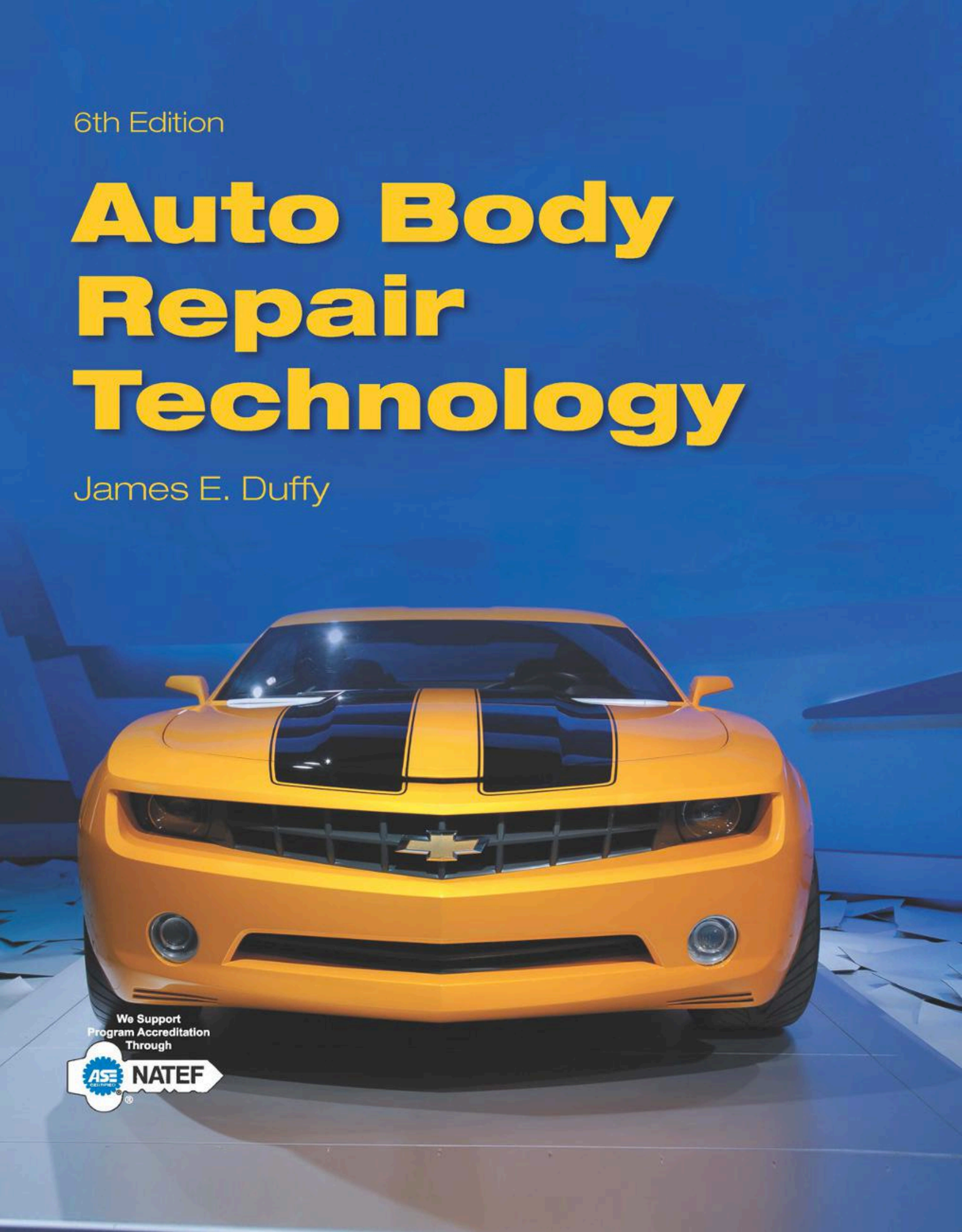
6th Edition

Auto Body Repair Technology

James E. Duffy



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Auto Body Repair Technology

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Sixth Edition

James E. Duffy

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Auto Body Repair Technology Sixth Edition
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Contents

Preface

Welcome to the rewarding world of auto body repair! Whether you simply want to make minor repairs on your own car or to become an ASE-certified collision repair technician, you will find this book a valuable resource.

Auto Body Repair Technology details how to properly restore a damaged vehicle to a like-new condition from start to finish. It is designed to help you work on any make and model passenger car, pickup truck, van, or sport utility vehicle (SUV).

Auto body repair, also called collision repair, is an exciting area to study. With millions of vehicles on the road today, there is a strong demand for well-trained collision repair technicians. Thousands of technicians are needed in the industry every year. Just look in the newspaper and you will find numerous openings for skilled people to work in body shops. With today's high-tech vehicles and varied construction methods and repair techniques, competent collision repair takes well-trained, knowledgeable professionals.

Section 1 provides an introduction to the industry. It explains all of the basic information that pertains to the industry in general. Section 2 covers estimating and has new material on electronic estimating and shop management software. Section 3 covers minor repairs—the kinds of repair tasks that can be done by a novice or trainee. Section 4 explains major body/frame repairs, including topics such as vehicle frame damage measurement and repair. Section 5 summarizes mechanical and electrical repairs to the steering, suspension, and brake system parts, which are often damaged in a major accident. Section 6 details refinishing and how to prep and paint the vehicle. The last section explains how professionalism will help you prosper as a collision repair expert.

The text flows more like work actually does in the industry. For example, estimating is covered right after the fundamentals section because estimating is the first task when a vehicle needs repair. The estimate outlines what must be done to repair the vehicle. Proper estimating helps technicians plan and execute quality repairs.

Writing is all about communication between the writer and the reader. This edition of *Auto Body Repair Technology* is the most readable edition ever published. We have worked hard to make the book easier to understand without diminishing its technical completeness. Textbooks are just one part of a vocational technical education; it is our sincere desire that this book adds something positive to that education.

Unless you are experienced in collision repair, you will have to learn hundreds of new technical terms, which make up the language of collision repair personnel. These vocabulary terms are highlighted so that you know that the word must be learned and understood before reading on. Every effort has been made to help you identify new key terms and explain them on first use.

Auto Body Repair Technology has been used by thousands of students and continues to this day to be a market leader. All of the people involved in the publishing of this book hope that you will appreciate its improvements. Most of all, we hope that the students hoping to become collision repair professionals will take from this book the information they need to get started the right way.

New to this Edition

- A new chapter has been added. Chapter 30, Collision Repair for Hybrid and Electric Vehicles.
- Updated throughout to ensure all necessary NATEF competencies have been addressed.
- Video sequences demonstrating shop practices are included within the MindTap offering. Look for select videos within the instructor resource material.
- Every effort has been made to make this book accurate. Collision repair teachers, experts in the field, and others were brought in to review this book and ensure its accuracy. We worked with all of their comments and criticisms.

Safety is emphasized throughout the text. Safety cautions and warnings appear frequently, and we worked to make sure that all the illustrations represent safe practices.

Throughout this book, there are three special notes labeled "Shop Talk," "Warning," and "Danger." Each one has a specific purpose:

1. "Shop Talk" notes give examples of typical conversations between two technicians. Sometimes they show how someone did something wrong, which

damaged a part or caused injury. Shop Talk notes also provide "tricks of the trade" for doing better, more efficient repair work.

2. "Warning" notes are given to help prevent technicians from making errors that can damage a vehicle or a tool. These notes provide information about unsafe practices that can cause repair problems, waste time, and cost shops and technicians money for repairs.
3. "Danger" notes remind technicians to be especially careful of those tasks where carelessness can cause personal injury.

Remember to read these special notes carefully!

We are anxious to know what you think of the effort to update and upgrade *Auto Body Repair Technology*. Send letters or call the publisher so I can hear what you think.

We hope you will find this book a useful resource for many years to come.

Sincerely,

James E. Duffy
A Fellow Educator

Acknowledgments

REVIEWERS

The author and publisher would like to thank the following instructors for their help with reviewing this and previous editions of the book.

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Volkswagen of America, Inc.
Volvo Cars of North America
Wedge Clamp

Features of the Text


CHAPTER 1

Collision Repair: Introduction and Careers

OBJECTIVES

After studying this chapter, you should be able to:

- Describe what happens to a motor vehicle during a collision.
- Summarize the basic steps needed to repair a vehicle damaged in an accident.
- Explain the major work areas of a typical collision repair facility.
- Summarize the work flow through a typical body shop.
- Describe the types of positions or jobs available in the collision repair industry.
- Identify the setup and inner workings of a typical collision repair shop.
- Answer ASE-style review questions relating to collision repair.
- Understand fundamental terms used in the collision repair industry.

INTRODUCTION

This chapter will explore the challenging world of auto body repair, also called collision repair. It will give you the basic knowledge needed to fully grasp the more detailed information in later chapters. You will follow damaged vehicles through a typical repair process from beginning to end; estimating damage; metal straightening, filling, sanding, masking, painting, and detailing; and final delivery to the customer.

Considering that the United States is a "nation on wheels" and auto accidents happen, you have selected an excellent area for further study. The collision repair skills you learn will remain in high demand as long as there are people driving automobiles. The collision repair industry is vast. Body shops do an astounding $10 billion of repair work per year. This enormous amount of work requires a vast number of well-trained technicians and related personnel.

If you are just beginning your study of collision repair, you have much to learn. Only highly skilled, knowledgeable professionals can properly repair today's vehicles. Study the material in this textbook carefully and you will be on your way to a successful career in collision repair.

HISTORY NOTE

Believe it or not, the very first "motor car" ever built was in an accident the first time it was driven on public roads. The huge, crude car looked something like a steam locomotive. It was being test-driven down a country road. Chugging over a hill, the steel-wheeled, "smoke-belching monster" almost ran over a horse-drawn carriage. The car's startled driver had to swerve off the narrow dirt road to avoid running over the horses, and he plowed into a brick wall. After the first car crash, plow horses had to be used to tow the "horseless carriage" back to the barn for body shop repairs.

1.1 WHAT IS COLLISION REPAIR?

A **collision**, nicknamed a *crash* or a *wreck* in laypersons' terms, is damage caused by an **impact** (hit) on the vehicle.

Figure 1-1 During a major collision, like this head-on crash test, tremendous energy is dissipated into the body/frame structure of both cars. Modern vehicles are designed to absorb this energy by controlled collapse of structural body/frame members. The front and rear ends of the vehicles are designed to crush or collapse while keeping the passenger compartment intact. With today's front and side air bags and seat belts, the drivers and passengers would suffer little or no injury in this violent collision.

Figure 1-2 If the accident results in major damage and the vehicle cannot be driven, a wrecker is called to tow the car. Proper tow methods are needed to avoid further damage when moving the wrecked car.

the worst type of accident because the speed of both vehicles must be combined to determine the force of the impact. For example, if both vehicles are travelling 70 miles per hour (mph), the impact is similar to one vehicle smashing into a stationary brick wall at an astounding 140 mph. Refer to Figure 1–1.

Because cars can weigh well over a ton (2,000 to 3,000 pounds or more) and some trucks and sport utility vehicles (SUVs) can weigh over 2 tons (4,000 pounds or more), body parts are often crushed, bent, and torn in a collision. Major body/frame parts can even be forced out of alignment due to the tremendous energy dissipation produced when such heavy objects strike each other.

Auto body repair, also called **collision repair**, involves fixing a vehicle that has been damaged in an accident. With minor damage, this might only involve sanding and repainting a fender. With more serious damage, a large section of the frame or body might have to be straightened and numerous parts replaced.

Accident Scene

An **accident report** summarizes what happened during a collision and lists information about the drivers, their vehicles, and their insurance companies. Even after a minor accident, the police are usually called so that an accident report, or crash report, can be filled out. The police officer will ask the drivers questions about the accident and write down what happened so that the insurance companies can determine what caused the accident and who might be at fault. The car owners will also call their insurance companies to report the accident.

A **wrecker** is a truck equipped with special lifting equipment for raising and transporting a damaged vehicle away from an accident scene. Most wreckers have a power-operated cable or a large hydraulic arm for lifting one end of the damaged vehicle for towing. A flatbed wrecker has a winch for pulling the whole vehicle up and onto the bed of the truck for transport.

If the car is no longer driveable, a wrecker will tow the damaged vehicle to a body shop or **salvage yard**, a business that resells parts from collision-damaged vehicles. Look at Figure 1–2.

Body Shop

A body shop, or **collision repair facility**, has well-trained technicians, specialized tools, and heavy equipment for restoring damaged vehicles to their pre-accident condition. There are several ways to classify a body shop. A few of the most common are discussed in the following section (Figure 1–3).

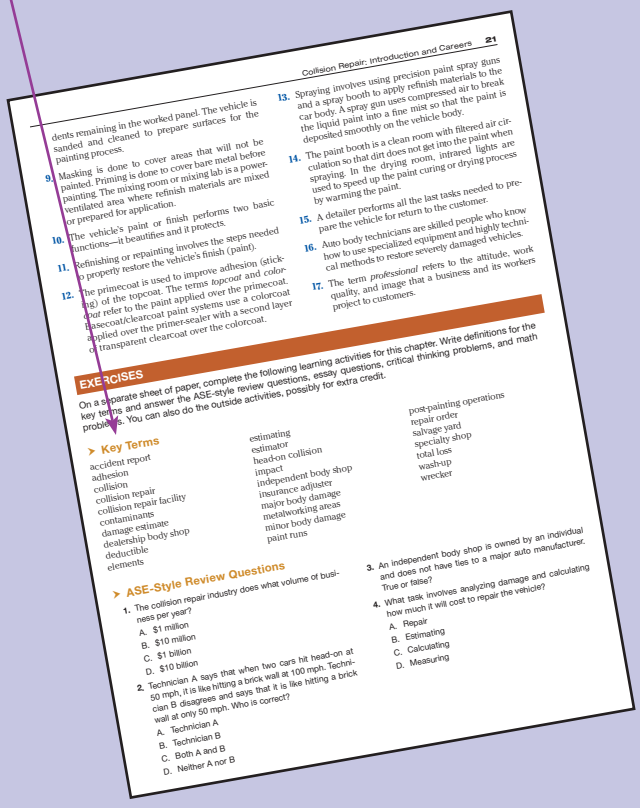
Figure 1-3 The modern body shop is equipped with specialized equipment and well-trained personnel. It can be a safe and enjoyable place to work, if safety rules are followed. If not, it can be a very dangerous place!

OBJECTIVES

Each chapter begins with a list of cognitive and performance-based *objectives*. The objectives state the knowledge and skills that should be learned after reading the entire chapter. This feature is an excellent way for the reader to gain a quick overview of the essential material within the chapter that will be learned before the reading begins.

KEY TERMS

The *Key Terms* are the most important technical words you will learn in the chapter. These are listed at the end of each chapter and appear in bold print where they are first defined. For added study, you can write the key terms on a sheet of paper with their definitions to make sure you can explain the terms. These terms are also given in the Glossary at the back of the book.



dents remaining in the worked panel. The vehicle is sanded and cleaned to prepare surfaces for the painting process.

9. Masking is done to cover areas that will not be painted. Priming is done to cover bare metal before painting. The mixing room or mixing lab is a power-ventilated area where refinish materials are mixed or prepared for application.
10. The vehicle's paint or finish performs two basic functions—it beautifies and it protects.
11. Refinishing or repainting involves the steps needed to properly restore the vehicle's finish (paint).
12. The primecoat is used to improve adhesion (sticking) of the topcoat. The terms *topcoat* and *colorcoat* refer to the paint applied over the primecoat. Basecoat/clearcoat paint systems use a colorcoat applied over the primer-sealer with a second layer of transparent clearcoat over the colorcoat.
13. Spraying involves using precision paint spray guns and a spray booth to apply refinish materials to the car body. A spray gun uses compressed air to break the liquid paint into a fine mist so that the paint is deposited smoothly on the vehicle body.
14. The paint booth is a clean room with filtered air circulation so that dirt does not get into the paint when spraying. In the drying room, infrared lights are used to speed up the paint curing or drying process by warming the paint.
15. A detailer performs all the last tasks needed to prepare the vehicle for return to the customer.
16. Auto body technicians are skilled people who know how to use specialized equipment and highly technical methods to restore severely damaged vehicles.
17. The term *professional* refers to the attitude, work quality, and image that a business and its workers project to customers.

EXERCISES

On a separate sheet of paper, complete the following learning activities for this chapter. Write definitions for the key terms and answer the ASE-style review questions, essay questions, critical thinking problems, and math problems. You can also do the outside activities, possibly for extra credit.

➤ Key Terms

accident report
adhesion
collision
collision repair
collision repair facility
contaminants
damage estimate
dealership body shop
deductible
elements
estimating
estimator
head-on collision
impact
independent body shop
insurance adjuster
major body damage
metalworking areas
minor body damage
paint runs
post-painting operations
repair order
salvage yard
specialty shop
total loss
washup
wrecker

➤ ASE-Style Review Questions

1. The collision repair industry does what volume of business per year?
   A. $1 million
   B. $10 million
   C. $1 billion
   D. $10 billion
2. Technician A says that when two cars hit head-on at 50 mph, it is like hitting a brick wall at 100 mph. Technician B disagrees and says that it is like hitting a brick wall at only 50 mph. Who is correct?
   A. Technician A
   B. Technician B
   C. Both A and B
   D. Neither A nor B
3. An independent body shop is owned by an individual and does not have ties to a major auto manufacturer. True or false?
4. What task involves analyzing damage and calculating how much it will cost to repair the vehicle?
   A. Repair
   B. Estimating
   C. Calculating
   D. Measuring

DANGER

Danger notes summarize critical safety rules. They alert you to operations that could hurt you or someone else. They do not only appear in the safety chapter; you will find them throughout the text where they apply. Read and remember all dangers. Your health is invaluable.

WARNINGS

Warnings provide important information to help prevent the kinds of accidents that can damage parts or tools. They are common mistakes that should be avoided. They appear throughout the text where they apply to the instructions being given.

SHOP TALK

Shop Talk notes give added information to help you complete a particular procedure successfully or to make a task easier. They are hints to help you work more efficiently and profitably.

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Figure 1–7 Before starting repairs, body shops usually wash the vehicle thoroughly to remove road dirt. Keeping the shop clean is important to refinishing quality because it keeps paint contaminants out of the shop work areas.

