MODERN DIESEL TECHNOLOGY

# Heavy Equipment Systems

2nd Edition

Robert Huzij
Angelo Spano
Sean Bennett

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# Modern Diesel Technology: Heavy Equipment Systems

## 2nd Edition

**Robert Huzij, Angelo Spano, Sean Bennett**

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**Modern Diesel Technology: Heavy Equipment Systems, 2nd Edition**
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# Preface for Series

The Modern Diesel Technology (MDT) series of textbooks debuted in 2007 as a means of addressing the learning requirements of schools and colleges whose syllabi used a modular approach to curricula. The initial intent was to provide comprehensive coverage of the subject matter of each title using ASE/NATEF learning outcomes and thus provide educators in programs that directly target a single certification field with a little more flexibility. In some cases, an MDT textbook exceeds the certification competency standards. An example of this is Joseph Bell's *MDT: Electricity & Electronics*, in which the approach challenges the student to attain the level of understanding needed by a technician specializing in the key areas of chassis electrical and electronics systems—in other words, higher than that required by the general service technician.

The MDT series now boasts nine textbooks, some of which are going into their second edition. As the series has evolved, it has expanded in scope with the introduction of books addressing a much broader spectrum of commercial vehicles. Titles now include *Heavy Equipment Systems, Mobile Equipment Hydraulics*, and *Heating, Ventilation, Air Conditioning & Refrigeration*. The latter includes a detailed examination of trailer reefer technology, subject matter that falls outside the learning objectives of a general textbook. While technicians specializing in all three areas are in demand in most areas of the country, there are as yet no national certification standards in place.

In addition, the series now includes two books that are ideal for students beginning their study of commercial vehicle technology. These two titles (*Preventive Maintenance and Inspection* and *Diesel Engines*) are written so that they can be used in high school programs. Each uses simple language and a no-nonsense approach suited for either classroom or self-directed study. That some high schools now option programs specializing in commercial vehicle technology is an enormous progression from the more general secondary school ''shop class'' which tended to lack focus. It is also a testament to the job potential of careers in the commercial vehicle technology field in a general employment climate that has stagnated for several years. Some forward-thinking high schools have developed transitional programs partnering with both colleges and industry to introduce motive power technology as early as Grade 10, an age at which many students make crucial career decisions. When a high school student graduates with credits in Diesel Technology or Preventive Maintenance Practice, it can accelerate progression through college programs as well as make those responsible for hiring future technicians for commercial fleets and dealerships take notice.

As the MDT series has evolved, textbooks have been added that target specific ASE certifications, providing an invaluable study guide for certified technicians who are adding to their qualifications along with college programs that use a modular learning approach. *Electronic Diesel Engine Diagnosis* (ASE L2), *Truck Brakes, Suspension, and Steering Systems* (ASE T4 and T5), and *Light Duty Diesel Engines* (ASE A9) detail the learning outcomes required for each ASE certification test.

Because each textbook in the MDT series focuses exclusively on the competencies identified by its title, the books can be used as a review and study guide for technicians prepping for specific certification examinations. Common to all of the titles in the MDT series, the objective is to develop hands-on competency without omitting any of the conceptual building blocks that enable an expert understanding of the subject matter from the technician's perspective. The second editions of these titles not only integrate the changes in technology that have taken place over the past five years, but also blend in a wide range of instructor feedback based on actual classroom proofing. Both should combine to make these second editions more pedagogically effective.

*Sean Bennett 2012*

# Preface

## ABOUT THIS TEXT

In approaching this 2nd Edition revision of Modern Diesel Technology (MDT) *Heavy Equipment Systems*, the author team accepted the reality that the first edition was not used as a stand-alone textbook by Heavy Equipment specialty programs. For this reason, we made the decision to drop a couple of chapters that more or less repeated content already covered in *Heavy Duty Truck Systems*, which tends to be used as a companion to this book. The trade-off was a real plus because it opened up space to add three brand-new chapters that are totally Heavy Equipment specific. One of these, the hoisting and rigging chapter, is essential to anyone working with heavy off-road machinery, and it came about as a result of feedback requests from our reviewers, a reinforcement of just how important it is to listen to our users. Because of this, we have located this chapter immediately following the chapter on safety.

