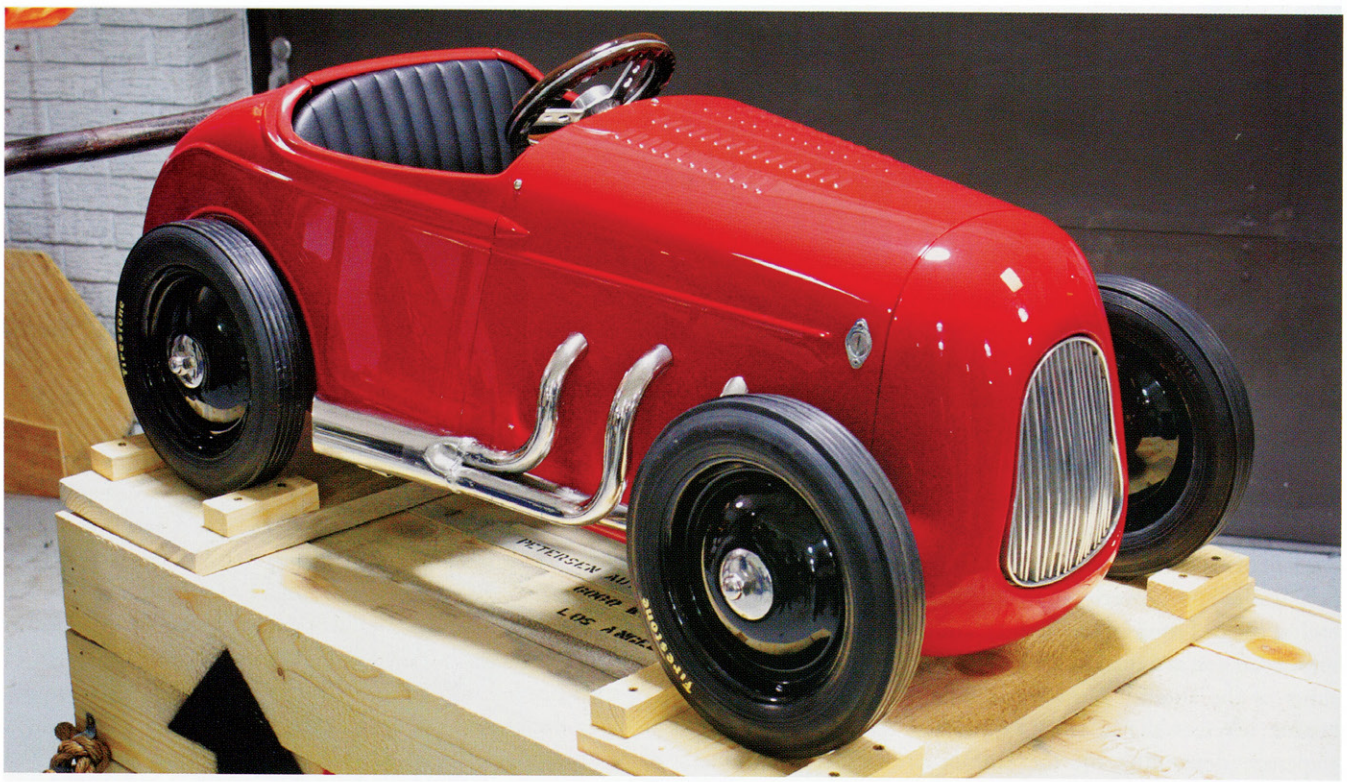


It is hard to believe that this pedal car header was made out of rusty bicycle handlebars and a length of automotive exhaust pipe. The transformation involved some welding, sanding, polishing, and nickel plating.

Chapter 10
Building a Custom Pedal Car

Our pedal car project came about in response to an invitation to participate in a fund-raiser auction celebrating the 80th anniversary of the Ford Deuce roadster at the Petersen Automotive Museum. Various car customizers around the country were invited to modify a standard pedal car from Warehouse 36 to showcase their creativity and skills and to pay tribute to this classic automobile, the '32 Ford roadster. The pedal car project was fun and challenging at the same time. The work involved was very much like one would expect to carry out on a full-size car, but the reduced scale meant much less time and fewer materials were needed to finish the project. One benefit I had not anticipated was how much creative problem solving a project like this demands and how quickly one can work through numerous solutions to each new problem. Fortunately, we learned a lot from our mistakes. Do not hesitate to undertake a free-form project like this. You will be hard-pressed to find another way to learn as much as quickly. Even if you do not have any interest in pedal cars, building a small-scale version of a car body is a great exercise. We have since built a small-scale Model A roadster pickup truck, but we ignored all of the pedal car mechanics, and it was well worth the effort.