Figure 1–8 To start work, you must normally remove damaged outer body parts to gain access to hidden parts that require straightening or replacement. Here the technician is removing a front fender.

wiping the body down with wax and grease remover. These steps will remove mud, dirt, wax, and water-soluble **contaminants** (unwanted substances). These substances must be cleaned off before starting body-work because they could contaminate the paint and cause paint problems later. The car or truck should be completely dry before being moved to the repair area. Look at Figure 1–7.

Metalworking Areas

The **metalworking areas** are shop locations where damaged parts are removed, repaired, and installed. Such damage can result from either a collision or part deterioration. The metalworking area is where the shop performs most of the collision repair tasks. Because of all of the grinding, sanding, and welding, this area tends to become dusty and dirty quickly.

Before starting work in this area, the body technician must first study and diagnose the damage that has occurred. Body technicians use the information on the RO to determine what repairs are needed. The technician may need to consult with the estimator before proceeding. It is then up to the technician to decide how to accomplish the repairs outlined on the estimate and RO.

Once the damage and repair methods are analyzed, the repairs must be completed in a systematic manner. For example, if a panel is creased, torn, or caved in, it can be straightened using hammers, hydraulic jacks, and other body shop tools. If the panel is badly crushed and folded, it must be replaced. If the unibody or frame is damaged, it must be straightened or parts replaced according to factory recommendations.

A *stall* is a work area for one vehicle, often marked off with painted lines on the floor. Also termed a *bay*, each stall is large enough so that the technician has room to work all the way around the vehicle.

Often, one of the first steps completed in the metalworking area is part removal. Badly damaged bolt-on parts must be removed to gain access to hidden damage. This might involve unfastening the bumper, grille, or fenders, for example Figure 1–8.

DANGER Dangers in the metalworking area are many and varied—tasks such as cutting metal, straightening frames, welding, grinding, and sanding can all result in injuries. Do not attempt to work in the metalworking areas of a body shop until you have studied the basic safety rules and repair methods that are explained in later chapters of this book.

WARNING Always refer to factory service information for details when working. Factory publications will give specifications, detailed procedures, and other information specific to the exact make and model vehicle being repaired. This information is often needed to do professional, quality work!

Vehicle Measurement

Vehicle measurement helps determine the extent and direction of major damage. If the vehicle has been in a serious accident, vehicle measurement is often done to find out whether the frame/unibody has been forced out of alignment. Specialized measuring tools are used to measure across specific reference points on the vehicle to find out whether body damage exists.

Measurement systems are specialized tools and equipment that allow the technician to check for frame

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shop manager is usually the same person. In large operations or dealerships, the owner might hire a shop manager. In all cases, the person in charge should understand all of the work done in the shop as well as its business operations.

The *shop supervisor* is in charge of the everyday operation of the shop. This job involves communication with all personnel who contribute to the body shop's success.

The *parts manager* is in charge of ordering all parts (both new and salvaged), receiving all parts, and seeing that they are delivered to the right technician. Because not every collision repair shop has a parts manager, the task of ordering parts can fall on all employees at one time or another.

The *bookkeeper* keeps the shop's books, prepares invoices, writes checks, pays bills, makes bank deposits, checks bank statements, and takes care of tax payments. Many shops hire an outside accountant to help perform these tasks.

The *office manager's* duties include various aspects of the business—handling letters, estimates, and receipts, for example. In many small shops, the office manager also acts as the parts manager and bookkeeper.

A *receptionist* is sometimes employed to greet customers, answer the phone, route messages, and do other tasks.

Larger shops generally have trained *tow truck operators* to operate their wrecker(s). Rather than own these expensive pieces of equipment, many smaller shops depend on independent towing services or farm out such work to other repair garages.

SHOP TALK It is important for body shop personnel to have good communication and cooperation skills. Everyone in the shop should work as a team member to make the facility profitable, enjoyable, and safe. "A chain is only as strong as its weakest link"—this saying applies to the smooth operation of a body shop. If anyone—from the estimator to the painter—does not do the job right, everyone suffers. Customers will not return to the shop, and everyone's paycheck will be affected in the long run.

There are other career openings in the collision repair field. Some of these include:

- Insurance adjuster or appraiser
- Vocational/technical instructor
- Salvage yard technician
- Dealership parts counterperson
- Paint company representative
- Auto manufacturer representative
- Equipment salesperson

To research these and other career opportunities, talk to your guidance counselor, visit your local library, or search the Internet. There you can obtain more detailed information on the qualifications and training requirements for each position.

SUMMARY

1. A collision, nicknamed a *crash* or a *wreck*, is damage caused by an impact (hit) on the vehicle.
2. Auto body repair, also called collision repair, involves fixing a vehicle that has been damaged in an accident. The vehicle is first brought into the shop, where a damage estimate is prepared to calculate the cost of repairs.
3. Minor body damage only requires that a few parts be replaced or repaired before the car is repainted. Major body damage usually must be corrected by replacing, repairing, and straightening large body parts before repainting. A collision can also be severe enough to cause a total loss, where repairs would be more expensive than buying another car.
4. Repair instructions are summarized on a printed repair order (RO), and the repairs are carried out according to those instructions. The metalworking areas are shop locations where damaged parts are removed, repaired, and installed. A stall is a work area for one vehicle, often marked off with painted lines on the floor.
5. Vehicle measurement is done to determine the extent and direction of major damage. Measurement systems are specialized tools and equipment that help the technician to check and measure for frame or body misalignment resulting from a high-impact collision.
6. Frame straightening equipment (also called a frame rack) uses a large steel framework, pulling chains, and hydraulic power to pull or force the frame or body back into its original position.
7. A panel is a large metal or plastic body part—a fender, hood, truck, or roof panel, for example. Structural panel replacement involves welding a new panel in place of an old, damaged one. Panel adjustment involves moving or shifting a part to properly align with other parts or panels. When parts are replaced, corrosion protection coatings must be applied to prevent the new parts from rusting.
8. Panel straightening involves using various hand tools and equipment to force the panel back into its original shape. Body filler is used to cover any small

20 Chapter 1

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CHAPTER SUMMARY

Each *Chapter Summary* gives a brief list of the most important information in the chapter. It will help you review and understand which points were the most important.

REVIEW QUESTIONS

Review Questions will help you to measure the skills and knowledge you learned in the chapter. To check your "brain power," different types of questions are given: ASE, Essay, Critical Thinking Problems, and Math Problems. The ASE questions will help you prepare to pass auto body repair certification tests.

ACTIVITIES

These are practical, hands-on activities that challenge the student to apply the skills learned in the chapter to real-life experiences. *Activities* often include going to a body shop or other workplaces to gather some type of research for analysis. This feature is a wonderful way to teach students how and where they will eventually use their skills.

PHOTO SUMMARIES

Several step-by-step photo summaries illustrate common auto body repair procedures.


Photo Summary

Unibody/Frame Realignment

Figure P18-1 Remove any parts that are in the way of clamping and pulling operations.

Figure P18-2 Anchor the vehicle so it will not move when pulling force is applied. Pinch weld clamps are often tightened down around the lower rocker panel flange to secure the vehicle.

Figure P18-3 Attach pulling chains at the locations of damage. Generally, you want to pull out damage in the reverse of the order in which it was formed by the collision impact forces.

Figure P18-4 Stand to one side of the chains as force is applied. Do not exceed the recommended equipment pressure.

Figure P18-5 Stop periodically to measure progress. Remove the pulling forces and measure the area being pulled. Keep pulling until all reference points are within specifications.

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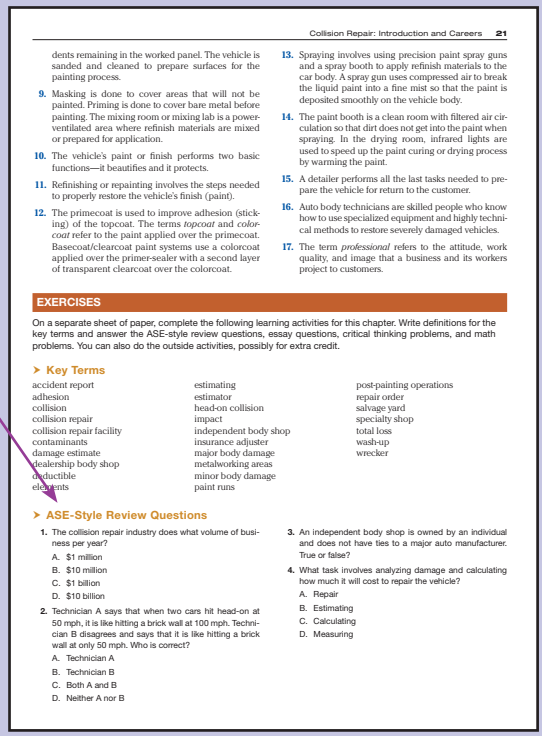

Collision Repair: Introduction and Careers 21

dents remaining in the worked panel. The vehicle is sanded and cleaned to prepare surfaces for the painting process.

9. Masking is done to cover areas that will not be painted. Priming is done to cover bare metal before painting. The mixing room or mixing lab is a power-ventilated area where refinish materials are mixed or prepared for application.
10. The vehicle's paint or finish performs two basic functions—it beautifies and it protects.
11. Refinishing or repainting involves the steps needed to properly restore the vehicle's finish (paint).
12. The primecoat is used to improve adhesion (sticking) of the topcoat. The terms *topcoat* and *colorcoat* refer to the paint applied over the primecoat. Basecoat/clearcoat paint systems use a colorcoat applied over the primer-sealer with a second layer of transparent clearcoat over the colorcoat.
13. Spraying involves using precision paint spray guns and a spray booth to apply refinish materials to the car body. A spray gun uses compressed air to break the liquid paint into a fine mist so that the paint is deposited smoothly on the vehicle body.
14. The paint booth is a clean room with filtered air circulation so that dirt does not get into the paint when spraying. In the drying room, infrared lights are used to speed up the paint curing or drying process by warming the paint.
15. A detailer performs all the last tasks needed to prepare the vehicle for return to the customer.
16. Auto body technicians are skilled people who know how to use specialized equipment and highly technical methods to restore severely damaged vehicles.
17. The term *professional* refers to the attitude, work quality, and image that a business and its workers project to customers.

EXERCISES

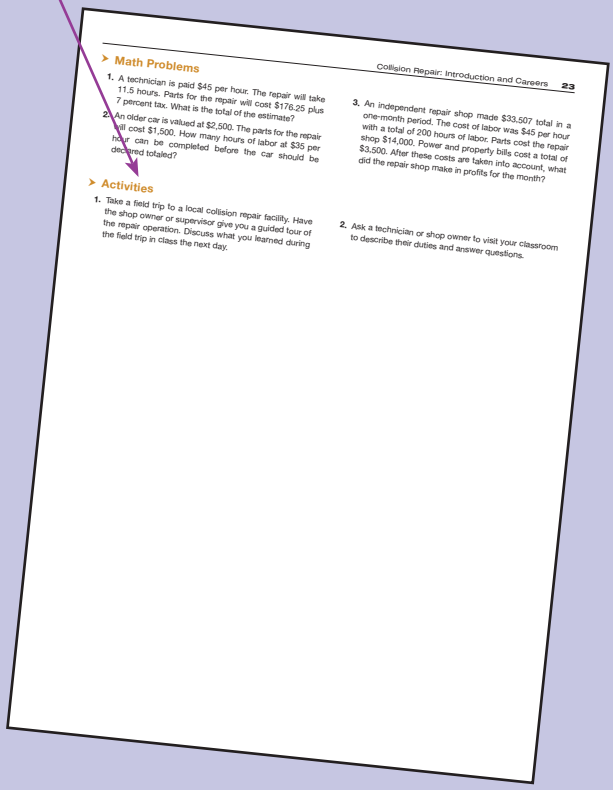
On a separate sheet of paper, complete the following learning activities for this chapter. Write definitions for the key terms and answer the ASE-style review questions, essay questions, critical thinking problems, and math problems. You can also do the outside activities, possibly for extra credit.

➤ Key Terms

accident report
adhesion
collision
collision repair
collision repair facility
contaminants
damage estimate
dealership body shop
deductible
elements
estimating
estimator
head-on collision
impact
independent body shop
insurance adjuster
major body damage
metalworking areas
minor body damage
paint runs
post-painting operations
repair order
salvage yard
specialty shop
total loss
wash-up
wrecker

➤ ASE-Style Review Questions

1. The collision repair industry does what volume of business per year?
   A. $1 million
   B. $10 million
   C. $1 billion
   D. $10 billion
2. Technician A says that when two cars hit head-on at 50 mph, it is like hitting a brick wall at 100 mph. Technician B disagrees and says that it is like hitting a brick wall at only 50 mph. Who is correct?
   A. Technician A
   B. Technician B
   C. Both A and B
   D. Neither A nor B
3. An independent body shop is owned by an individual and does not have ties to a major auto manufacturer. True or false?
4. What task involves analyzing damage and calculating how much it will cost to repair the vehicle?
   A. Repair
   B. Estimating
   C. Calculating
   D. Measuring


➤ Math Problems

Collision Repair: Introduction and Careers 23

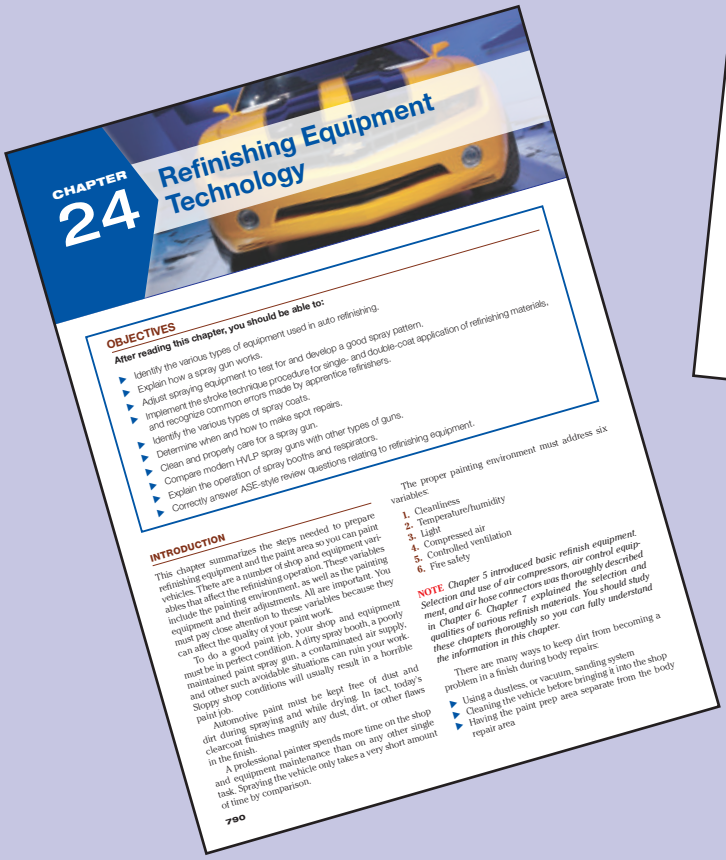
1. A technician is paid $45 per hour. The repair will take 11.5 hours. Parts for the repair will cost $176.25 plus 7 percent tax. What is the total of the estimate?
2. An older car is valued at $2,500. The parts for the repair will cost $1,500. How many hours of labor at $35 per hour can be completed before the car should be declared totaled?
3. An independent repair shop made $33,507 total in a one-month period. The cost of labor was $45 per hour with a total of 200 hours of labor. Parts cost the repair shop $14,000. Power and property bills cost a total of $3,500. After these costs are taken into account, what did the repair shop make in profits for the month?

➤ Activities

1. Take a field trip to a local collision repair facility. Have the shop owner or supervisor give you a guided tour of the repair operation. Discuss what you learned during the field trip in class the next day.
2. Ask a technician or shop owner to visit your classroom to describe their duties and answer questions.

FULL-COLOR CHAPTERS

Every chapter in *Auto Body Repair Technology* is now in full color, bringing the text to life with more detailed and realistic illustrations of collision repair technologies.


CHAPTER 24

Refinishing Equipment Technology

OBJECTIVES

After reading this chapter, you should be able to:

- Identify the various types of equipment used in auto refinishing.
- Explain how a spray gun works.
- Adjust spraying equipment to test for and develop a good spray pattern.
- Implement the stroke technique procedure for single- and double-coat application of refinishing materials, and recognize common errors made by apprentice refinishers.
- Identify the various types of spray coats.
- Identify when and how to make spot repairs.
- Determine when and how to care for a spray gun.
- Clean and properly care for spray guns with other types of guns.
- Compare modern HVLP spray guns with other types of guns.
- Explain the operation of spray booths and respirators.
- Correctly answer ASE-style review questions relating to refinishing equipment.

INTRODUCTION

This chapter summarizes the steps needed to prepare refinishing equipment and the paint area so you can paint vehicles. There are a number of shop and equipment variables that affect the refinishing operation, as well as the painting equipment and their adjustments. All are important. You must pay close attention to these variables because they can affect the quality of your paint work.

To do a good paint job, your shop and equipment must be in perfect condition. A dirty spray booth, a poorly maintained paint spray gun, a contaminated air supply, and other such avoidable situations can ruin your work. Sloppy shop conditions will usually result in a horrible paint job.

Automotive paint must be kept free of dust and dirt during spraying and while drying. In fact, today's clearcoat finishes magnify any dust, dirt, or other flaws in the finish.

A professional painter spends more time on the shop and equipment maintenance than on any other single task. Spraying the vehicle only takes a very short amount of time by comparison.