In the modern post-secondary environment, it is necessary to use multiple textbooks and online resources along with OEM service literature in order to meet increasingly more exacting exit competencies . . . and employer expectations of entry-level employees. MDT *Heavy Equipment Systems* has no current competitors because it competes in a relatively small market in which the alternatives are extremely out of date. The author team opted to keep this book as up to date as possible, but there is only just so much that can be packed in, given the page count limitations we are required to work within, so we have only addressed the technology that is unique to heavy equipment. The bottom line is that there are current textbooks that adequately cover subject matter such as diesel engines, electronic system management, and multiplexing, along with those chassis systems that are common to both commercial vehicles, agricultural, and heavy off-road equipment.

## TECHNOLOGICAL CHANGES

Technology continues to change at an astounding rate. The spectrum of technology used in the heavy equipment field is much broader than in the automotive or heavy commercial vehicle fields. Because a price tag of $5 million is not unheard of for a single piece of equipment, there is a major incentive to maximize machine longevity: for this reason, we see equipment repaired rather than replaced with more frequency than in other motive power areas. This emphasizes the importance of repair techniques for heavy equipment technicians, rather than the diagnose/replace techs that are more common in the truck service and repair industry. In a current open-face mining operation, it is not unusual to observe 30-year-old machinery operating alongside brand-new equipment.

The hydromechanical controls common a generation ago have generally given way to computer processed, data bus-driven, pilot-actuated circuits. To work on the hydraulic circuits in modern equipment, it is a requirement that the repair technician understand the electronics that manage the hydraulics. The challenge we face as educators in this field in keeping up with technological changes is a daunting one, and a good education program should be based on more than reliance on a single textbook: it should be complemented by online references and OEM support literature. In addition, both instructors and their students can benefit from observation and participation in online discussion threads such as in iatn (www.iatn.net) troubleshooting discussions: the trick is to teach students and technicians into how to manage the excess of information available, and learn how to discard what is not accurate. The approach used in this book is to deliver the fundamentals in each subject area, before progressing to the components and circuits specific to off-road equipment.

## WHAT'S NEW TO THIS EDITION?

As indicated earlier in the preface, this book does not pretend to cover everything the novice heavy equipment technician is required to know before pulling a wrench. What has been added or removed

from this second edition has been done with the objective of optimizing its content, and maximizing its usefulness to the heavy equipment technician. The chapter on safety has been enhanced with additional emphasis on hydraulic safety related to high oil temperatures and high pressure hazards. Also in this chapter, a new section has been added that explains the importance of OPS, ROPS, and FOPS systems on off-road equipment. Following the chapter on safety, a new chapter on hoisting and rigging techniques has been added, explaining safety and handling techniques that are essential and distinct to this field. The hydraulics section, which consists of four chapters in this revised edition, has been enlarged to address the importance and complexity of modern hydraulic systems. More emphasis has been placed on interpreting hydraulic symbols and schematics, and the sections on maintenance and diagnostics, troubleshooting basics, and bleeding procedures for hydraulic pumps have all been expanded. The chapter on final drives has been enlarged to include a new section on double reduction drives along with a technical updating of the existing drive systems. The chapter on tracks and undercarriages has been updated to reflect some of the new maintenance practices used on track equipment. Electronic system management has been covered within the core chapters and further enhanced in a new chapter titled *Machine and Equipment Electronics*, which takes a closer look at how off-road industries use multiplexing and devices such as haptic joysticks, which are not used on highway vehicles. The book ends with a brand-new chapter on AC-drive systems: the AC drivetrain provides a good model for increasingly used hybrid drive technology and the system described in this book is adaptable to AC trolley drive, which has significant appeal in modern open-face mining operations because of its ability to significantly reduce fuel and downtime costs.

## THE OFF-ROAD EQUIPMENT INDUSTRY

The prolonged economic downturn that began in 2008, and continues until the time of writing of this edition, has demonstrated how the off-road industry is somewhat insulated from economic ups and downs. Through all of the past five years, there has been a shortage of skilled workers in the mining and construction industries; some of this may be attributable to an unwillingness of domestic workers to move to where the work is, but it also suggests that as a society we are producing an excess of liberal arts majors and not nearly enough motive power technicians.

When it comes to the design, construction, and quality of off-road equipment, North American manufacturers continue to lead the way worldwide. Caterpillar has reported increased profits in each of the past five years, while many industries have stagnated. In addition, industry analysts suggest that the shortage of heavy equipment repair technicians will become more acute over the next few years, underlining the importance of educators in attracting workers of the future into their programs and instilling the skills and work ethics in future mechanical technicians. Any technician working in motive power today understands the importance of staying current in their field, and that means embracing education throughout a career. Learning is and always has been a lifelong process that must be passed on to our young trades persons both in school and on the job.