Although the stock pedal car we began with was fancy for a toy, it cried out for modification. The car's ride height was unacceptably tall and the rear of the body was much too square for our tastes. For inspiration, we looked to a famous hot rod that belongs to our school, a Ford roadster that was modified in the late 1940s by a Californian named Paul Harris. In 1950, Harris took the flathead-powered roadster to Bonneville, where he was clocked at 131 miles per hour. Harris later drag raced the car through the 1950s and sold it in 1958. The roadster was raced, shown, and finally rebuilt in 1972 by James Handy, Andy Brizio, and Jack Hageman. As a tribute to the Paul Harris roadster, we incorporated some of the original car's features into our pedal car. The most distinctive elements of the Harris car in its early years were its track nose, custom long exhaust headers, and steel wheels with Firestone tires.



The complete transformation of this pedal car required many of the same skills one needs to restore full-sized cars—paint, trim, sheet metal, and fabrication skills—plus, it was great fun.

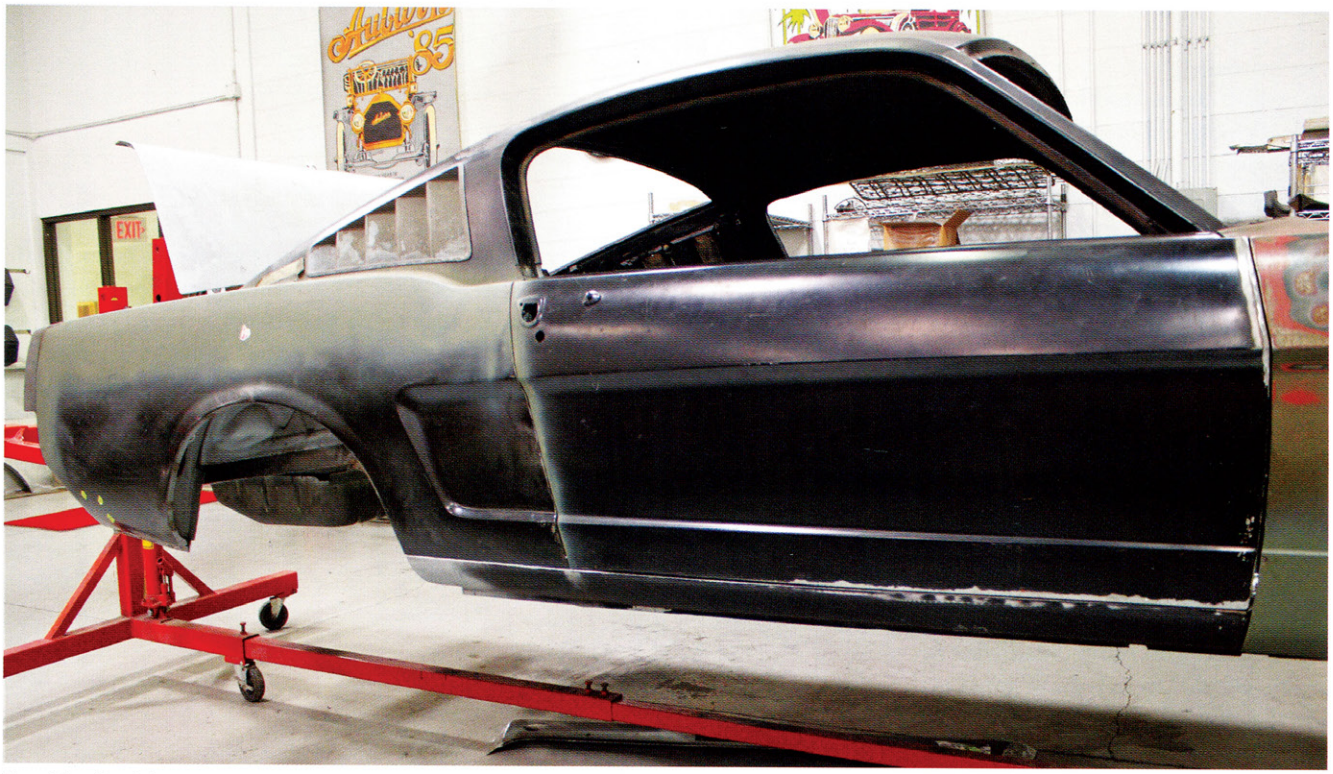
Chapter 11
Floorpans, Rocker Panels, and Rear Quarter Panels

From this point forward in this book, I would like to address major areas of automotive sheet metal repair and look at ways of resolving common problems that arise. First I will discuss floors, rockers, and quarter panels, as those are almost universal problems. I will examine these problems in their order of increasing difficulty.