The proper painting environment must address six variables:

1. Cleanliness
2. Temperature/humidity
3. Light
4. Compressed air
5. Controlled ventilation
6. Fire safety

NOTE *Chapter 5 introduced basic refinish equipment. Selection and use of air compressors, air control equipment, and air hose connectors was thoroughly described in Chapter 6. Chapter 7 explained the selection and qualities of various refinish materials. You should study these chapters thoroughly so you can fully understand the information in this chapter.*

There are many ways to keep dirt from becoming a problem in a finish during body repairs:

- Using a dustless, or vacuum, sanding system
- Cleaning the vehicle before bringing it into the shop
- Having the paint prep area separate from the body repair area

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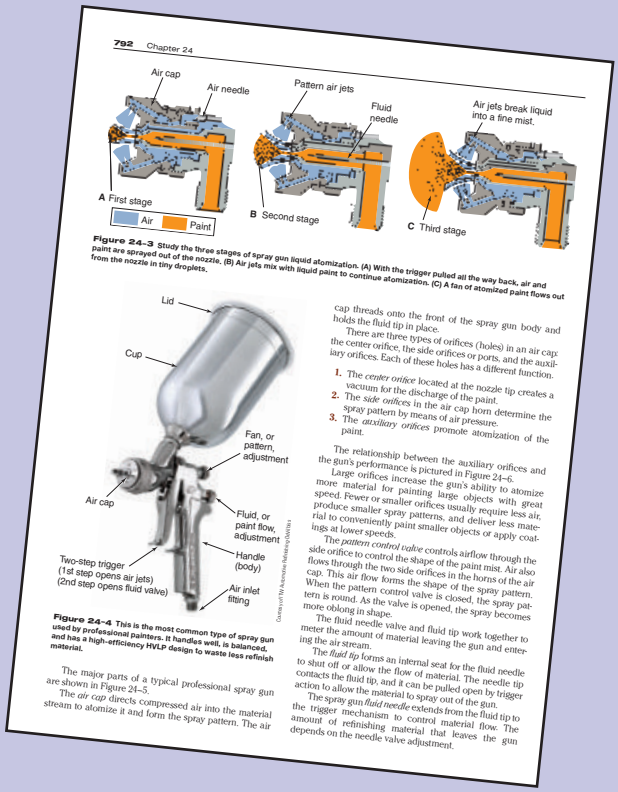

Figure 24–3 Study the three stages of spray gun liquid atomization. (A) With the trigger pulled all the way back, air and paint are sprayed out of the nozzle. (B) Air jets mix with liquid paint to continue atomization. (C) A fan of atomized paint flows out from the nozzle in tiny droplets.

Figure 24–4 This is the most common type of spray gun used by professional painters. It handles well, is balanced, and has a high-efficiency HVLP design to waste less refinish material.

The major parts of a typical professional spray gun are shown in Figure 24–5.

The *air cap* directs compressed air into the material stream to atomize it and form the spray pattern. The air cap threads onto the front of the spray gun body and holds the fluid tip in place.

There are three types of orifices (holes) in an air cap: the center orifice, the side orifices or ports, and the auxiliary orifices. Each of these holes has a different function.

1. The *center orifice* located at the nozzle tip creates a vacuum for the discharge of the paint.
2. The *side orifices* in the air cap horn determine the spray pattern by means of air pressure.
3. The *auxiliary orifices* promote atomization of the paint.

The relationship between the auxiliary orifices and the gun's performance is pictured in Figure 24–6.

Large orifices increase the gun's ability to atomize more material for painting large objects with great speed. Fewer or smaller orifices usually require less air, produce smaller spray patterns, and deliver less material to conveniently paint smaller objects or apply coatings at lower speeds.

The *pattern control valve* controls airflow through the side orifice to control the shape of the paint mist. Air also flows through the two side orifices in the horns of the air cap. This air flow forms the shape of the spray pattern. When the pattern control valve is closed, the spray pattern is round. As the valve is opened, the spray becomes more oblong in shape.

The fluid needle valve and fluid tip work together to meter the amount of material leaving the gun and entering the air stream.

The *fluid tip* forms an internal seat for the fluid needle to shut off or allow the flow of material. The needle tip contacts the fluid tip, and it can be pulled open by trigger action to allow the material to spray out of the gun.

The spray gun *fluid needle* extends from the fluid tip to the trigger mechanism to control material flow. The amount of refinishing material that leaves the gun depends on the needle valve adjustment.

Figure 24–50 For safety reasons and to avoid static electrical charges that can attract dirt, you should use a jumper wire to ground a vehicle in the spray booth before spraying.

Figure 24–52 Airbrushes are commonly used by experienced, talented painters to do custom finishes. This vehicle's painter was also an artist!

A

B

Figure 24–51 (A) A touch-up gun is sometimes used to spray very small areas with colorcoat. (B) An airbrush is used to do custom paint work.

24.8 SPRAY BOOTHS

A **spray booth** is designed to provide a clean, safe, well-lit, and well-ventilated enclosure for painting vehicles. A spray booth isolates the painting operation from dirt- and dust-producing activities and confines and exhausts the volatile fumes created by spraying automotive finishes. Please refer to Figure 24–54.

Modern one- and two-room spray booths are scientifically designed to create the proper air movement, provide necessary lighting, and safely enclose the painting operation. In addition, their construction and performance must conform to federal, state, and even local safety codes, not to mention those of insurance underwriters. In most areas, automatically operated fire extinguishers are required because of the highly explosive nature of the refinishing materials (Figure 24–55).

Cleaning preparation should be done outside the booth area. Steam clean the underbody of a vehicle thoroughly and air dust the entire vehicle before moving it into the spray booth. After the vehicle is in the booth, close the booth doors tightly and wipe the entire vehicle again with a tack cloth before proceeding with the painting operation.

All spray booth doors must be kept tightly closed during painting. If it becomes necessary to open a door, be sure the air supply is turned off. In fact, many spray booths are equipped with door switches that shut off the air supply when the doors are opened. The air compressor should be outside the booth with the air delivery pipes slanting back toward the compressor.

An *air makeup* or *air replacement system* is important because of the large volume of air exhausted from a spray booth. During the winter, the spray area can become cold and uncomfortable. Finish problems can arise from spraying cold materials on cold vehicles in cold air. An air makeup system will provide even temperatures and clean filtered air as well as ensure proper booth performance.

Sometimes paint shops employ an independent air replacement system specifically designed for the spray

Supplements

Student Technician's Manual

Written by an experienced automotive collision repair teacher the Student's Technician's Lab Manual has been developed as a supplemental learning tool. The job sheets provide detailed directions for doing hands-on learning activities. They outline and question students as they complete competency-based learning tasks.

Instructor Resources CD

Carefully prepared, the Instructor Resources CD brings together several time-saving tools that allow for effective, efficient instruction. The Instructor Resources CD contains the following components:

- **PowerPoint®** lecture slides, which present the highlights of each chapter.
- An **Image Gallery**, which offers a database of hundreds of images in the text. These can easily be imported into the PowerPoint® presentations.
- An **Answer Key** file, which provides the answers to all end-of-chapter questions.
- **NATEF Correlations**
- **End-of-Chapter Review Questions**, which are provided in MS Word format.

Instructor Companion Website

The Instructor Companion Website, found on cengagebrain.com, includes the following components to help minimize instructor preparation time and engage students:

- **PowerPoint®** lecture slides, which present the highlights of each chapter.
- An **Image Gallery**, which offers a database of hundreds of images in the text. These can easily be imported into the PowerPoint® presentations.
- An **Answer Key** file, which provides the answers to all end-of-chapter questions.
- **NATEF Correlations**
- **End-of-Chapter Review Questions**, which are provided in MS Word format.

Cengage Learning Testing Powered by Cognero is a flexible, online system that allows you to:

- Author, edit, and manage test bank content from multiple Cengage Learning solutions.
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MindTap for Auto Body Repair Technology

MindTap is a personalized teaching experience with relevant assignments that guide students to analyze, apply, and improve thinking, allowing you to measure skills and outcomes with ease.

- *Personalized Teaching*: Becomes YOURS with a Learning Path that is built with key student objectives. Control what students see and when they see it—match your syllabus exactly by hiding, rearranging, or adding your own content.
- *Guide Students*: Goes beyond the traditional "lift and shift" model by creating a unique learning path of relevant readings, multimedia and activities that move students up the learning taxonomy from basic knowledge and comprehension to analysis and application.
- *Measure Skills and Outcomes*: Analytics and reports provide a snapshot of class progress, time on task, engagement and completion rates.

SECTION

1

Introduction

CHAPTER 1

Collision Repair: Introduction and Careers

OBJECTIVES

After studying this chapter, you should be able to:

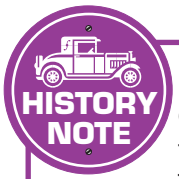
- Describe what happens to a motor vehicle during a collision.
- Summarize the basic steps needed to repair a vehicle damaged in an accident.
- Explain the major work areas of a typical collision repair facility.
- Summarize the work flow through a typical body shop.
- Describe the types of positions or jobs available in the collision repair industry.
- Identify the setup and inner workings of a typical collision repair shop.
- Answer ASE-style review questions relating to collision repair.
- Understand fundamental terms used in the collision repair industry.

INTRODUCTION

This chapter will explore the challenging world of auto body repair, also called collision repair. It will give you the basic knowledge needed to fully grasp the more detailed information in later chapters. You will follow damaged vehicles through a typical repair process from beginning to end: estimating damage; metal straightening, filling, sanding, masking, painting, and detailing; and final delivery to the customer.

Considering that the United States is a "nation on wheels" and auto accidents happen, you have selected an excellent area for further study. The collision repair skills you learn will remain in high demand as long as there are people driving automobiles. The collision repair industry is vast. Body shops do an astounding $10 billion of repair work per year. This enormous amount of work requires a vast number of well-trained technicians and related personnel.

If you are just beginning your study of collision repair, you have much to learn. Only highly skilled, knowledgeable professionals can properly repair today's vehicles. Study the material in this textbook carefully and you will be on your way to a successful career in collision repair.



Believe it or not, the very first "motor car" ever built was in an accident the first time it was driven on public roads. The huge, crude car looked something like a steam locomotive. It was being test-driven down a country road. Chugging over a hill, the steel-wheeled, "smoke-belching monster" almost ran over a horse-drawn carriage. The car's startled driver had to swerve off the narrow dirt road to avoid running over the horses, and he plowed into a brick wall. After the first car crash, plow horses had to be used to tow the "horseless carriage" back to the barn for body shop repairs.

1.1 WHAT IS COLLISION REPAIR?

A **collision**, nicknamed a *crash* or a *wreck* in laypersons' terms, is damage caused by an **impact** (hit) on the vehicle. This impact might be from another vehicle or from another object. The collision might be minor enough to only scratch the paint, or it might be severe enough to cause thousands of dollars' worth of damage to numerous metal and plastic parts.

A **head-on collision** results when two vehicles driving toward each other accidentally collide. It is often

Courtesy of Saab Cars USA, Inc.

Figure 1–1 During a major collision, like this head-on crash test, tremendous energy is dissipated into the body/frame structures of both cars. Modern vehicles are designed to absorb this energy by controlled collapse of structural body/frame members. The front and rear ends of the vehicles are designed to crush or collapse while keeping the passenger compartment intact. With today's front and side air bags and seat belts, the drivers and passengers would suffer little or no injury in this violent collision.

Figure 1–2 If the accident results in major damage and the vehicle cannot be driven, a wrecker is called to tow the car. Proper tow methods are needed to avoid further damage when moving the wrecked car.

the worst type of accident because the speed of both vehicles must be combined to determine the force of the impact. For example, if both vehicles are travelling 70 miles per hour (mph), the impact is similar to one vehicle smashing into a stationary brick wall at an astounding 140 mph. Refer to Figure 1–1.

Because cars can weigh well over a ton (2,000 to 3,000 pounds or more) and some trucks and sport utility vehicles (SUVs) can weigh over 2 tons (4,000 pounds or more), body parts are often crushed, bent, and torn in a collision. Major body/frame parts can even be forced out of alignment due to the tremendous energy dissipation produced when such heavy objects strike each other.

Auto body repair, also called **collision repair**, involves fixing a vehicle that has been damaged in an accident. With minor damage, this might only involve sanding and repainting a fender. With more serious damage, a large section of the frame or body might have to be straightened and numerous parts replaced.

Accident Scene

An **accident report** summarizes what happened during a collision and lists information about the drivers, their vehicles, and their insurance companies. Even after a minor accident, the police are usually called so that an accident report, or crash report, can be filled out. The police officer will ask the drivers questions about the accident and write down what happened so that the insurance companies can determine what caused the accident and who might be at fault. The car owners will also call their insurance companies to report the accident.

A **wrecker** is a truck equipped with special lifting equipment for raising and transporting a damaged vehicle away from an accident scene. Most wreckers have a power-operated cable or a large hydraulic arm for lifting one end of the damaged vehicle for towing. A flatbed wrecker has a winch for pulling the whole vehicle up and onto the bed of the truck for transport.

If the car is no longer driveable, a wrecker will tow the damaged vehicle to a body shop or **salvage yard**, a business that resells parts from collision-damaged vehicles. Look at Figure 1–2.

Body Shop

A body shop, or **collision repair facility**, has well-trained technicians, specialized tools, and heavy equipment for restoring damaged vehicles to their pre-accident condition. There are several ways to classify a body shop. A few of the most common are discussed in the following section (Figure 1–3).

Figure 1–3 The modern body shop is equipped with specialized equipment and well-trained personnel. It can be a safe and enjoyable place to work if safety rules are followed. If not, it can be a very dangerous place!

An **independent body shop** is owned and operated by a private individual. The shop is not associated with other shops or companies.

A *franchise body shop* is tied to a main headquarters that regulates and aids the operation of the shop. The shop logo, materials used, fees, and so on are all set by the corporate headquarters, and the franchisee must follow these guidelines.

A **dealership body shop** is owned and managed under the guidance of a new car dealership, such as General Motors, Chrysler, Lexus, Toyota, Jaguar, or Ford. This type of shop often concentrates on repairs of the specific make of cars sold by the dealership.

A *progression* or *production shop* often has an assembly line organization with specialists in each area of repair. One person might do nothing but heavy frame repair work. Another technician might be good at "building the body," or installing parts and panels. The shop might have a wheel alignment technician, prep people, painter, and cleanup specialists. The vehicle will move from one area and specialist to the next until fully repaired.

A **specialty shop** performs only specific types of repairs. For example, the body shop might send a radiator with a small hole in it to a specialty radiator shop for repair with specialized equipment.

A body shop that provides *complete collision services* might do wheel alignments, cooling system repairs, electrical system diagnosis and repair, suspension system work, and other repairs. Today, more and more collision repair shops are offering complete collision services. They have both a body shop area and a mechanical repair area.

Damage Estimating

A vehicle involved in a collision is first brought into the shop, where a **damage estimate** is prepared to calculate the cost of repairs. The labor, parts, and materials must be added to find the total cost of vehicle repair (Figure 1–4).

Estimating involves analyzing damage and calculating how much it will cost to repair a vehicle. It is critical that the quote on the repair be neither too high nor too low. If the estimate is too high, another shop with a lower bid will usually get the job. If too low, the profits may not be enough to cover the cost of repairs, and the shop could lose money.

In most shops, a well-trained **estimator** makes an appraisal of vehicle damage and determines what must be done to repair the vehicle. This person must be well versed in how cars and trucks are made and be good with numbers, computers, and communicating with people. An estimator at work is shown in Figure 1–5.

Minor body damage requires that only a few parts be replaced or repaired before being refinished or painted. Minor damage is often due to a low-speed "fender bender" in which two cars hit at low speed or one car runs into something. Such damage might be as minor as a tiny "door ding" that occurs when someone

A The estimator must study the damage carefully to determine the cost of repairs. Today's estimators often use an electronic storage unit and electronic camera so that data about damage can be input into the shop's computer.

B The vehicle interior is often damaged in a major collision. Replacing deployed air bags is expensive and must be included in the estimate.

C Damage to the engine, engine mounts, pulleys, and underbody parts must be accounted for in an estimate. Sometimes the vehicle is raised on a lift for undercarriage inspection.

Figure 1–4 Estimating is done to evaluate the extent of the damage and to arrive at a cost for repairing the vehicle.

A Data is downloaded into a personal computer in the business office.

B A special estimating computer program will speed tabulation of labor rates and parts costs.

Figure 1–5 Once damage has been inspected, a computer is used to streamline estimating and ordering parts.

accidentally opens a car door into the side of another car, making a small paint chip.

Major body damage must usually be corrected by replacing, repairing, and straightening large body parts before refinishing. Parts might have to be cut off and new ones welded into place. Though severe, repairing the damage is less than the cost of vehicle replacement or less than the value of the vehicle.

A collision can also be severe enough to cause a **total loss**, in which repairs would be more expensive than buying another car. In this case, the insurance company does not pay for repairs but instead gives the driver enough money to purchase another similar year, make, and model vehicle.

Remember that nearly any damaged automobile can be restored to a safe, driveable condition if the vehicle owner or insurance company is willing to pay for the repair. It is this cost that is the major consideration (Figure 1–6).

The estimate is usually given to the customer, who submits it to the insurance company. **The insurance adjuster** reviews the estimates and determines which one best reflects how the vehicle should be repaired. The

Figure 1–6 Once parts, labor, and materials have been tabulated, a printout or hard copy of the estimate summarizing what must be done to repair the vehicle and the repair costs is given to the customer and/or insurance adjuster.

adjuster may inspect the wrecked car to determine that the repairs will be done in a cost-effective fashion. The insurance company usually writes a check to the owner of the damaged vehicle to cover the cost of the repair, minus any **deductible** (amount the owner agrees to co-pay on the insurance policy).

1.2 BODY SHOP REPAIRS

Once the owner and the insurance company approve the repairs, the vehicle is turned over to the shop supervisor. The shop supervisor, sometimes with the help of a technician, will then review the estimate to determine how to do the repair.

Repair instructions are summarized on a printed **repair order** (RO), and the repairs are carried out according to these instructions. Once the RO is received in the shop, body shop repair procedures follow a general sequence. The basic repair sequence for a vehicle that has major frame/body damage is as follows:

1. Clean vehicle before moving it into repair area.
2. Study the RO and vehicle damage to determine repair procedure.
3. Remove badly damaged bolt-on parts.
4. Measure damage.
5. Straighten frame/unibody damage on frame rack.
6. Replace badly damaged welded-on parts.
7. Straighten minor body damage.
8. Apply body filler and coarse-sand repair area.
9. Apply a primer-filler around body filled area.
10. Fine-sand repair area and all parts to be refinished.
11. Mask areas not to be painted.
12. Clean surfaces to be painted.
13. Refinish (prime, seal, paint) damaged body parts.
14. Detail vehicle (unmask, clean, and polish) as needed.