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*Robert Huzij*
*Angelo Spano*

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## INSTRUCTOR RESOURCES

Time-saving instructor resources are available at the Instructor Companion Web site for the text or on CD. Either delivery option offers the following resources: PowerPoint chapter presentations with selected images, an Electronic Test Bank, an Image Gallery containing images from the book, and Instructor's Guide which includes an answer key to chapter review questions, Word documents containing the chapter review questions, and a set of job sheets for use in the shop.

CHAPTER

# 1 Safety

## Learning Objectives

After reading this chapter, you should be able to:

- Evaluate potential danger in the workplace.
- Describe the importance of maintaining a healthy personal lifestyle.
- Outline the personal safety clothing and equipment required when working in a service garage or field location.
- Distinguish between different types of fire and identify the fire extinguishers required to suppress small-scale fires.
- Outline some procedures required to use shop jacking and hoisting equipment safely.
- Recognize the potential danger when using different types of shop equipment and the importance of using exhaust extraction piping.
- Identify what is required to work safely with chassis electrical systems and shop mains electrical systems.
- Outline the safety procedures required to work with oxyacetylene cutting and welding equipment and how to safely use arc welding stations.

## Key Terms

Canadian Standards Association (CSA)
chain hoist
cherry picker
come-along
electric shock resistant (ESR) footwear
falling-object protection system (FOPS)
operator protective structures (OPS)
personal protective equipment (PPE)
pinhole injection injury
rollover protection system (ROPS)
scissor jack
single-phase main
Standards Australia
static charge
static discharge
three-phase main
Underwriters Laboratories (UL)

## INTRODUCTION

The mechanical repair trades are physical by nature, and those employed as technicians probably have higher than average levels of personal fitness. Technicians are required to work safely when handling heavy equipment, and to safely handle materials that can be hazardous.

Modern living requires that we assess risk on a minute-by-minute basis and then strategize how to

handle a given situation to avoid potential danger. After all, the simple act of crossing a city street requires some planning. There may be a law that prohibits jaywalking so the first decision you make is whether or not you observe that law. Most cities (in North America) accord the pedestrian some rights over vehicles when it comes to crossing a street, but to be eligible for those rights, you may have to observe such things as crosswalk paths and stop/go lights. The result is that you get to choose whether you make the act of crossing a busy city street one of indescribable adventure and danger or a relatively safe procedure that millions successfully perform daily.

The same can be said of working safely in a repair shop environment. There are a multitude of rules and regulations, most of them posted for maximum exposure. But ultimately, it is up to the individual whether he or she chooses to observe those rules. The great thing about the free world we live in, is you get to decide. Nevertheless, if you are planning on a career in the heavy service-repair industry, you should attempt to stack your decisions in favor of your ultimate safety.

A major heavy equipment manufacturer monitored accidents over a five-year period in one of its assembly plants and came up with the following conclusion: a line-production employee's risk of serious injury (defined as one that required some time off work) during the first year of employment was equal to that of years two through six combined. In simple terms: if you can survive your first year injury-free, thereafter, your risk diminishes significantly.

Instructors of mechanical technology often complain that it is difficult to teach safe work practices to entry-level technicians. The difficulty arises from the fact that entry-level motive power students may be motivated to learn transportation technology but tend to turn off when asked to learn about the health and safety issues that accompany working life. It is sometimes difficult to teach safe work practices to persons who have never been injured and may harbor an illusion that they are immune from injury. On the other hand, an injured person probably has acquired, with the injury, some powerful motivation to avoid a repeat.

## Shake Hands with Danger!

''Shake Hands with Danger!'' *www.youtube.com/watch?v=3_gEVILWVUM* is a film about workplace safety made by Caterpillar many years ago. It uses some painfully realistic shop scenarios to drive its message home. The film's title is the chorus in a catchy, drawled country-and-western ballad that repeats itself many times over during the film, usually just before someone is about to sustain a deadly or limb-severing experience. The hard message of the film is that most lapses in safety are caused by stupidity. This is accurate, and the great feature of this cautionary and often humorous presentation is that helps us identify some of the dangerous shortcuts we take on a daily basis without giving a thought to the consequences. Every technician working with heavy on- and off-highway equipment should see this film at least once during his or her career. I know of one dealership that shows this film once a year to all their service personnel and they claim a 50% lower overall accident rate as a result.