FLOORPANS

Floorpans are easy to repair and will provide a surge of satisfaction and a boost to your self-confidence once completed. Furthermore, finished floorpans are tangible proof of progress on your project in case other members of your household covet your garage space. Before you begin, honestly assess the extent of the damage to your floors and the adjacent sills or inner rockers. If the damage you face can be repaired by tracing around a small patch panel and butt welding in a replacement, make sure there are no critical lines or wires nearby and forge ahead. If, however, the support structure along the outer edges of the floor is going to need to be repaired, you might be better off tackling the floors after you have fixed the main structural members along the sills. You do not want to be in the position of installing a new floorpan that cannot be attached along its length because the sill is bad.

For small floor repairs, decide if you want to butt weld a patch in place that will be indistinguishable from the factory appearance or if you are willing to flange one piece over its neighbor after you've cut out the damage. Overlapping one piece of metal over another by flanging it along its length cuts down significantly on fit-up time and may or may not stray from factory appearance, but it increases the chance of corrosion because water can get inside the flange.



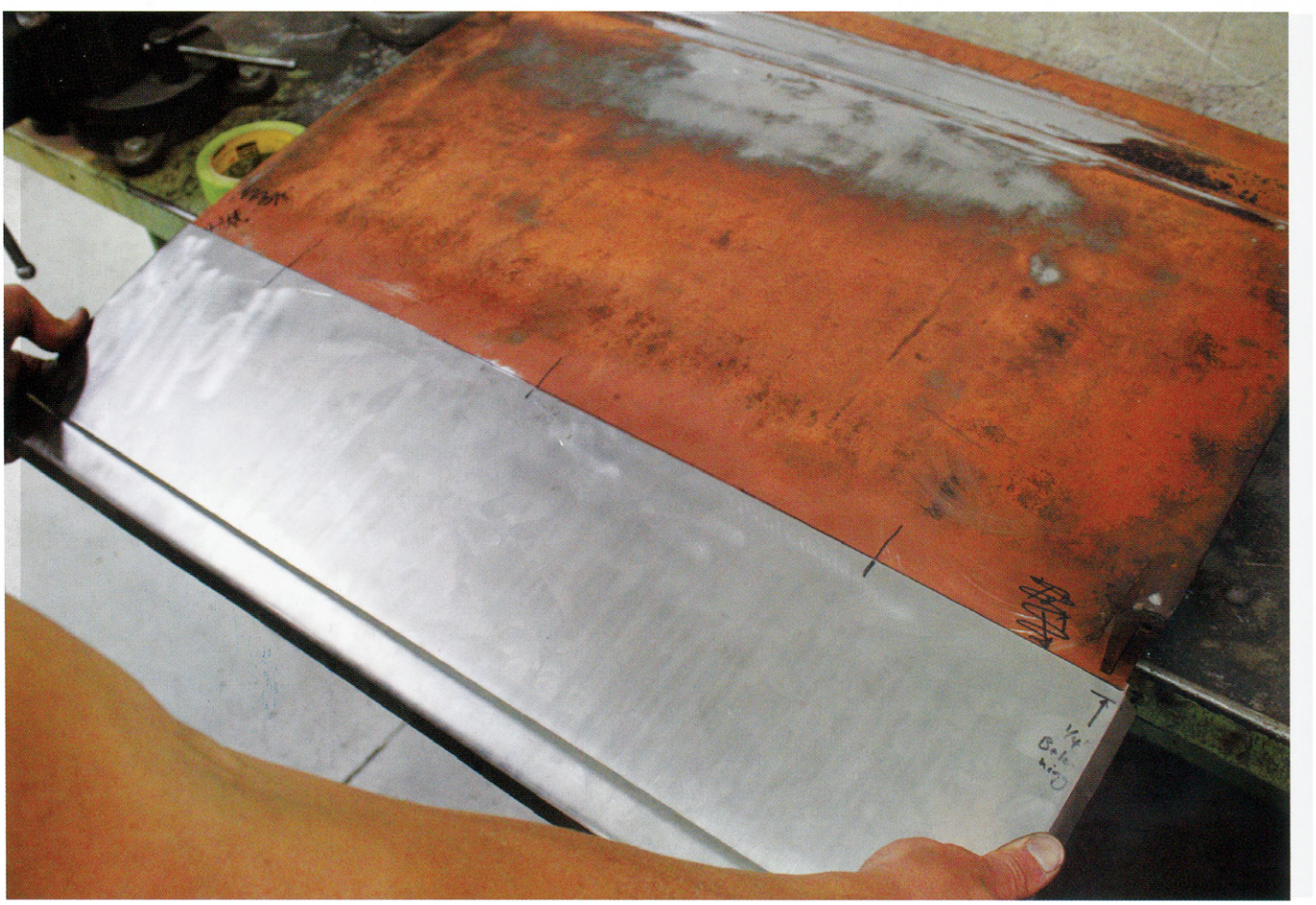
The relationship of the panels on the right side of this Ford Mustang look really nice, but it wasn't always this way. The clean lines and even panel gaps are artificial constructions created by the restorer looking for tasteful over-restoration.