Wash-Up Area

When a car is brought into the shop, the first step is usually wash-up. **Wash-up** involves a thorough cleaning of the vehicle with soap and water. This is followed by

Figure 1–7 Before starting repairs, body shops usually wash the vehicle thoroughly to remove road dirt. Keeping the shop clean is important to refinishing quality because it keeps paint contaminants out of the shop work areas.

Figure 1–8 To start work, you must normally remove damaged outer body parts to gain access to hidden parts that require straightening or replacement. Here the technician is removing a front fender.

wiping the body down with wax and grease remover. These steps will remove mud, dirt, wax, and water-soluble **contaminants** (unwanted substances). These substances must be cleaned off before starting bodywork because they could contaminate the paint and cause paint problems later. The car or truck should be completely dry before being moved to the repair area. Look at Figure 1–7.

Metalworking Areas

The **metalworking areas** are shop locations where damaged parts are removed, repaired, and installed. Such damage can result from either a collision or part deterioration. The metalworking area is where the shop performs most of the collision repair tasks. Because of all of the grinding, sanding, and welding, this area tends to become dusty and dirty quickly.

Before starting work in this area, the body technician must first study and diagnose the damage that has occurred. Body technicians use the information on the RO to determine what repairs are needed. The technician may need to consult with the estimator before proceeding. It is then up to the technician to decide how to accomplish the repairs outlined on the estimate and RO.

Once the damage and repair methods are analyzed, the repairs must be completed in a systematic manner. For example, if a panel is creased, torn, or caved in, it can be straightened using hammers, hydraulic jacks, and other body shop tools. If the panel is badly crushed and folded, it must be replaced. If the unibody or frame is damaged, it must be straightened or parts replaced according to factory recommendations.

A *stall* is a work area for one vehicle, often marked off with painted lines on the floor. Also termed a *bay*, each stall is large enough so that the technician has room to work all the way around the vehicle.

Often, one of the first steps completed in the metalworking area is part removal. Badly damaged bolt-on parts must be removed to gain access to hidden damage. This might involve unfastening the bumper, grille, or fenders, for example Figure 1–8.

DANGER

Dangers in the metalworking area are many and varied—tasks such as cutting metal, straightening frames, welding, grinding, and sanding can all result in injuries. Do not attempt to work in the metalworking areas of a body shop until you have studied the basic safety rules and repair methods that are explained in later chapters of this book.

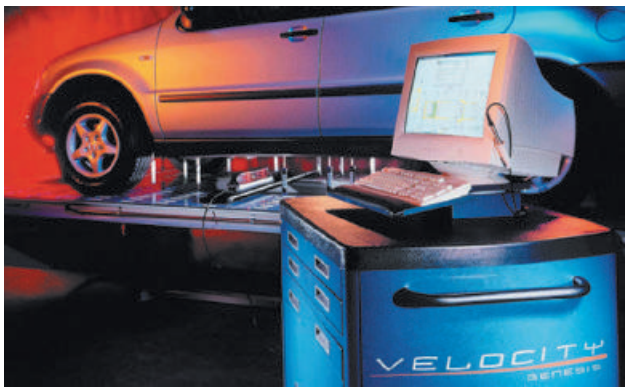
WARNING

Always refer to factory service information for details when working. Factory publications will give specifications, detailed procedures, and other information specific to the exact make and model vehicle being repaired. This information is often needed to do professional, quality work!

Vehicle Measurement

Vehicle measurement helps determine the extent and direction of major damage. If the vehicle has been in a serious accident, vehicle measurement is often done to find out whether the frame/unibody has been forced out of alignment. Specialized measuring tools are used to measure across specific reference points on the vehicle to find out whether body damage exists.

Measurement systems are specialized tools and equipment that allow the technician to check for frame



Chief Automotive Technologies

A To use this modern computerized measuring system, targets are hung from specific points on a vehicle. Laser light is reflected off the targets to make quick, accurate readings of the distance between targets.

Chief Automotive Technologies

B Computers can quickly compare known good specifications with laser measurements to calculate whether any section of a vehicle has been pushed out of alignment by a collision.

Figure 1–9 A measuring system is used to determine whether major body parts have been forced out of alignment by a major collision.

or body misalignment resulting from a collision. Various types of gauges and measuring devices can be used to compare *body specifications* to actual measurements taken from the damaged vehicle. The measurements will help determine what must be done to straighten any frame or body misalignment. If any measurement is not within factory specifications, the frame or unibody must be forced back into alignment using powerful hydraulic equipment (Figure 1–9).

Frame/Unibody Straightening

Once the extent and direction of frame misalignment are known, frame (unibody) straightening equipment can be used to pull the frame or body structure back into alignment.

Frame *straightening equipment* (also called a *frame rack*) uses a large steel framework, large steel towers, pulling chains, and hydraulic rams to pull the frame or body back into its original position (Figure 1–10).

Chief Automotive Technologies

Figure 1–10 A frame rack is a heavy steel framework with hydraulic equipment for forcing major structural parts back into alignment. The vehicle is anchored to the rack so it cannot move. Then pulling towers and chains can be attached to the damaged section of the vehicle to pull out the structural damage.

The vehicle frame or unibody is clamped down onto the frame equipment so it cannot move. Clamps and chains are then fastened to the damaged portion of the vehicle. Tremendous hydraulic pulling force is then applied to the chains to force the frame or body in the opposite direction of the collision impact. Refer to Figure 1–11.

After pulling, more measurements are taken to determine whether everything has returned to specification (Figure 1–12).

Panel Replacement

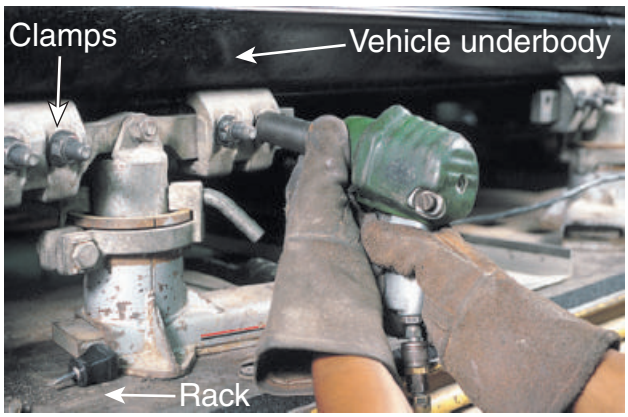
A *panel* is a large metal or plastic body part—a fender, hood, deck lid, or roof panel, for example. A vehicle body is made up of numerous panels welded, chemically bonded, or bolted together.

Panel replacement involves removing a panel or body part that is too badly damaged to be fixed. The new part has to be properly fit and fastened in place on the vehicle. This takes considerable skill (Figure 1–13).

Structural panel replacement involves welding a new panel in place of an old, damaged one. First, the badly damaged part is removed by drilling or grinding off its spot welds. Then the new parts are fitted into place while part locations are measured. Clamping pliers or self-taping screws are used to hold the new panel in place while welding. First, a welder is used to tack weld and fuse the part in place. Before final welding, measurements are again taken to make sure the new part is aligned properly. Look at Figure 1–14.

Panel adjustment involves moving or shifting a part to properly align it with other parts or panels. Accurate adjustment of body assemblies, such as hoods, deck lids, and doors, is often made by the technician. For example, if a door is not adjusted correctly, it may be difficult to close or may rattle when the car is driven over rough roads. The poorly adjusted door might also leak air and water. Such failures by the technician are bound to cause customer complaints.

When parts are replaced, *corrosion protection* coatings must be applied to prevent the new parts from rusting.



A First, the vehicle is clamped down to the frame rack using large clamps on the bottom of the unibody or frame. The vehicle must be anchored securely before pulling. Here pinch weld clamps are being installed to secure the vehicle while applying straightening force.

B After the vehicle is anchored, pulling clamps and chains are attached to the area to be straightened.

C Pulling power is applied to remove damage opposite to how it occurred. When pulling damage, you must be careful not to overpull. Metal will only flex back a small amount after releasing pulling force. If you overpull, it may be impossible to repair without part replacement.

Figure 1–11 Note how the technician is using a frame rack during a major repair.

Figure 1–12 Constantly measure as you pull out damage. This will let you pull in the right direction with the right amount of power. Here the tram gauge has been set to vehicle specs and compared to reference points on the damaged vehicle. If the tram gauge does not align with reference points on the vehicle, further pulling is needed until the points are lined up to specifications.

A Here a technician uses a plasma arc cutter to slice off a part for replacement.

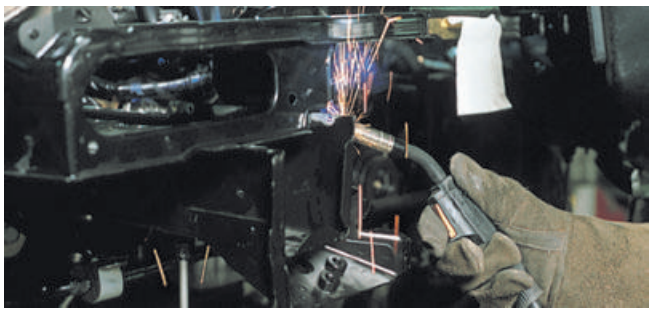
B Many parts or panels are attached with spot welds. A spot weld remover, a specialized drill, is often used to cut out each spot weld for part removal.

Figure 1–13 After the frame or unibody is straightened, you can then cut off damaged parts that require replacement.

A New structural parts must be temporarily held in place with clamping pliers or screws.

B First, tack weld parts in place, using only a few welds to hold the parts in alignment.

C After tack welding a part, measure its location before final welding. You may need to adjust a part's position while it is still tacked in place.



D If aligned properly, weld the structural parts into their final position following manufacturer recommendations. Proper welding skills are needed to do major collision damage repair. You may want to sign up for a welding class to further your career opportunities.

Figure 1–14 Replacing welded-on structural parts takes skill and training.

Weld-through primer and other materials are applied to the new parts to protect them from the **elements**—moisture, road salt, mud, and so on (Figure 1–15).

A technician must be able to hang the door in proper alignment and also transfer all internal parts (window mechanism, door handle, latch, and trim panel) to the new door. Look at Figure 1–16.

An air bag can cause injury if it fires accidentally. A technician replacing a side air bag should stand to one side of the bag in case it accidentally deploys. Refer to Figure 1–17.

Figure 1–15 You must restore corrosion protection to all repair panels. Various products are available to prevent corrosion or rusting of new panels.

Figure 1–16 Here the entire door frame and skin had to be replaced because it was too damaged to be repaired.

Figure 1–17 A technician replaces a small air bag located on the inside of the door frame. Note how the technician stays to one side in case the air bag accidentally deploys. Air bags deploy with a "bang" and can cause injury to your arms, hands, and face.

Panel Straightening

Panel straightening involves using various hand tools and equipment to force a damaged panel back into its original shape. Body hammers, body filler, and sanders are a few of the tools and materials used to repair panel damage. A somewhat different approach is needed with plastic panels. Small parts (trim pieces, emblems, wiper blades, and so on) are removed before panel straightening to protect them.

With damage to a metal panel, a grinder is first used to remove the paint from the damaged area. Then small pull pins are welded to the lowest area of the dent. A puller can then be attached to the pins to force the dent back out. Once the area is almost back to its original contour, the welded pull pins can be ground off. See Figure 1–18.

When you can access the back of the panel, leave the paint on until the panel is straightened as close to its original contour as possible. The reflection of light off the shiny paint surface will reveal highs and lows when you use straightening tools on the back side of the damage.

Body filler is used to cover any small imperfections remaining in the worked panel. Use compressed air to blow dust off the area so that the filler will stick or bond to the area securely. Mix *hardener* into the body filler to make the material *cure*. Use a metal or plastic *spreader* to apply the body filler over the repair area on the panel. The filler cures or hardens quickly, so skill is needed to properly apply the body filler.

When partially cured, a coarse file is often used to knock off the high spots in body filler. This will save sanding time. After the filler fully cures, the area is coarse sanded to the original panel contour.

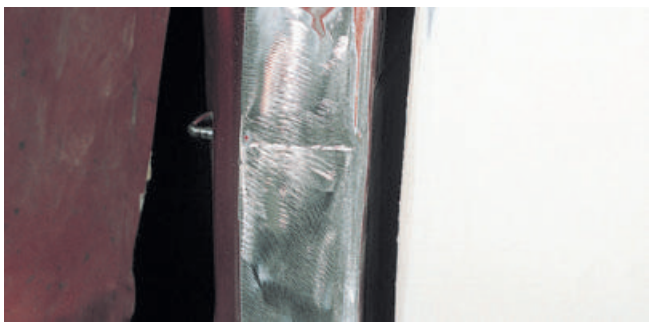
The mixing, application, filling, and sanding of body filler is shown in Figure 1–19.

Coarse sanding is done by the metalwork technician using an abrasive coated paper to level and smooth the body surface that is being repaired. Coarse, rough sandpaper may be used to level body filler.

Paint Preparation

In *paint preparation*, the vehicle is fine sanded and cleaned to prepare surfaces for the refinishing process. Fine, smooth sandpaper is used to lightly scuff old paint so the new paint will stick. The vehicle is moved from the metalworking area to a prep area in the shop. Dust is blown off the vehicle with compressed air (Figure 1–20).

Masking is used to cover areas that are not going to be painted to protect them from paint spray and physical damage. Parts of the car that are not to be



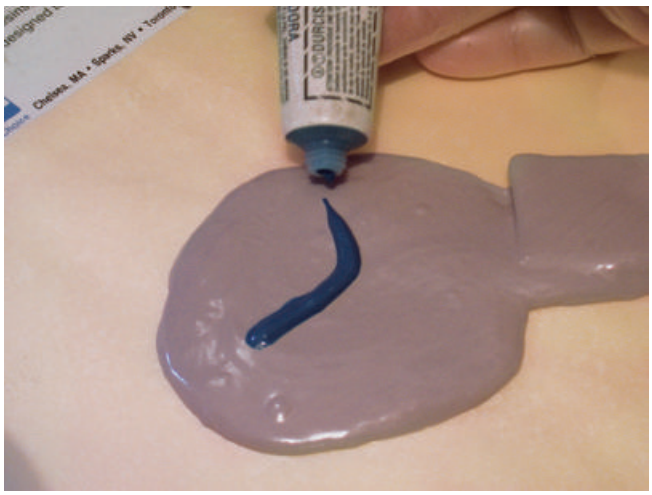
A

C

B

D

Figure 1–18 Note the basic steps for removing a dent from a metal part. (A) Often panels have minor damage that can be repaired. The cost of labor and materials must be weighed against the cost of new or salvaged parts. (B) When a dent cannot be hammered out from inside the panel, a nail weld gun can be used. The gun welds metal pull pins onto the damaged panel. (C) With pull pins welded into the dent, attach a puller to each pin for forcing out the low spot. Metal must be straightened to within 1/8 inch of the original contour so that the body filler is not too thick. (D) After pulling damage, cut and grind off the pins until they are almost flush with the panel surface. A slight depression is needed for body filler.



A

C

B

D

Figure 1–19 Body filler is commonly needed to smooth and level metal that has been straightened. (A) Mix body filler and hardener in correct proportions. As a general rule, for each golf ball-size lump of filler, use a 1-inch (25 mm) bead of hardener. If the amount of filler is as "big as a baseball," use a 6-inch (152 mm) bead of hardener. Do not stir hardener into body filler or you can cause air bubbles and pin holes. Wipe back and forth to mix ingredients completely. (B) Apply the body filler to the clean body surface right away. It will start to harden in a few minutes. Try to spread it out to match the body shape to reduce filing and sanding times. (C) As soon as filler starts to solidify, use a coarse "cheese grater" file to rough out the shape. File in multiple directions until the filler is contoured properly. Do not file too much. You want the filler to stick up above the panel surface a little so it can be sanded smooth. (D) After grating the filler, use an air sander and coarse grit sandpaper to cut the filler down more. Finish with a medium grit sandpaper. Featheredge the filler and old paint for a smooth transition into the panel.

Figure 1–20 Before masking and priming, use a blowgun to clean the vehicle of dust and debris. Aim the blowgun down into all gaps between parts that could hold dust and dirt. Do this before final masking and moving the vehicle into the paint booth.

painted—windows, chrome, lights, and so on—are covered with masking material, such as paper, plastic, tape, or a water-based spray-on coating (Figure 1–21).

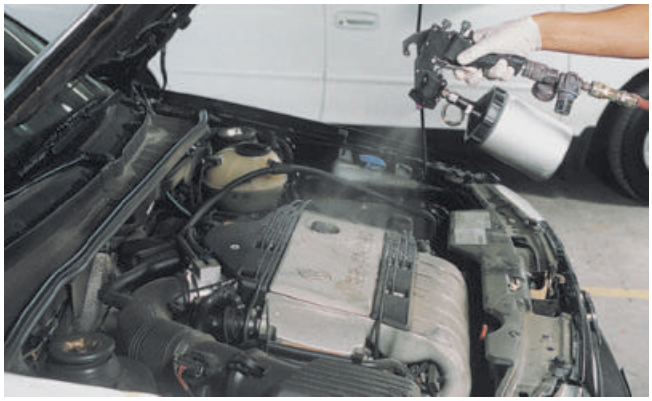
In large shops, the sanding jobs are handled by the prep person, whereas the masking operation is performed by the masker or painter. In small shops, the final prep jobs are usually done by the painter or a helper.

Primer is applied to bare metal and body filler before painting. *Priming* is necessary because paint alone will not properly adhere to or stick to bare metal. A spray can or spray gun is used to apply primer to all exposed metal surfaces (Figure 1–22).

Fine sanding is done to remove scratches left from coarse sanding and also to scuff unrepaired areas so that the new paint will not peel off. All surfaces to be painted must be fine sanded or scuffed to provide a good bond between the old paint and the new, fresh paint. Refer to Figure 1–23.

Wax and grease remover is then wiped over the surfaces to be refinished to remove any remaining contaminants. A rag soaked in the cleaning agent is wiped over the body surfaces. A second clean, dry rag is used

A Here a technician uses masking tape and masking paper to cover the area not to be painted.



B Spray-on masking material is handy when masking a large area, such as underhood components. It is water-based masking coating and can be washed off with soap and water after painting.

C Plastic wheel masks are installed over tires to protect them from paint spray.

Figure 1–21 Masking is used to protect parts of the car that are not going to be painted.

to wipe off the solvent while the surface is still wet. Look at Figure 1–24.