## A Healthy Lifestyle

Repairing on- and off-highway heavy equipment certainly requires more physical strength than working at a desk all day, but it would be a tough call to say it was in itself a healthy occupation. Lifting a clutch pack or pulling a high load on a torque wrench for sure requires some muscle power but does not parallel lifting weights in a gym where the repetitions, conditions, and movements are carefully coordinated to develop muscle power. Jerking on a torque wrench while attempting to establish final torque on main caps during an in-chassis engine job can tear muscle as easily as it can develop it. It pays to think about how you use your body and to use your surroundings to maximize leverage and minimize wear and tear. Make a practice of using hoists to move heavier components, even if you know you could manually lift the component: you may believe it is macho to manhandle a 150-pound clutch pack into position, but all it needs is a slight twist of the back while doing so and you can sustain an injury that can last a lifetime. There is nothing especially macho about hobbling around, suffering in the throes of chronic back pain for years.

Part of maintaining a healthy lifestyle means eating properly and making physical activity a component of everyday living. What this means for each individual will differ. Team sports are not just for teenagers, and whether your sport is hockey, baseball, basketball, or football, there are plenty of opportunities to compete at all ages and at a range of levels. If team sports are not your thing, there are many individual pursuits that you can explore. Working out in a gym, hiking, and canoeing are good for your mind as well as your body, and even golf gets you outside and walking. Because of the physical nature of repair technology, it makes sense to routinely practice some form of weight conditioning, especially as you get older.

## PERSONAL PROTECTIVE EQUIPMENT

**Personal protective equipment (PPE)** covers a range of safety apparel we use to protect our bodies. Some of this personal safety equipment, such as safety boots, should be worn continually in the workplace, while other equipment, such as hearing protection, may be worn only when required—for instance, when noise levels are high.

### Safety Boots

Safety boots or shoes are required footwear in a repair shop. In most jurisdictions, legislation mandates the use of safety shoes with steel shanks, steel toes, and **Underwriters Laboratories (UL)** *www.ul.com* certification in the United States, **Canadian Standards Association (CSA)** *www.csa.ca* certification in Canada, and **Standards Australia** *www.standards.org.au/* in Australia. That said, beyond any legal requirements, common sense dictates the use of protective footwear in a shop environment. Given the choice, especially in a heavy equipment service and repair facility, safety boots (see **Figure 1-1**) are a better choice than safety shoes because of the additional support and protection to the ankle area. To learn more about footwear standards and how footwear is tested to meet those standards, visit the Web site of the American Society for Testing and Materials (ASTM) *www.astm.org*.

There is a range of options when it comes to selecting a pair of safety boots, cost being a major factor. If you are going to work on a car under a tree over a weekend, it may be that a low-cost pair of safety boots will suffice, but for the professional mobile-equipment technician who wears this footwear daily for the lifetime of the boot, it pays to invest a little more. Generally, the higher the cost of the footwear, the longer it will last, and, more importantly, the greater the comfort level. Because safety footwear standards are slightly different in the United States and Canada, they are briefly outlined here. Australian and New Zealand standards conform to the U.S. ASTM standard.



**Figure 1-1** UL-approved safety boots.

**ASTM Class 75.** ASTM Class 75 approved footwear must meet an internal clearance height of 0.5 inches (12 mm) when impacted with a force of 75 ft-lbf (102 joules); this is equivalent to having a 40-pound object dropped from a height of 2 feet onto the toe of the boot. The crush standard must be met whether the toe protective cap is of steel or composite construction.

**CSA Class 1.** CSA Class 1 approved footwear must meet an internal clearance height of 12 millimeters (0.5 in) when impacted with a force of 100 joules (74 ft-lbf); this is equivalent to having a 20-kilogram weight dropped from a height of 0.5 meters onto the toe of the boot. The crush standard must be met whether the toe protective cap is of steel or composite construction.

**AS/NZ.** The Australia and New Zealand standard pertaining to safety boots is known as AS/NZ 2210.3 and conforms to ASTM Class 75. This requires that they meet an internal clearance height of 0.5 inches (12 mm) when impacted with a force of 75 ft-lbf (102 joules).