Chapter 12
Repairing Doors

DOOR SKINS

Replacing a door skin is one of the more common sheet metal projects you are likely to encounter if you dabble in the restoration of old cars. For some car models, aftermarket door skins are available, but they vary greatly in quality. If the panels are high quality, re-skinning your door with an aftermarket door skin will be infinitely easier than making your own. Do not be ashamed to take the easier path if it is available. There will be enough challenges in restoring any car, no matter how common it is, to allow you to accumulate plenty of sweat equity in your project. Join a car club or online forum and find out what other people's experiences have been with various suppliers' products so that you can make an informed buying decision. Keep in mind, too, that one company's panels may originate in several different places depending on the specific panel, so the quality may vary accordingly. When I worked in a shop restoring British cars, I learned which panels were good and which were not from any given supplier, so pay close attention to exactly what products other car enthusiasts recommend.

If good aftermarket door skins are not available for your car, or if you simply welcome the challenge of making your own, I will describe the best procedure I have found for making door skins. First, assess how well the door really fits on the car. Correct body issues with your original door before you start tampering with the skin. Adjust the latch and shim the hinges if necessary to obtain the best fit with the door you have. The status quo contains a lot of



Besides a nasty karate chop across the belt line and some rust along the bottom, Joe McCullough's Model A door was fine. After a couple of tedious hours pushing inside the door with a dolly and tapping on the outside with a hammer, the belt line dent was repaired. The new skin was basically a crowned panel with a bead rolled along the bottom.

Chapter 13
Repairing Fenders, Hoods, and Trunk Lids

In this chapter I will examine some common maladies that afflict fenders, hoods, and trunk lids. Each car is different, of course, but patterns of corrosion and collision damage are surprisingly almost universal. Start with something small to build your skills and your confidence. Before long, very few projects will intimidate you.

FENDER FUN

Fenders form part of the tender epidermis of our beloved automobiles. As such, they tend to receive a lot of damage, both from collisions and from the weather. I have presented here some examples of widespread fender problems with the hope that readers will be able to apply the techniques represented to repair their cars, whatever they may be.

Rust holes at the bottom of front fenders on the slab-sided cars of the 1950s and newer are extremely common and easy to fix. Because patch panels vary in quality, it is difficult to know whether an aftermarket panel is a good option for your repair. I have illustrated a typical Ford Mustang patch panel to show how replacement panels compare to the original. In this case, the pressed body line in the reproduction piece resembled the original body line, and the fender lip along the wheel opening was somewhat close to the original, but it wasn't close enough simply to weld the new panel in place of the original. For $25, the patch panel was not a bad deal—and it would suffice for someone who did not feel confident to try making his or her own patch—but the finished result would not have had the quality we wanted. Furthermore, we had a rust hole about the size of a golf ball, so there was no reason to jeopardize the appearance of the body line and the fender lip.

No one would ever guess that the lower third of this Austin-Healey boot lid was a rusty, perforated disaster a few months prior. With the help of a hand-shrinking machine, fabricating a repair patch was not difficult.