Mixing Room

The mixing room, or *mixing lab*, is a power-ventilated area where refinish or paint materials are mixed and

Figure 1–22 Self-etch or epoxy primer must be sprayed over all bare metal to bond to the metal. Primer-surfacer is often sprayed over body filler and the repair area to help level the repair area. Allow each coat of primer to flash properly before applying the next coat.

A A large sanding board is commonly used to smooth and level the repair area with the surrounding undamaged areas.

B An orbital sander or hand sanding with fine sandpaper is needed to scuff the old paint to prepare it to accept and bond with the new paint.

Figure 1–23 Finish sanding is needed between priming and painting to final smooth out the repair area.

prepared for application. Most large body shops have an in-house mixing room. Smaller shops have their materials mixed by an outside paint supplier (Figure 1–25).

Paint mixing involves carefully measuring out the correct amount of refinish ingredients following manufacturer instructions. For example, when mixing a paint

Figure 1–24 Before painting, use two rags to wipe the repair area clean. First, use a rag soaked with wax and grease remover to remove any surface contaminants. Then use a clean rag to wipe the surface while the solvent is still wet.

Figure 1–25 Most large body shops have their own paint mixing room. It has all color pigments and other ingredients for mixing paint materials. Mixing rooms also have forced ventilation to prevent buildup of paint fumes.

color, it is critical that the correct color pigments be added so that the new paint matches the existing color on the vehicle. Mixing usually involves adding reducer to make the paint the right viscosity (thickness or fluidity) for spraying. With water-based paints, distilled water is used to reduce the paint to a sprayable consistency. Mixing might also involve pouring in a recommended amount of *catalyst* (hardener) to make the top clearcoat cure or dry (Figure 1–26).

Refinishing

The vehicle's paint, or *finish*, performs two basic functions—it beautifies and it protects. Can you imagine what a car body would look like without paint? For a day or so, it would be the drab, steel gray of bare sheet metal. Then, as rusting eats into the metal, the body would turn an ugly, reddish brown. This degeneration, or oxidation, would continue until the body was solidly coated with rust.

The term *paint* generally refers to the visible topcoat. The most elementary painting system consists of a primer and final topcoat over the *substrate* (body surface material). This process can vary considerably and generally is more complex, as you will learn later.

Refinishing, or *repainting*, involves the steps needed to properly restore the vehicle's finish. Refinishing is a very important part of the auto repair process.

Damage caused by both minor and major accidents usually requires some painting. However, many older automobiles are repainted to simply enhance their beauty.

A Mix paint according to label directions or instructions given on the manufacturer procedure sheet. The label or procedure sheet gives ratios for reducer, catalyst, and paint.

B A computerized electronic scale aids in mixing paint ingredients. Some will give an electronic readout that tells you how much of each ingredient to add while mixing.

C Filter everything that goes into the spray gun cup. One piece of dirt or cured paint can ruin a paint job.

Figure 1–26 Paint mixing is like working in a chemistry lab. All ingredients must be added accurately to produce the correct color and chemical content.


Courtesy of Team Blowtherm

Figure 1–27 Refinish technicians must wear safety gear and be highly skilled at using painting tools and equipment. Here the technician is turning on the fans in a paint spray booth.

New and used-car dealers repaint automobiles to attract buyers. Sometimes an owner simply gets tired of looking at the same old color.

With today's high-tech paint materials, it is critical that painters wear proper safety gear (Figure 1–27).

A car's finish consists of several coats of two or more different materials. The most basic finish consists of:

1. Primecoat
2. Topcoat

The *primer* is used to improve **adhesion** (sticking) of the topcoat. It is the first coat applied. Paint alone will not stick or adhere as well as a primer. If you apply a topcoat to bare substrate, the paint will peel, flake off, or look rough. This is why you must "sandwich" a primecoat between the substrate (car body) and the topcoat. Primer-sealers also prevent any chemicals from bleeding through and showing in the topcoats of paint.

The terms *topcoat* and *colorcoat* refer to the paint applied over the primer-sealer coat. This usually consists of several thin coats of paint. The topcoat is the "glamour coat" because it features the eye-catching gloss.

Figure 1–28 The spray gun is the main tool of a body shop paint technician. It must be adjusted properly to produce a smooth, even paint film on the vehicle.

Basecoat/clearcoat paint systems use a colorcoat applied over the primer-sealer with a second layer of transparent clearcoat over the colorcoat. The basecoat is sometimes a water-based paint. To protect the water-based paint from the elements, a conventional oil-based urethane clear topcoat is sprayed over the waterborne color coats. Basecoat/clearcoat is the most common paint system used today. The clear paint brings out the richness or shine of the underlying color and also protects it. The resulting *gloss* is superior to that of standard paint systems.

A *spray gun* uses compressed air to break the liquid paint into a fine mist so that the paint is deposited smoothly on the vehicle body. The *paint booth* is a clean room with filtered air circulation so that dirt does not get in the paint when spraying (Figure 1–28).

Spraying is the physical application of paint using an air pressure-powered paint spray gun. The technician methodically moves the spray gun next to the body while

A

B

Figure 1–29 Excellent hand–eye coordination and specialized knowledge is needed to be a professional painter. (A) When painting a vehicle, keep the gun the correct distance from the surface. Also keep the gun parallel with the surface. (B) When painting, try to move the spray gun smoothly and evenly. Use straight line paint strokes that overlap evenly. If you move the gun at different speeds or move it further or closer to the surface, paint problems will result.

Figure 1–30 Here a refinish technician is spraying the colorcoat along the bottom and side of the car body. This will be followed by spraying the clearcoat to bring out the gloss or shine.

spraying accurate layers of paint onto it. This requires a high degree of skill to prevent **paint runs** (when excess paint flows down or runs) and other painting problems. Refer to Figure 1–29 and Figure 1–30.

In addition to being able to apply the new finish properly, the painter or refinishing technician must have knowledge of paint products and how to mix and match them. If the refinishing job looks good and the color matches well, the customer will usually be satisfied with all of the other repair work.

REMEMBER *The car owner notices the quality of the metal straightening and paint job more than any other aspect of collision repair.*

ECO-TECH

Eco-Tech stands for ecology technology. Eco-tech deals with how a body shop can conserve materials to reduce the amount of air, water, and ground pollutants resulting from vehicle repairs. As you learn the information in this textbook, you will be given many tips for avoiding material waste and for recycling all useful materials. The information in this book will stress the recycling of unused paint solvents, metal body panels, plastic parts, air conditioning refrigerant, paper, antifreeze, motor oil, and other materials.

Drying

Drying involves using different methods to cure the fresh paint. If only partially dry when returned to the customer, the new paint can be easily damaged.

Air drying is done by simply letting the paint dry in the atmosphere. This can take a long time with enamel paint if a hardening agent is not added before applying the paint.

Forced drying uses special heat lamps or other equipment to speed the paint curing process. Most shops use drying equipment to speed up drying.

Post-Painting Operations

Post-painting operations include the tasks that must be done after painting but before returning the vehicle to the customer. These tasks include removing masking tape, reinstalling parts, and cleaning the vehicle.

Once the paint is hard enough so that it will not be easily damaged by being touched, any parts removed for repairs or painting must be reinstalled. This is done carefully, often by the original technician (Figure 1–31).

If the painted surface has a rough, textured surface like that of an orange peel, you may have to extra-fine sand and polish the hardened paint. This will remove the surface roughness of the paint.

Wet sanding involves using a water resistant, ultrafine sandpaper and water to level the paint. It can sometimes be done to fix small imperfections (orange peel, dirt, runs, and so on) in the paint. Dry ultrafine sanding uses 1000 grit or finer sandpaper on an air sander to repair minor paint imperfections.

Compounding, or buffing, may be required to smooth newly painted surfaces, after wet sanding, for example, or to remove a thin layer of old, dull paint. Compounding makes the paint smooth and shiny. An air or electric buffing machine equipped with a soft pad is used to apply buffing compound to the paint. The abrasive action cuts off a thin layer of topcoat to brighten the color and shine the paint (Figure 1–32).

Detailing is a final cleanup and touch-up on the vehicle. It involves washing any unpainted body sections, cleaning and vacuuming the interior, and touching up any chips in sections not painted. Detailing can also involve tasks such as polishing chrome, cleaning glass, installing trim, and cleaning the vinyl top and tires. This will ready the vehicle for return to the customer.

Figure 1–31 After the car body is painted, parts must often be reinstalled. Here a technician reinstalls taillights on this late model sports car.

A After paint cures properly overnight, it may be possible to wet sand or ultrafine dry sand any imperfections, such as a small protrusion or orange peel. Use a small sanding block and ultrafine (1000 or finer grit) sandpaper, and be careful not to cut through the clearcoat, or repainting will be required. A little dishwashing liquid in water will help keep the sandpaper from sticking to the surface.

B After ultrafine wet or dry sanding, compound the area to revive the paint's gloss. When machine buffing, be careful not to cut through paint on body contours or panel edges. Most technicians like to apply masking tape to sharp edges to protect the finish from burn-through.

Figure 1–32 Minor problems in the paint, such as small dust or dirt particles, can often be removed without repainting.

Mechanical/Electrical Repairs

Mechanical repairs include tasks such as replacing a damaged water pump, radiator, or engine bracket. Mechanical components like these are often damaged in a major collision. Many mechanical parts are easy to replace and can be done by the auto body technician. However, other mechanical repairs may require special skills and tools. In this case, the vehicle would be sent to a professional mechanic or to the mechanical repair area of the shop (Figure 1–33).

Electrical repairs include tasks such as repairing severed wiring, replacing engine sensors, and scanning for computer or wiring problems. During a collision, the impact on the vehicle body and the resulting metal deformation can easily crush wires and electrical components.

Courtesy of Hunter Engineering Company.

A A technician uses special equipment to adjust wheel alignment. This must be done if suspension parts are damaged in an accident.

Courtesy of Hunter Engineering Company.

B Mechanical skills are helpful to the auto body technician.

Figure 1–33 Mechanical–electrical repairs are sometimes done in larger body shops.

For this reason, today's auto body technician must have the basic skills needed to work with and repair electrical/electronic components.

Complete Collision Services

More and more body shops are offering complete collision services, such as:

- Wheel alignment
- Cooling system repairs
- Electrical repairs
- Suspension repairs
- Air conditioning repairs
- Glass replacement

Many of these repairs are still done by auto specialty shops, which only do one type of repair (glass, air conditioning, and so forth). However, the expanding scope of

Figure 1–34 A final cleanup of the interior and exterior of a repaired vehicle is important. You want the first impression customers have of your work to be pleasing so they will return to your shop again someday.

the body shop has made it necessary for the body technician to have some knowledge of these repairs.

As an auto body technician, it is critical that you learn to repair a damaged vehicle properly. Your reputation as a professional technician and the safety of the occupants of the repaired vehicle depend on how well you do your work (Figure 1–34).

NOTE *Several chapters in this book are devoted to helping you learn to work on mechanical and electrical systems.*

1.3 AUTO BODY CAREERS

Auto body technicians are skilled, knowledgeable people who know how to use specialized equipment and highly technical methods to restore severely damaged vehicles. An auto body technician must be a "jack-of-all-trades." They must have basic skills in the following eight areas:

1. *Metalworker*—An auto body technician must be able to do all types of metalworking to properly form and shape sheet metal car bodies after an accident.
2. *Welder*—An auto body technician must weld and cut steel, aluminum, and plastic efficiently during major body repairs.
3. *Auto mechanic*—An auto body technician must remove and install mechanical systems; this requires some skill in auto mechanics.
4. *Sculptor*—An auto body technician must form body filler to match body shape, much like a sculptor shapes a piece of art.
5. *Plumber*—An auto body technician must work with numerous lines, hoses, and fittings during power steering, brake system, and fuel system service.
6. *Electrician*—An auto body technician must be good at testing and repairing wiring and electrical components after damage. Being able to find shorts, opens, and other wiring problems is essential with today's computer-controlled vehicles.
7. *Air-conditioning technician*—An auto body technician may be required to work on air-conditioning systems.
8. *Computer technician*—An auto body technician should be able to scan and repair computer problems stemming from collision damage.

Obviously, today's auto body technician must be a highly trained professional. The days of the "mud builder" or "parts replacer" are over. Individuals who lack specialized skills can no longer survive and earn a living with modern, complex automotive technology.

The term *professional* refers to the attitude, work quality, and image that a business and its workers project to customers. It is interesting to note that in Europe a shop cannot open without the presence of a "meister," or master craftsperson. A professional technician:

- Is customer oriented
- Is up-to-date on vehicle developments
- Keeps up with advancements in the repair industry
- Pays attention to detail
- Ensures that their work is up to specification
- Belongs to trade associations

Some shops have specialized technicians who concentrate their knowledge and skills in one area of collision repair.

Metalworking technicians are skilled at part removal/replacement, part repair, welding, and the use of body filler. They can also use frame straightening and measuring equipment to repair vehicles with frame damage.

Refinish technicians, also called painters or refinishers, specialize in vehicle prep and spraying. They are versed in paint mixing, color matching, and the use of spray equipment. These people must have good color perception and excellent hand–eye coordination.

Helpers work under the supervision of one or more professional technicians. They might help a technician mask a car before painting, install a hood, run for parts, or help clean up the work area at the end of the day. The helper is often an *apprentice* who is learning the trade by working with an experienced technician.

Other Collision Repair Personnel

Foremost in any collision repair business are the collision repair and paint technicians. However, there are other jobs that must be done as well. This section describes other personnel who work in and with the staff of a collision repair shop.

The *shop owner* must be concerned with all phases of work performed. In smaller shops, the owner and

shop manager is usually the same person. In large operations or dealerships, the owner might hire a shop manager. In all cases, the person in charge should understand all of the work done in the shop as well as its business operations.

The *shop supervisor* is in charge of the everyday operation of the shop. This job involves communication with all personnel who contribute to the body shop's success.

The *parts manager* is in charge of ordering all parts (both new and salvaged), receiving all parts, and seeing that they are delivered to the right technician. Because not every collision repair shop has a parts manager, the task of ordering parts can fall on all employees at one time or another.

The *bookkeeper* keeps the shop's books, prepares invoices, writes checks, pays bills, makes bank deposits, checks bank statements, and takes care of tax payments. Many shops hire an outside accountant to help perform these tasks.

The *office manager's* duties include various aspects of the business—handling letters, estimates, and receipts, for example. In many small shops, the office manager also acts as the parts manager and bookkeeper.

A *receptionist* is sometimes employed to greet customers, answer the phone, route messages, and do other tasks.

Larger shops generally have trained *tow truck operators* to operate their wrecker(s). Rather than own these expensive pieces of equipment, many smaller shops depend on independent towing services or farm out such work to other repair garages.

It is important for body shop personnel to have good communication and cooperation skills. Everyone in the shop should work as a team member to make the facility profitable, enjoyable, and safe. "A chain is only as strong as its weakest link"—this saying applies to the smooth operation of a body shop. If anyone—from the estimator to the painter—does not do the job right, everyone suffers. Customers will not return to the shop, and everyone's paycheck will be affected in the long run.

There are other career openings in the collision repair field. Some of these include:

- Insurance adjuster or appraiser
- Vocational/technical instructor
- Salvage yard technician
- Dealership parts counterperson
- Paint company representative
- Auto manufacturer representative
- Equipment salesperson

To research these and other career opportunities, talk to your guidance counselor, visit your local library, or search the Internet. There you can obtain more detailed information on the qualifications and training requirements for each position.

SUMMARY

1. A collision, nicknamed a *crash* or a *wreck*, is damage caused by an impact (hit) on the vehicle.
2. Auto body repair, also called collision repair, involves fixing a vehicle that has been damaged in an accident. The vehicle is first brought into the shop, where a damage estimate is prepared to calculate the cost of repairs.
3. Minor body damage only requires that a few parts be replaced or repaired before the car is repainted. Major body damage usually must be corrected by replacing, repairing, and straightening large body parts before repainting. A collision can also be severe enough to cause a total loss, where repairs would be more expensive than buying another car.
4. Repair instructions are summarized on a printed repair order (RO), and the repairs are carried out according to those instructions. The metalworking areas are shop locations where damaged parts are removed, repaired, and installed. A stall is a work area for one vehicle, often marked off with painted lines on the floor.
5. Vehicle measurement is done to determine the extent and direction of major damage. Measurement systems are specialized tools and equipment that help the technician to check and measure for frame or body misalignment resulting from a high-impact collision.
6. Frame straightening equipment (also called a frame rack) uses a large steel framework, pulling chains, and hydraulic power to pull or force the frame or body back into its original position.
7. A panel is a large metal or plastic body part—a fender, hood, truck, or roof panel, for example. Structural panel replacement involves welding a new panel in place of an old, damaged one. Panel adjustment involves moving or shifting a part to properly align with other parts or panels. When parts are replaced, corrosion protection coatings must be applied to prevent the new parts from rusting.
8. Panel straightening involves using various hand tools and equipment to force the panel back into its original shape. Body filler is used to cover any small

dents remaining in the worked panel. The vehicle is sanded and cleaned to prepare surfaces for the painting process.

9. Masking is done to cover areas that will not be painted. Priming is done to cover bare metal before painting. The mixing room or mixing lab is a power-ventilated area where refinish materials are mixed or prepared for application.
10. The vehicle's paint or finish performs two basic functions—it beautifies and it protects.
11. Refinishing or repainting involves the steps needed to properly restore the vehicle's finish (paint).
12. The primecoat is used to improve adhesion (sticking) of the topcoat. The terms *topcoat* and *colorcoat* refer to the paint applied over the primecoat. Basecoat/clearcoat paint systems use a colorcoat applied over the primer-sealer with a second layer of transparent clearcoat over the colorcoat.
13. Spraying involves using precision paint spray guns and a spray booth to apply refinish materials to the car body. A spray gun uses compressed air to break the liquid paint into a fine mist so that the paint is deposited smoothly on the vehicle body.
14. The paint booth is a clean room with filtered air circulation so that dirt does not get into the paint when spraying. In the drying room, infrared lights are used to speed up the paint curing or drying process by warming the paint.
15. A detailer performs all the last tasks needed to prepare the vehicle for return to the customer.
16. Auto body technicians are skilled people who know how to use specialized equipment and highly technical methods to restore severely damaged vehicles.
17. The term *professional* refers to the attitude, work quality, and image that a business and its workers project to customers.