**Electric Shock Resistant (ESR) Footwear.** Any mechanical technician working around high-voltage potential chassis equipment should wear **electric shock resistant (ESR) footwear**. ESR footwear is designated by an orange omega on a white rectangle in both the United States and Canada. The standards are as follows:

- ASTM ESR footwear: must withstand the application of 14,000 volts at 60 hertz for 1 minute with zero current flow or leakage exceeding 3.0 milliamperes under dry conditions.
- CSA ESR footwear: must withstand the application of 18,000 volts at 60 hertz for 1 minute with zero current flow or leakage exceeding 1.0 milliamperes under dry conditions.

### Safety Glasses

Many shops today require all employees to wear safety glasses while on the shop floor. This is really just common sense. Eyes are sensitive to dust, metal shavings, grinding and machining particulate, fluids, and fumes. They are also more complex to repair than feet.

Perhaps the major problem, when it comes to making a habit of using safety glasses, is the poor

quality of most shop-supplied eyewear. Shops supply safety glasses because liability issues mandate their availability. Low-cost, mass-produced, and easily scratched plastic safety glasses may meet the employer's obligation to make safety glasses available to employees, but these glasses are unlikely to encourage the daily use of eye protection.

The solution is to not to depend on your employer to provide this essential safety apparel. Get out of the mindset that safety glasses should be free. Free safety glasses are uncomfortable and, although they may protect eyes from flying particulate, they may actually impair vision. Spend a little more and purchase a good quality pair of safety glasses. Even if you do not normally wear eyeglasses, after a couple of days, you will forget you are wearing them. **Figure 1-2** shows three methods of protecting your eyes in the workplace.

## Hearing Protection

Two types of hearing protection are used in shops. Hearing muffs are connected by a spring-loaded band and enclose the complete outer ear. This type of hearing protection is available in a range of qualities, determined by the extent to which they muffle sound. Cheaper versions may be almost useless, but good quality hearing muffs can be the most effective when noise levels are high and exposure is prolonged.

A cheaper and generally effective alternative to hearing muffs is a pair of ear sponges (plugs). Each sponge is a malleable cylindrical or conical sponge that can be shaped for insertion into the outer ear cavity; after insertion, the sponge expands to fit the ear cavity. The disadvantage of hearing sponges is that they can be uncomfortable when used for prolonged periods. They are designed for one time use and should be disposed of after removal: reuse can introduce contaminants into the outer ear. **Figure 1-3** shows some typical shop hearing protection devices.

For high-noise-level activities, such as riveting or operating dynamometers, the use of both hearing muffs and sponges should be considered; however, you should be aware that insulating the brain from sound can be disorientating, resulting in loss of balance.

**CAUTION** *Damage to hearing is seldom incurred by a single exposure to a high level of noise; it is something that more typically results from years of exposure to excessive and repetitive noise levels. Protect your hearing! And note that hearing can be as easily damaged by listening to music at excessive volume as by exposure to buck riveting.*