EXERCISES

On a separate sheet of paper, complete the following learning activities for this chapter. Write definitions for the key terms and answer the ASE-style review questions, essay questions, critical thinking problems, and math problems. You can also do the outside activities, possibly for extra credit.

➤ Key Terms

accident report
adhesion
collision
collision repair
collision repair facility
contaminants
damage estimate
dealership body shop
deductible
elements
estimating
estimator
head-on collision
impact
independent body shop
insurance adjuster
major body damage
metalworking areas
minor body damage
paint runs
post-painting operations
repair order
salvage yard
specialty shop
total loss
wash-up
wrecker

➤ ASE-Style Review Questions

1. The collision repair industry does what volume of business per year?
   A. $1 million
   B. $10 million
   C. $1 billion
   D. $10 billion
2. Technician A says that when two cars hit head-on at 50 mph, it is like hitting a brick wall at 100 mph. Technician B disagrees and says that it is like hitting a brick wall at only 50 mph. Who is correct?
   A. Technician A
   B. Technician B
   C. Both A and B
   D. Neither A nor B
3. An independent body shop is owned by an individual and does not have ties to a major auto manufacturer. True or false?
4. What task involves analyzing damage and calculating how much it will cost to repair the vehicle?
   A. Repair
   B. Estimating
   C. Calculating
   D. Measuring

5. Technician A says that a collision can be severe enough to cause a total loss. Technician B says that the repairs would be more expensive than buying another car. Who is correct?
   A. Technician A
   B. Technician B
   C. Both A and B
   D. Neither A nor B
6. Body shop repairs are carried out according to the instructions on which form?
   A. Repair order
   B. Estimate
   C. Quote
   D. Data sheet
7. Technician A says that a damaged vehicle does not have to be cleaned before starting repairs. Technician B says that wash-up will remove mud, dirt, wax, and water-soluble contaminants that could affect the paint job. Who is correct?
   A. Technician A
   B. Technician B
   C. Both A and B
   D. Neither A nor B
8. Technician A says that vehicle measurement is done to determine the extent of major damage. Technician B says that it is also done to determine the direction of damage. Who is correct?
   A. Technician A
   B. Technician B
   C. Both A and B
   D. Neither A nor B
9. Technician A says that various types of gauges and measuring devices can be used to measure vehicle damage. Technician B says that you can compare known good body specifications (normal measurements from an undamaged vehicle) with the actual body measurements on the damaged vehicle. Who is correct?
   A. Technician A
   B. Technician B
   C. Both A and B
   D. Neither A nor B
10. Technician A says that a frame rack can be used to do a wheel alignment. Technician B says that a frame rack uses mechanical power to pull or force the frame or body back into its original position. Who is correct?
    A. Technician A
    B. Technician B
    C. Both A and B
    D. Neither A nor B
11. Technician A says that panel replacement involves removing a panel or body part that is too badly damaged to be fixed. The new part would have to be bolted or welded in place on the vehicle. This takes considerable skill. Technician B says that structural panel replacement involves welding a new panel in place of the old, damaged one. Who is correct?
    A. Technician A
    B. Technician B
    C. Both A and B
    D. Neither A nor B
12. Technician A says that panel straightening involves using various hand tools and equipment to force the panel back into its original shape. Technician B says that body hammers, body filler, and sanders are a few of the tools and materials used to fix panel damage. Who is correct?
    A. Technician A
    B. Technician B
    C. Both A and B
    D. Neither A nor B

➤ Essay Questions

1. What happens to a vehicle during a collision?
2. Explain the difference between a door ding and a total loss.
3. What is estimating?
4. Describe the differences between panel straightening and panel replacement.
5. Define the term *collision*.
6. Name two contaminants that must be cleaned off before starting bodywork.
7. Why is estimating the cost of a repair such an important step to consider for a body shop?

➤ Critical Thinking Problems

1. How would you determine whether a car is a total loss?
2. Write the 14 steps of a basic repair sequence so you can memorize what is done when a vehicle enters a body shop.

Math Problems

1. A technician is paid $45 per hour. The repair will take 11.5 hours. Parts for the repair will cost $176.25 plus 7 percent tax. What is the total of the estimate?
2. An older car is valued at $2,500. The parts for the repair will cost $1,500. How many hours of labor at $35 per hour can be completed before the car should be declared totaled?
3. An independent repair shop made $33,507 total in a one-month period. The cost of labor was $45 per hour with a total of 200 hours of labor. Parts cost the repair shop $14,000. Power and property bills cost a total of $3,500. After these costs are taken into account, what did the repair shop make in profits for the month?

Activities

1. Take a field trip to a local collision repair facility. Have the shop owner or supervisor give you a guided tour of the repair operation. Discuss what you learned during the field trip in class the next day.
2. Ask a technician or shop owner to visit your classroom to describe their duties and answer questions.

CHAPTER 2

Vehicle Construction Technology

OBJECTIVES

After studying this chapter, you should be able to:

- Explain the past and present designs of motor vehicles.
- Summarize the various types of frames commonly used on modern cars, trucks, vans, and SUVs.
- Compare and contrast modern body-over-frame and unibody construction technology.
- Locate the major parts of a perimeter frame.
- Locate the major parts of a unibody frame.
- Compare a conventional full frame with modern hydroformed frames.
- Identify the major structural components, sections, and assemblies of a motor vehicle.
- Explain how simulated and actual crash tests are used to evaluate the structural integrity of a motor vehicle.
- Describe the layperson's names for body shapes used on passenger vehicles.
- Answer ASE-style review questions relating to vehicle construction.

INTRODUCTION

The term *vehicle construction* refers to how a passenger car, truck, van, or sport utility vehicle (SUV) is assembled at the factory. A typical car has over 15,000 parts that all work together to provide a safe, dependable means of transportation. As you will discover, the modern automobile is one of the most amazing engineering feats ever devised by humans (Figure 2–1).

This chapter familiarizes you with the auto parts vocabulary needed to become a successful auto body technician. You will learn to locate and describe the major body panels of an automobile.

Knowledge of vehicle construction will help you answer questions such as: What is the name of that part? How are the parts fastened together? What is that part made of? Does the vehicle use a full perimeter frame or does it have unibody construction?

To accurately repair a damaged car, you must fully understand the construction methods used during the manufacture of the particular make or model vehicle. You must accurately identify all damaged components and select the proper repair options from those available. To do this, you must know what kinds of materials are used and understand how these materials affect the repair process (Figure 2–2).

The goal of collision repair is to restore the vehicle to its preaccident condition. During repairs, you should use repair methods that closely duplicate how the car was manufactured on its assembly line.

2.1 BODY AND CHASSIS

To avoid confusion, the major parts of a vehicle can be categorized as parts of the body, the chassis, or the frame. You must understand each major division.

Vehicle Body

The *vehicle body* provides a protective outer hull, or "skin," around the outside of an automobile. The body is an attractive, colorful covering over the other parts. Body parts may also contribute to the structural integrity (safety and strength) of the vehicle.

A Modern manufacturing facilities and dedicated people are needed to assemble modern cars, trucks, vans, and SUVs.

B Unibody vehicles move down an assembly line as automated robots weld the various body panels together.

Figure 2–1 Today's auto manufacturers design and build safe and efficient motor vehicles.

A Factory workers are inspecting the build quality of the Model T Ford.

B Modern vehicles are far superior to the cars and trucks of just a few years ago.

Figure 2–2 Great changes have occurred in automotive design since the early years of the automobile.

The vehicle body can be made from steel, aluminum, fiberglass, plastic, or composite (a combination of materials like carbon fiber). The body is normally painted to give the vehicle its appealing, shiny color and appearance. Refer to Figure 2–3.

Vehicle Chassis

The **vehicle chassis** includes the frame, engine, suspension system, steering system, and other mechanical parts with the body removed. The body and chassis are two major categories used to classify the repair areas of a vehicle (Figure 2–4).

2.2 VEHICLE FRAME

The *vehicle frame* is a high-strength structure used to support all other parts of the vehicle. Besides bolt-on body panels, the frame holds the engine, transmission, suspension, and other parts in position. Frames are usually made of steel or aluminum and sometimes composite materials. The frame can be separate from the body or integrated into the body shell, as in the case of unibody design (Figure 2–5).

Body-Over-Frame

Body-over-frame construction has a separate body structure bolted to a thick steel framework. The engine and other major assemblies forming the chassis are mounted on the frame. Rubber body mounts fit between the frame and body structure to reduce road noise (unwanted sounds entering the passenger compartment from outside the vehicle). See Figure 2–6.

A *full frame* has a thick metal box or U-shaped stampings or rails welded and/or riveted together. The main structural members are two side rails connected by a series of cross members. For high load-carrying capabilities, the separate frame is made of much heavier gauge steel than the body panels.

A This minivan with rounded body and large fenders resembles the vehicles built in the 1940s.

B Modern pickup trucks perform like performance cars and are built to last hundreds of thousands of miles.

C This "super car" has the looks and performance of a jet fighter.

Figure 2–3 Vehicle designs vary more today than ever.

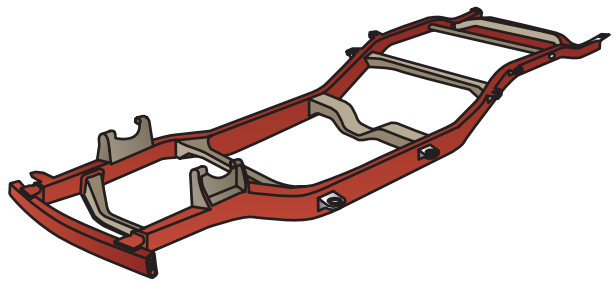


Figure 2–4 The oldest and strongest frame design is the perimeter frame. A thick steel framework supports the chassis and body panels.

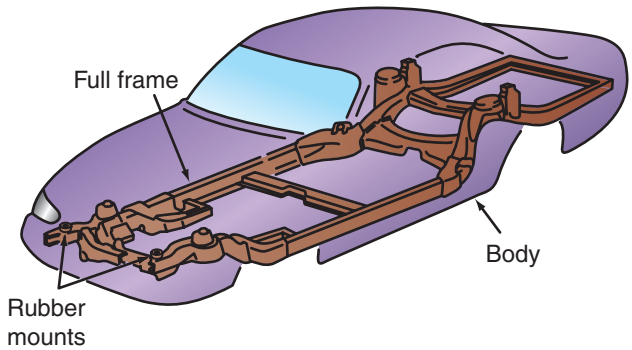


Figure 2–5 Illustration of a vehicle with body panels removed shows chassis construction. Study the part names.

The full frame rails extend the entire length of the vehicle. The frame cross members run sideways to secure the frame rails together. Body-over-frame or full frame construction is commonly used on pickup trucks, SUVs, and most full-size vans. Some larger luxury cars still use traditional body-over-frame construction.

A **hydroformed frame** is manufactured by using water under high pressure to force straight box-extruded frame rails into the desired shape or contour. A hydroformed frame is made of a thinner gauge metal than a conventional perimeter frame. Hydroformed frames are lighter, almost as strong, and equally as stiff as conventional heavy-gauge steel or aluminum frames.

Unibody

Unibody construction uses body parts welded or adhesive-bonded (glued) together to form an integral (built-in) frame. The body structure is designed to secure other chassis parts. No separate heavy-gauge steel frame under the body is needed.

Today's vehicles are manufactured using both unibody and body-over-frame construction. Refer to Figure 2–7.

Unibody construction is a totally different concept in vehicle design that requires more complex assembly techniques, new materials, and a completely different

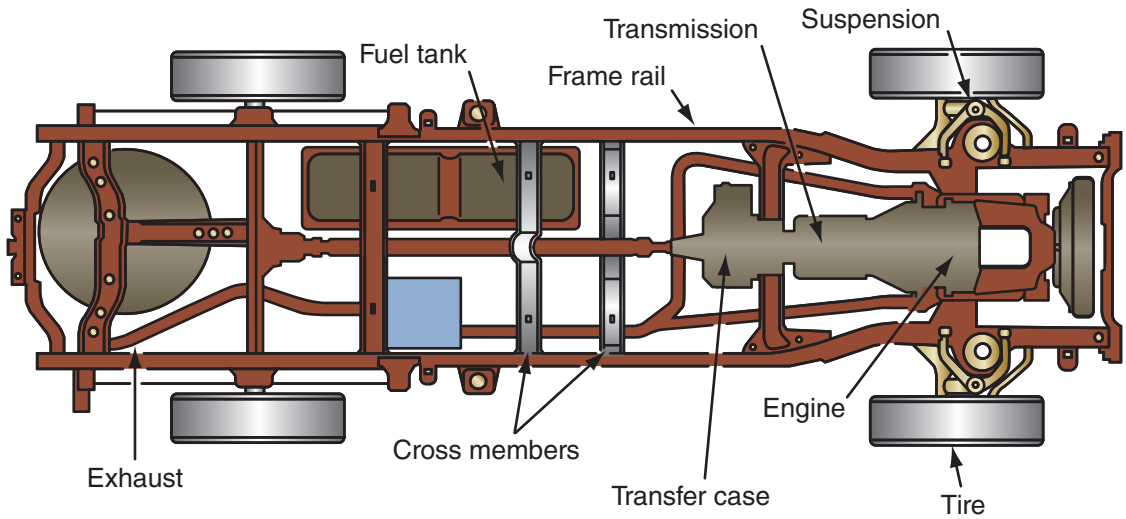
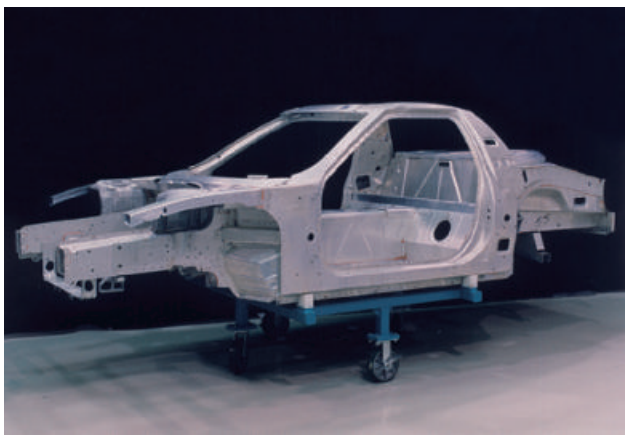


Figure 2–6 Rubber "biscuits," or mounts, fit between frame and body to reduce noise and vibration.



Courtesy of Saab Cars USA, Inc.

Figure 2–7 Unibody vehicles consist of small body panels welded together to serve as the vehicle frame. Unibody vehicles are light yet very strong. They are built for controlled collapse during a collision to help keep the passenger compartment intact.

approach to repairs. In unibody designs, heavy-gauge, cold-rolled steels have been replaced with lighter, thinner, high-strength steel or aluminum alloys. This requires new handling, straightening, and welding techniques.

2.3 MAJOR BODY SECTIONS

For simplicity and to help communication in auto body repair, a vehicle is commonly divided into three body sections—front, center, and rear. You should understand how these sections are constructed and which parts are included in each. See Figure 2–8.

Front Section

The *front section*, also called the nose section, includes everything between the front bumper and the fire wall. The bumper, grille, frame rails, front suspension parts, and the engine are a few of the items included in the front section of a vehicle.

The nickname **front clip**, or "doghouse," is used to refer to the front body section. It is often purchased from an automotive recycler or salvage yard and cut off from a wreck in one piece. The empty engine compartment forms the doghouse.

Center Section

The vehicle's *center section*, or midsection, typically includes the body parts that form the passenger compartment. A few parts in this section are the floor pan, roof panel, cowl, doors, door pillars, glass, and related parts. The center section is nicknamed the "greenhouse" because it is surrounded by glass.

Rear Section

The *rear section* (the tail section, or rear clip) commonly consists of the rear quarter panels, trunk or rear floor pan, rear frame rails, trunk or deck lid, rear bumper, and related parts. Also called the "cathouse," it is often sectioned or cut off of a salvaged vehicle to repair severe rear impact damage.

When discussing collision repair, body shop personnel often refer to these sections of the vehicle. It simplifies communication because everyone knows which parts are included in each section.

Vehicle Left and Right Sides

The left and right sides of a vehicle are determined by standing behind the vehicle or sitting in the driver's seat behind the steering wheel. In either position, the vehicle's left side is to your left; the right side is to your right.

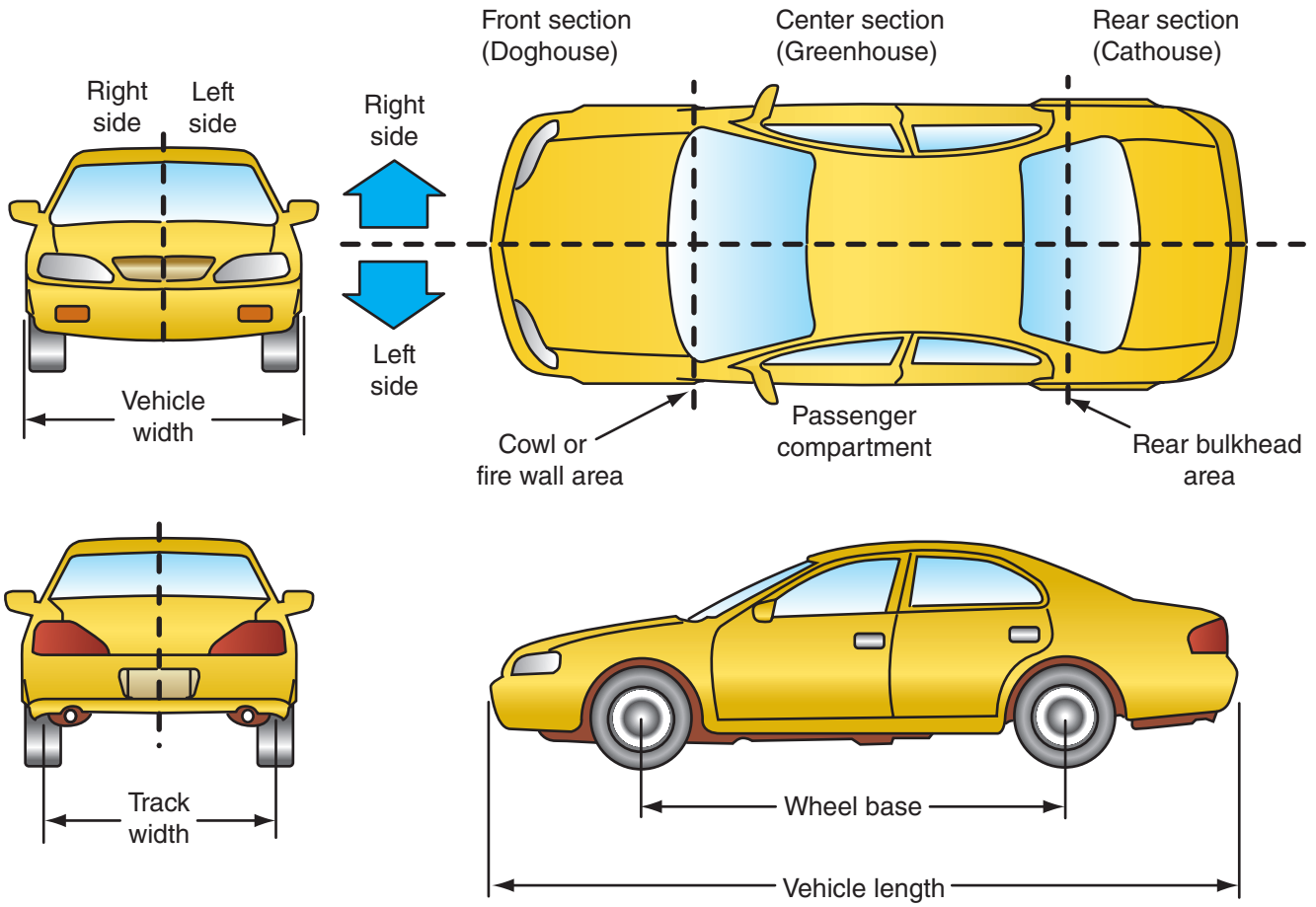


Figure 2–8 Study the locations of the basic sections of an automobile carefully.

Panels and parts are often named for the left or right side of the vehicle.

Note that vehicles built for American roads have the steering wheel on the left. Vehicles built for use in other countries may have the steering wheel on the right side of the passenger compartment.

Driveline Configuration

Driveline configuration refers to how power is transmitted from the engine to the drive wheels. There are six basic drivetrain designs: front-wheel drive; rear-wheel drive; rear-engine, rear-wheel drive; mid-engine, rear-wheel drive; four-wheel drive; and all-wheel drive.

The vast majority of unibody vehicles on the road today are front-wheel drive with the engine in the front. These variations affect vehicle construction and repair methods.

A **transverse engine** mounts sideways in the engine compartment. Its crankshaft centerline extends toward the right and left of the body. Both front-engine and rear-engine vehicles use this configuration (Figure 2–9A).

A **longitudinal engine** mounts the crankshaft centerline front to rear when viewed from the top. Front-engine, rear-wheel drive vehicles use this type of engine mounting (Figure 2–9B).

A *front-engine, front-wheel drive* (FWD) vehicle has both the engine and transaxle in the front. Drive axles extend out from the transaxle to power the front drive wheels. This is one of the most common configurations. The heavy drivetrain adds weight to the front drive wheels for good traction on slippery pavement.

A *front-engine, rear-wheel drive* (RWD) vehicle has the engine in the front and the drive axle in the rear. The transmission is usually right behind the engine, and a drive shaft transfers power back to the rear axle (Figure 2–9C).

A *rear-engine, rear-wheel drive* (RRD) vehicle has the engine in the back, and a transaxle transfers power to the rear drive wheels. Traction upon acceleration and cornering is good because more of the weight of the drivetrain is over the rear drive wheels.

A *mid-engine, rear-wheel drive* (MRD) vehicle has the engine centrally located, right behind the front seat. This helps to place the center of gravity in the middle so that the front and rear wheels hold the same amount of weight, which improves cornering ability (Figure 2–9D).

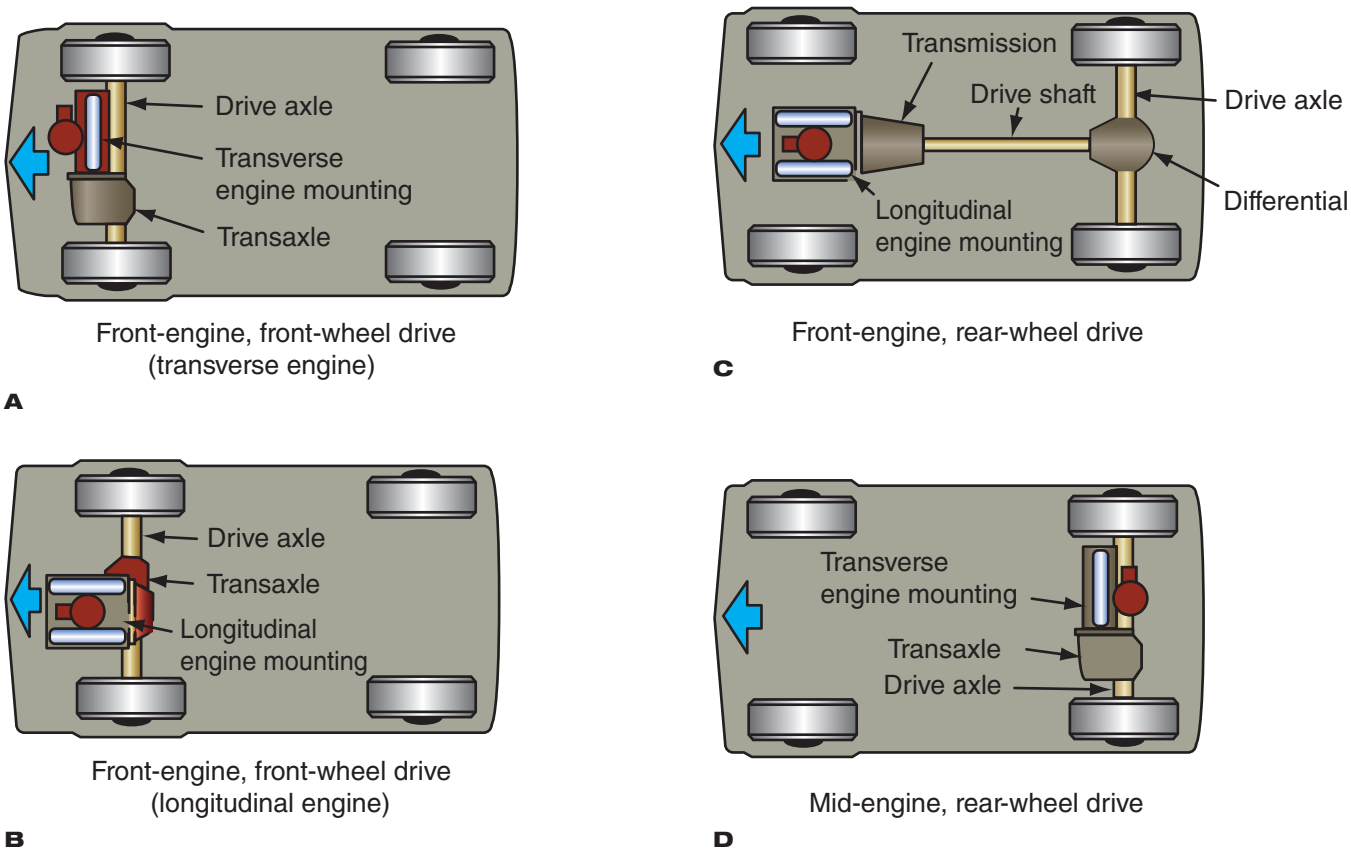


Figure 2–9 **Compare the layout of common driveline configurations. The type of driveline used affects vehicle construction and repair methods. (A) Front-engine, front-wheel drive with a transverse engine mounting is the most common driveline configuration. The heavy engine and transaxle are in the front to place more weight over the front drive wheels. (B) This front-wheel drive arrangement places the engine longitudinally in the engine compartment. It is not as common as the transverse engine arrangement. (C) The front-engine, rear-wheel drive setup is still common on many sports sedans. This design steers and handles well on dry pavement. It does not provide as much traction on snow as front-wheel drive, however. There is less engine and transmission weight over the drive wheels. (D) A mid-engine, rear-wheel drive layout is the least common. It can be found on a few sports cars.**

All-wheel drive (AWD) uses two differentials to power all four drive wheels. This is a relatively new design used on several makes of passenger vehicles.

Four-wheel drive (4WD) systems use a transfer case to send power to two differentials and all wheels. The transfer case can be engaged and disengaged to select two- or four-wheel drive as desired. It is common on off-road vehicles.

NOTE *For more information on vehicle construction (air bags, drivelines, and so on) and related subjects, refer to the Index. For example, Chapter 21 explains the operation and repair of mechanical systems in more detail. Air bag operation and service are explained in Chapter 23.*

2.4 BODY CLASSIFICATIONS

Various methods of classifying vehicles exist: engine type (gas or diesel), fuel system type (carburetor or injection), driveline type (automatic or manual transmission, front-wheel versus rear-wheel drive), and so forth.

The body classifications most recognized by consumers are car size, body shape, seat arrangement, number of doors, and so on. You should be familiar with these to communicate well on the job.

Car Size

A *compact car*, also called an economy car, is the smallest body classification. It normally uses a small, four-cylinder engine, is very light in weight, and gets the highest gas mileage.

A *micro car* is a tiny passenger vehicle for one or two adults. This type of car is often powered by a motorcycle engine. Micro cars are very popular in Europe. They are very light and have a very small cross-sectional area for low drag and wind resistance.

An *intermediate car* is medium in size. It often uses a four-, six-, or eight-cylinder engine and has average weight and physical dimensions. It usually has unibody construction, but a few older vehicles have body-over-frame construction.

A *full-size car*, or luxury car, is the largest classification of passenger car. It is larger and heavier and often uses a high-performance V8 engine. Full-size cars can have either unibody or body-over-frame construction. Full-size cars get lower fuel economy ratings, primarily because of their increased mass.

General Vehicle Data

Auto manufacturers or auto makers design, model, test, and build passenger vehicles in automated factories. The major auto companies include:

Vehicle curb weight is the total mass of the vehicle with a full tank of gas and no driver. Vehicle curb weights vary.

Generally, pickup trucks and SUVs are the heaviest vehicles and weigh 2.5 tons or approximately 5,000 lb. (2,267.96 kg). Full-size cars, station wagons, and full-size vans weigh about 2 tons or 4,000 lb. (1,814.369 kg). Economy cars have a low curb weight of about 3,000 lb. (1,360.777 kg). Small sports cars and micro cars are the lightest passenger vehicles, weighing in at about a ton or 2,000 lb. (907.185 kg).

Vehicle weight distribution is a measurement of how much force is pushing down on the front and rear tires of the vehicle. An ideal weight distribution of economy and corning ability is 50/50 or 50 percent front and 50 percent rear, as is found with many high-performance sports cars. Front-wheel drive vehicles have about a 70 percent front/30 percent rear weight distribution for good two-wheel drive traction at both front-axle hubs.

Vehicle wheelbase is the distance from the centerline of the front wheels to the centerline of the rear wheels.

Vehicle track is the distance between the right and left wheel or tire centerlines. The trend is to make vehicles wider so that they can corner more quickly without a rollover accident. A typical track rating might be 62 inches (0.0015748 km) front and 64 inches (0.0016256 km) rear.

Vehicle length is a measurement from the front of the front bumper to the back of the rear bumper. *Vehicle width* is a measurement between the two widest points on the right and left sides of the body. *Vehicle height* is measured from the ground to the top of the highest point on the roofline.

Roof Designs

There are several basic body shapes or roof designs in use today:

- A *sedan* refers to a body design with a center pillar that supports the roof. Sedans come in both two-door and four-door versions.
- A *hardtop* does not have a center pillar to support the roof, so the roof must be reinforced to provide enough strength. A hardtop is also available in both two- and four-door versions.
- A *hatchback* has a large third door at the back. This design is commonly found on small compact cars so that more rear storage space is available.
- A *convertible* uses a retractable canvas roof with a steel tube framework. The top folds down into an area behind the seat. Some convertibles use a removable hardtop. Some newer vehicles have gone back to the use of retractable hardtops.
- A *station wagon* extends the roof straight back to the rear of the body. A rear hatch or window and tailgate open to allow access to the large storage area.
- A crossover vehicle is a mixed design using traits from both a station wagon and an SUV.
- A *van* has a large, box-shaped body to increase interior volume or space. A full-size van normally is front-engine, rear-wheel drive with a full perimeter frame. A minivan is smaller and often uses front-engine, front-wheel drive with unibody construction.
- An *SUV*, or sport utility vehicle, has four-wheel drive and room for multiple passengers. This all-weather vehicle generally sits higher than passenger cars for increased ground clearance on rough terrain. Often classified as an off-road vehicle, the SUV is ideal for driving through snow and mud.
- A *pickup truck* normally has a separate cab and bed. Most pickup trucks use a front-engine, rear-wheel drive setup. Some are four-wheel drive.

The basic vehicle body shapes are shown in Figure 2–10.

Part/Panel Nomenclature

A *part*, also called a *component*, generally refers to an individual unit used to build a vehicle. Several parts fastened together form an assembly. For example, a steering column **assembly** is made up of the steering wheel, trim cover, air bag, turn signal mechanism, and other parts.

Stationary parts, such as the floor, roof, and quarter panels, are permanently welded or adhesive bonded into place. *Hinged parts* (the hood or trunk lid) and *hinged assemblies* (doors) can open and close.

Fastened parts are held together with various fasteners (bolts, nuts, clips, adhesive, and so forth). Many parts, such as the fenders, hood, and grille, are fastened or bolted into place.

Welded parts are permanently joined by heat fusing the material so that it flows together and bonds when cooled. Both metal and plastic parts can be welded.

Press-fit, or snap-fit, parts use clips or an interference (friction) fit to hold parts together. This assembly method is becoming more common to reduce manufacturing costs.

Adhesive-bonded parts use a high-strength epoxy or special glue to hold the parts together. Both metal and plastic parts can be joined with adhesive. *Structural adhesive* can also be used to bond parts together.

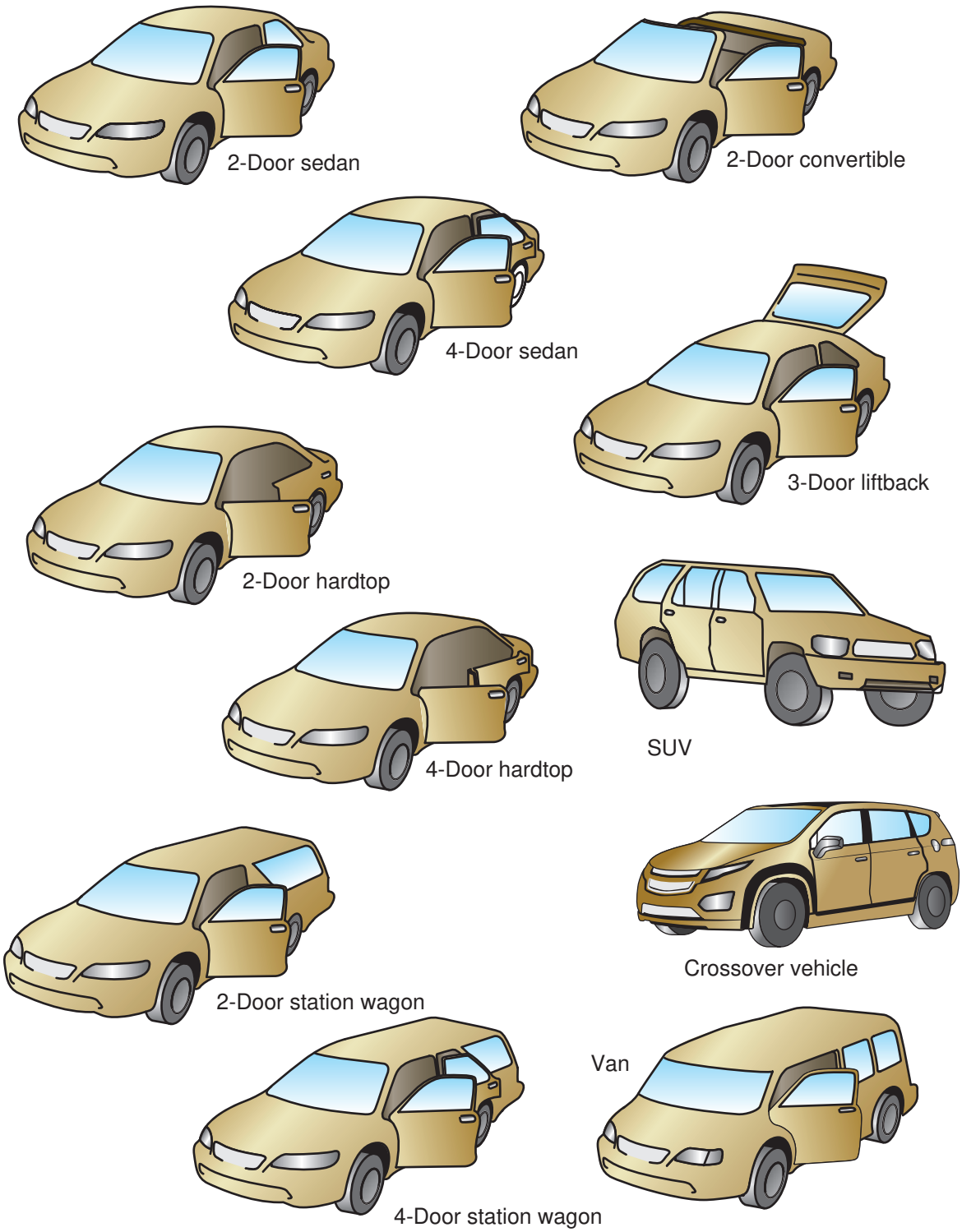


Figure 2–10 Memorize the names of the basic body shapes or configurations.

Body Panels

A **panel** is a steel, aluminum, or plastic sheet stamped or molded into a body part. Various panels are used in a vehicle. Usually, the name of the panel is self-explanatory: hood panel, fender panel, trunk lid panel, or roof panel.

Study the names and locations of each part or panel carefully. The major outer panels of a vehicle are shown in Figure 2–11.