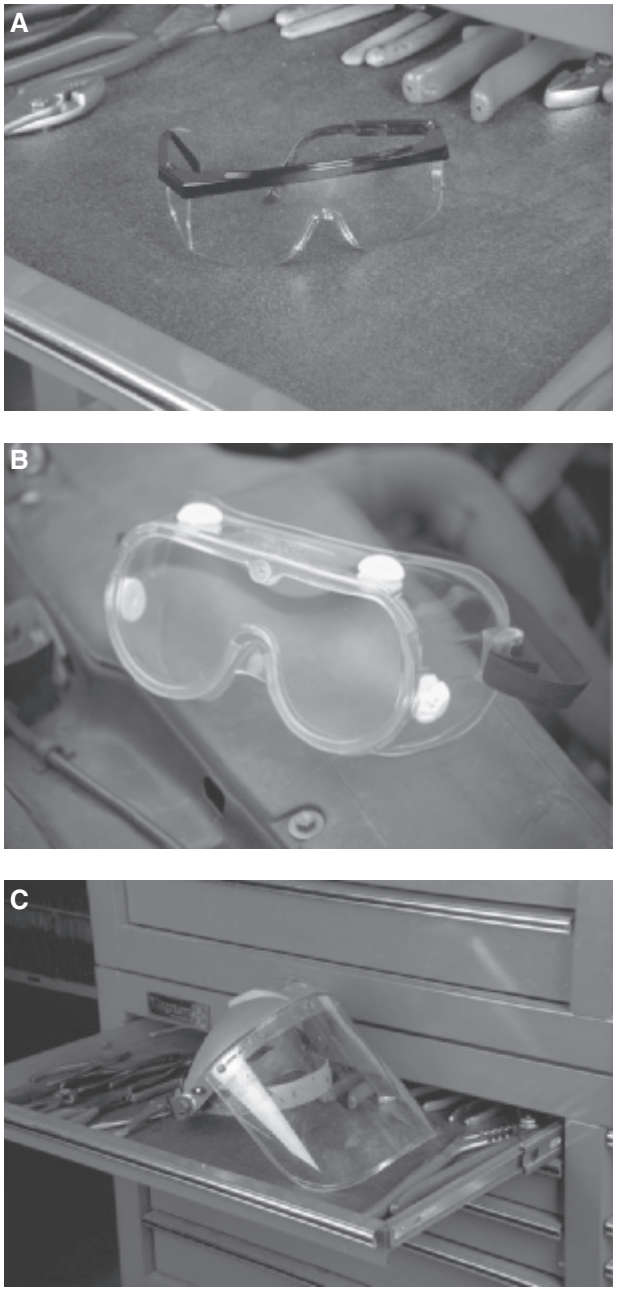


**Figure 1-2** (A) Safety glasses, (B) splash goggles, and (C) face shield.

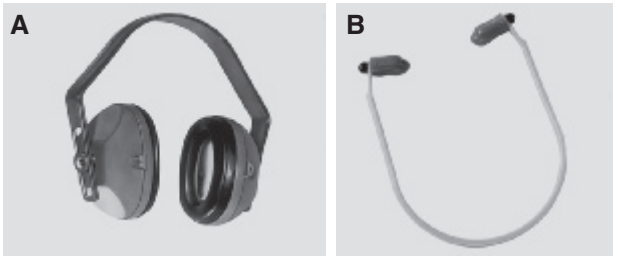


**Figure 1-3** Typical (A) ear muffs and (B) ear plugs.

## Gloves

A wide range of gloves can be used in shop applications to protect the hands from exposure to dangerous or toxic materials and fluids. The following are some examples.

**CAUTION** *Never wear any type of glove when using a bench-mounted, rotary grinding wheel. There have been cases where a glove has been snagged by the abrasive wheel, dragging the whole hand with it.*

**Vinyl Disposable.** Most shops today make vinyl disposable gloves available to service personnel. These protect the hands from direct exposure to fuel, oils, and grease. The disadvantage of vinyl gloves is that they do not breathe, and some find the sweating hands that result uncomfortable. Most shop-use vinyl gloves today are made of thin gossamer that minimizes the loss of tactile awareness.

**Mechanic's Gloves.** These artificial fiber, stretchable gloves have become popular in recent years. They are thin and fit tight to the hand, and so therefore provide the technician with some tactile sense. They are suitable for working on light-duty jobs.

**Cloth and Leather Multipurpose Gloves.** A typical pair of multipurpose work gloves consists of a rough leather palm and a cotton back. They can be used for a variety of tasks ranging from lifting objects to general protection from cold when working outside. This category of work glove can also provide some insulation for the hands when performing procedures such as buck riveting. You should cease to use this type of glove after it becomes saturated with grease or oil because they can become a fire hazard.

**Welding Gloves.** Welding gloves are manufactured from rough cured leather. They are designed to protect the hands from exposure to the high temperatures created in welding and flame cutting processes. Such gloves should be task-specific. The rough leather they are made from absorbs grease and oil easily, reducing their ability to insulate. Avoid using welding gloves rather than tools to handle heated steel because the gloves will rapidly harden and require replacement.

Some shops recommend the use of welding gloves when performing heavy suspension work because of their ability to protect fingers. If you perform both welding and suspension work in your job, make sure you use separate gloves for each. The gloves you use for suspension work will absorb oil and grease, after which they should not be used for welding.

**Dangerous Materials Gloves.** Gloves designed to handle acids or alkalines should be used for the specific task only. Gloves in this category are manufactured from nonreactive, synthetic rubber compounds. Care should be taken when washing up after using this type of glove.