During manufacturing, these complexly contoured panels are often stamped out of sheet metal, using a huge multi-ton drop forger. The giant machines crush the thin,

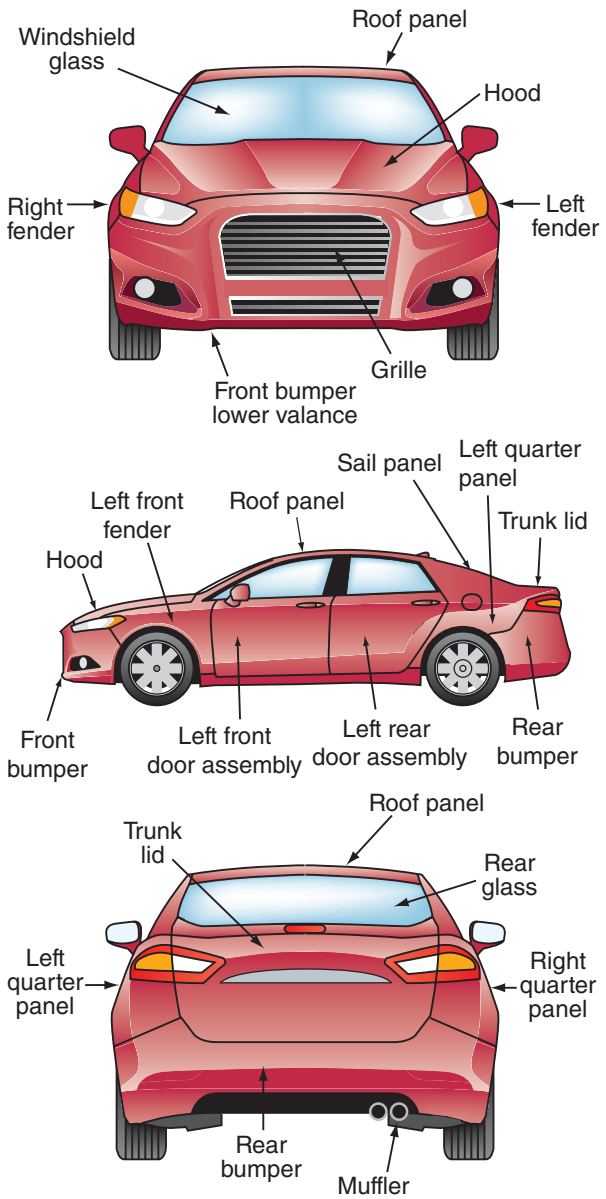


Figure 2–11 **Study the major outer body panels, viewed from outside.**

flat sheet metal in a die machined to match the shape of the desired body panel.

Body panels usually have compound curves formed to increase stiffness. With unibody construction, these panels are welded together to form the unibody frame at the vehicle assembly plant.

Make sure you fully understand correct repair procedures and construction technology before working on a vehicle. It can be costly and dangerous, even deadly, if you do not understand how a car or truck is made and should be repaired.

2.5 AUTO BODY REPAIR HISTORY

To provide background about how the passenger vehicle has changed over the years, this section of the chapter summarizes the history of automobile construction.

The First Motor Cars

The early automobile manufacturing companies originated in various ways. They evolved from bicycle makers, carriage and wagon makers, and other types of industry.

The very first motor cars were nothing more than a horse buggy with an engine. They had large, spoked wheels and a long bar for steering the front wheels. The small gas engine used a chain and sprockets to drive the rear axle. Other early motor cars used steam engines or electric motors and batteries for power.

Henry Ford developed the Model T, the first car mass-produced on an assembly line. Affectionately called the "Tin Lizzie," this car was introduced and sold in 1908. The Model T was deemed "the car for the multitude" and was an instant success, upon which Ford succeeded in building one of the largest auto manufacturing companies in the world.

During manufacturing, the Model T's rolling chassis was built first. The axles, wheels, and tires were attached to the frame, then the chassis was pulled down the assembly line by a floor conveyor. As the chassis reached each workstation, another part or assembly was installed. The body was one of the last units lowered onto the chassis. It had a 4-cylinder, 20-horsepower engine mounted in the front. To operate the planetary transmission, you had to use foot pedals on the floor.

The Model T was painted only one color—black. This and other mass-production steps helped Henry Ford keep the cost of his car down, low enough for the average American worker to afford. The first Model Ts cost about $850. However, by the early 1920s, the least expensive model sold for only $290.

Other car makers came along and imitated many of Henry Ford's assembly line techniques. American automobile companies used parts made by independent suppliers. These outsourced parts were shipped to the factory for assembly.

In the mid- to late 1920s, the two largest manufacturers were Ford and General Motors. The other major manufacturers at the time were Packard, Hudson, Maxwell, and Chrysler. Most of these companies were located in Detroit, Michigan, which became the center for world automotive production.

General Motors overtook Ford in sales volume in 1925 by producing vehicles more refined than the Model T. Because of this, the last Model T was manufactured in 1927.

The Sixties

Up through the 1960s, American automobiles were manufactured in pretty much the same way, with similar characteristics:

- Body-over-frame construction
- Rear drive, with solid axle housing
- Independent front suspension

By the 1960s, people wanted speed, power, and styling in their cars. Americans wanted cars that had low elapsed times in the quarter mile. They craved big, loud, "muscle cars" with huge V8 engines, such as the legendary 427 Chevy Big Block, 428 Ford Cobra Jet, 426 Dodge Maxi Wedge, Pontiac 421, and Oldsmobile 455. The "King Kong" 426-inch Chrysler Hemi Head engine with 2 four-barrel carburetors and 425 horsepower was stuffed into the small Plymouth Challenger. Chevrolet shoehorned a 454-cubic inch big block into a Chevelle. Ford installed a 429 Hemi in a Mustang. The Corvette had a 427 with 3 two-barrel carburetors, or for even more power, you could order "2-fours." These classic American icons are still increasing in value on the collector market.

The Seventies

In 1974, a variety of events took place that rocked the foundations of the automobile industry. First, the government placed strict fuel economy and emission control laws and standards on automobile manufacturers. This was because many large cities were suffering from smog caused by air pollution. This increased the public demand for safe as well as cleaner running vehicles. Second, the Arab oil embargo also occurred at this time. The price of gasoline went up quickly, and people often had to wait in long lines to buy fuel. Consumers started purchasing cars with increased fuel efficiency (smaller bodies and engines) to save money on gasoline. This meant that American automotive manufacturers had to start building cars with better fuel economy.

To combat one source of pollution and reduce our consumption of petroleum, the fuel economy standard known as **Corporate Average Fuel Economy (CAFE)** was set by the Environmental Protection Agency. The **Environmental Protection Agency (EPA)** was established in 1970 as an independent agency in the executive branch of the U.S. government. The purpose of the EPA is to coordinate government and industry action to protect the Earth's environment from chemical damage.

Foreign car makers, who had always manufactured smaller, lighter, more fuel-efficient vehicles, captured an increasing share of the domestic new car market. American auto makers reacted to the competition by producing smaller, more efficient cars. This sped the development of the millions of unibody cars on the roads today.

Third, because of the construction of interstate highways and higher speed limits, along with more high-performance cars on the road, accidents and deaths from auto accidents had increased dramatically. As a result of this growing problem, federal laws were passed to regulate safety standards for motor vehicles. Numerous regulations mandated the installation of seat belts, safety glass windshields, head restraints to prevent whiplash, tire standards, body strength, and other design factors to improve passenger safety.

In 1979, the first driver's side air bag was introduced in the passenger car. It worked in conjunction with the seat belts to protect the driver from injuries during a frontal collision. If the car was in a major head-on collision, the air bag deployed like a big cushion to keep the driver's body and head from hitting the steering wheel and other interior parts. Air bags were made mandatory in motor cars produced after 1990.

Modern Motor Vehicles

With the advancement of technology, modern motor vehicles are engineering marvels. Today's passenger cars, light trucks, vans, and SUVs are more powerful, cleaner running, and safer than ever. On-board computers add to driver control of everything from engine management to antiskid braking systems. On-board navigation and automation provide today's drivers with luxury and convenience.

It is amazing how much more refined present-day automobiles are compared to just a few years ago. Sports car icons like the Corvette and Dodge Viper produce over 400 horsepower while emitting far fewer pollutants than their muscle car counterparts of the past. High-performance, "race-bred" parts are found in every major system of today's "super cars."

To avoid a collision, computer-controlled disc brake systems let drivers almost "stop on a dime," while maintaining steering control without skidding. If drivers have to swerve to avoid a collision, computer-assisted handling packages sense vehicle speed, cornering forces, tire loss of traction, and other factors to help cars "corner as if on rails."

Today's small cars have set remarkable records for fuel efficiency. Fifty miles per gallon, once said to be impossible, is now a reality. Small but powerful engines squeeze more energy out of every drop of fuel. Lighter body/frame structures and sleeker body shapes have all helped reduce fuel consumption, conserving our natural resources.

The technology in a typical late-model vehicle has also helped to prevent thousands of highway deaths per year. High-speed auto accidents that used to be fatal in yesterday's low-tech cars now result in less severe injuries. People now walk away from car crashes that earlier would have killed them.

This improved safety record is primarily due to the superior structural body/frame designs as well as more advanced computer control of various safety systems. Air bags, front and rear structural crush zones, stronger pillars going up to the roof, and reinforced passenger compartment areas have contributed the most to these improved highway safety statistics.

At present, the largest U.S. auto manufacturers are:

- General Motors Corporation (Chevrolet, Pontiac, Cadillac, GMC)
- Ford Motor Company (Ford, Mercury Jaguar)
- Chrysler Corporation (Dodge, Plymouth, Jeep)

Ford, General Motors, and Chrysler are often called the "Big Three" because they are the largest U.S. auto manufacturers. Other auto manufacturers include Porsche, Audi, Volkswagen, BMW, Honda, Acura, Infinity, Lexus, Nissan, Saab, Subaru, Toyota, and Volvo.

The automotive industry is becoming more global in nature, with the major manufacturers owning many of the smaller auto makers. This aids technology transfer from country to country and from corporation to corporation, which in turn improves vehicle quality while reducing fuel consumption and emissions (pollution).

Other than the United States, countries with large automotive industries include Japan, Canada, France, Italy, Sweden, Korea, and Russia. The places in the world with the most motor vehicles are North America, Western Europe, Japan, Australia, and New Zealand. These countries have ratios of approximately one automobile for every three people.

Hybrid Motor Vehicles

The hybrid car is a glimpse into the future. The hybrid has tremendous potential to reduce fuel consumption and exhaust emissions. Hybrid vehicles are now being built and sold by several auto manufacturers.

The *hybrid vehicle* uses two power sources: an engine and an electric motor. When driving, the hybrid car uses batteries and its large electric motor to accelerate up to cruising speed. Then as the batteries become discharged, the gas or diesel engine starts up to generate electricity to keep the car moving and also to recharge the batteries. By using regenerative braking, the hybrid car saves even more fuel. Hitting the brakes actually generates and stores energy for the next acceleration. The hybrid car now holds the record for fuel economy at around 50 miles per gallon.

The Future

What will future motor vehicles be like? Will our automobiles be made of all plastics or carbon fiber or some yet to be invented material? Will car unibodies have fewer parts? Could the unibody be made of one large injection-molded piece of plastic? Will cars drive themselves? Engineers are studying self-steering cars that follow a strip of metal embedded in the highway. Will automatic braking systems sense an impending crash and apply the brakes by computer control?

Construction Methods Change

Passenger cars, trucks, vans, and SUVs use one of two types of construction:

1. Conventional body-over-frame
2. Unitized or unibody

The five construction areas in which domestic automobiles have changed since the mid-1970s are:

Hybrid vehicles are now the "Gas Mileage Champions" of the auto industry. Plug-in hybrids can be charged overnight and then driven up to about 50 miles on full electric propulsion. The gasoline or diesel engine does not have to start and run at all. Only when the high-voltage battery becomes almost fully discharged does the gas engine start and run to propel the car. Many manufacturers claim that their hybrids produce zero emissions while driving in full electric mode. With millions of hybrid vehicles on the road today, this accounts for a substantial reduction in air pollution.

1. Body/frame construction (more unibody than full frame)
2. Weight (average vehicle weight has decreased)
3. Part composition (more use of thin, high-strength steels, aluminum, plastics, and composites)
4. Suspension/steering (more use of independent suspension, rack-and-pinion steering, and four- or all-wheel drive)
5. Engine location/drive (more front-engine, front-wheel drive vehicles)

In 1977, most new cars still used a full frame. They averaged around 4,500 lb. (2,038 kg) and used comparatively heavy, thick, 18-gauge, mild-strength steel in body panels. They were still predominantly front-engine, rear-wheel drive vehicles.

After that, body weight began to decrease, and thinner-gauge metal was used. Also, the first American-made transverse (sideways-mounted) engine, front-wheel drive, strut suspension cars were introduced.

By 1981, unibodies were used in almost half of American-made cars. Average weight decreased 600 lb. (272 kg), and 22-gauge high-strength steel was used in construction. At the same time, there was a shift toward rack-and-pinion steering, to the MacPherson strut–type suspension, and from rear- to front-wheel drive.

At the present time, most unibodies are constructed of thin, 24-gauge, high-strength steel; have an average weight of 900 lb. (407 kg) less than in 1980; and feature MacPherson struts, rack-and-pinion steering, and front-wheel drive. Today, most passenger cars on U.S. roads are unibodies.

Repair Methods Change

As design innovations and the construction of vehicles have changed over the years, so too has the collision repair profession. The job of repairing vehicles has also become more complex.

In the early days of Model T automobiles, there were no specialized shops for automobile collision repair.

When a car was brought in for repair, the damaged part was usually removed and replaced with a new one that was either forged from steel or cut from wood. This method was expensive and time-consuming. Many times there was a long wait for parts and to complete repairs. Most of the early body/frame technicians were carpenters or blacksmiths.

As automobile body/frame designs became more complex, it became more practical to repair than replace, even though early repair procedures often involved days of hammering on parts to straighten them. Early body repair was delicate and time-consuming because parts had to be straightened without using body filler. (None existed at this time.)

When the Nash Company introduced its unitized body in 1940, a whole new set of collision repair problems arose. Because there was no frame to apply pressure against, the technique of internal body and frame pushing was of little value. There was not enough material in any one place to push against without bending the body and causing further damage.

The basic repair technique of pushing out damaged sections evolved to one of pulling out damaged sections. Out of necessity, the portable body and frame puller was developed and was soon accepted on a worldwide basis.

The manufacturers of stationary frame equipment also had to modify their equipment. The change to a pull technique was made by adding adjustable pull towers. These units remained functional but grew more massive, complicated, and expensive.

It is important to know which type of auto body construction is used. Detailed in later chapters, repair work is different for each type of vehicle construction. Modern body technicians need a great deal more knowledge than their counterparts in the era prior to the advent of the unibody. Now technicians must know how to repair both full frame and unibody vehicles with great precision. The safety of the driver and passengers relies on the skill of the auto body technician who repairs their vehicle.

2.6 UNIBODY PANELS

To become a competent collision repair technician, it is important that you be able to quickly locate and identify the major panels of a motor vehicle. As you will learn, some are the same for both unibody and full frame vehicles, whereas others differ significantly depending on vehicle construction. Please refer to Figure 2–12.

Front Section Parts

The **frame rails** are the box members extending out near the bottom of the front section. They are usually the strongest part of a unibody. Frame members, or rails, are normally welded to the fire wall and to the bottom of the fender aprons. They usually have crush zones in them to absorb collision energy from a frontal impact.

The **cowl** is the assembly of panels at the rear of the front section, right in front of the windshield. This assembly includes the top cowl panel and side cowl panels.

The *front fender aprons* are inner panels that surround the wheels and tires to keep out road debris. They are often bolted or welded to the frame rails and cowl. They also add to the structural integrity of the front end (Figure 2–13).

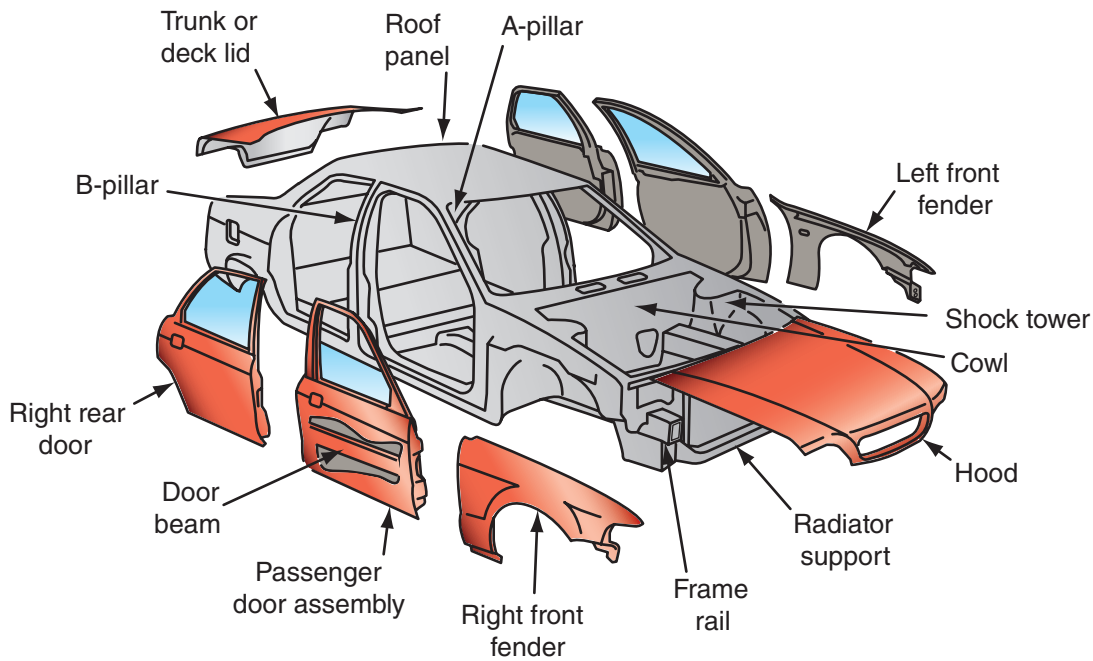


Figure 2–12 Here is a front-drive unibody vehicle with the bolt-on parts removed. Study the names and locations of the parts and panels.