**CAUTION** *Never wear leather gloves to handle refrigerants. Leather gloves rapidly absorb liquid refrigerant and can adhere to the skin.*

## Back Care

Back injuries are said to affect 50% of repair technicians, at some point in their careers, seriously enough for them to have to take some time off work. A bad back does not have to be an occupational hazard. Most of us begin our careers in our twenties when we have sufficient upper-body strength to be able to sustain plenty of abuse. As we age, this upper-body strength gradually diminishes and bad lifting practices can take their toll.

The best strategy for taking care of your back is to observe some simple rules for lifting heavy items. These rules can be summarized as follows:

- Keep your back erect while lifting.
- Keep the weight you are lifting close to your body.
- Bend your legs, and lift using the leg muscles.

**Figure 1-4** shows the correct method of using your back while lifting.

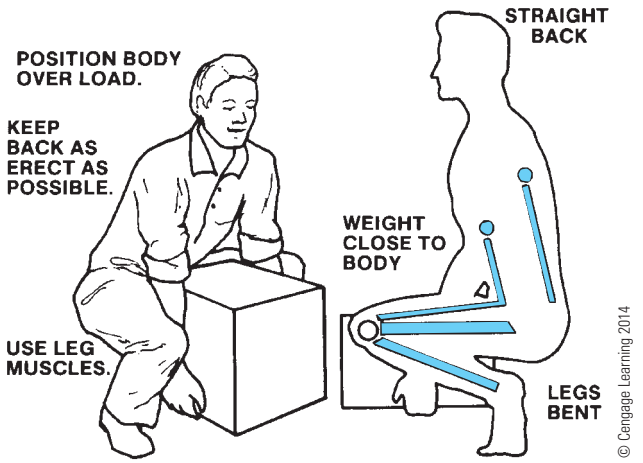


**Figure 1-4** Use your leg muscles—never your back—when lifting any heavy load.

**Back Braces.** A back brace may help you avoid injuring your back. Wearing a back brace makes it more difficult to bend your back, ''reminding'' you to keep your back straight when lifting. You may have noticed that the sales personnel in one national hardware and home-goods chain are all required to wear back braces. As a mobile equipment technician, you will be required to use your back for lifting, so you should consider the use of a back brace. Body shape plays a role when it comes to back injuries: if you are either taller than average height or overweight, you will be more vulnerable to back injuries.

## Coveralls

Many shops today require their service employees to wear a uniform of some kind. These may be work shirts and pants, shop coats, or coveralls. Uniforms have a way of making service personnel look professional. Given the nature of the work, the uniform of choice in truck, bus, and heavy equipment service facilities should be coveralls. The coveralls should preferably be made out of cotton for reasons of comfort and safety. When ordering cotton coveralls for personal use, remember to order at least a size larger than your usual nominal size; unless otherwise treated, cotton shrinks when washed. **Figure 1-5** shows a well-organized workspace around a wheel loader being worked on, free of clutter: this along with wearing the proper PPE is essential to minimize workplace injuries.

**CAUTION** *Avoid wearing any type of loose-fitting clothing when working with machinery. Shop coats, neckties, and untucked shirts can all be classified as loose-fitting clothing.*


**Figure 1-5** When working around equipment such as this Komatsu wheel loader, technicians should stack the odds in the favor of safety by ensuring that all PPE is worn and used properly.

When artificial fibers are used as material for coveralls, they should be treated with fire retardant. Cotton smolders when exposed to fire (that is, when it is not saturated with oil, fuel, or grease, which cause it to be highly flammable). Cleanliness is essential: oily shop clothing not only looks unprofessional, it can be dangerous! Artificial fibers, when not treated with fire retardant, melt when exposed to high temperatures and may fuse to the skin.

**CAUTION** *Note that, even when treated with fire retardant, some artificial fibers will burn vigorously when exposed to direct flame for a period of time.*

## Butane Lighters

There are few more dangerous items routinely observed on the shop floor than the butane cigarette lighter. The explosive potential of the butane lighter is immense, yet it is often stored in a pocket close to where it can do the most amount of damage. A chip of hot welding slag will almost instantly burn through the plastic fuel cell of a butane lighter. Owners of these devices will often compound the danger they represent by lighting torches with them. If you must have a lighter on your person while working, purchase a Zippo!

## Hair and Jewelry

Long hair and personal jewelry produce some of the same safety concerns as loose-fitting clothing. If it is your style to wear long hair, it should be secured behind the head and you should consider wearing a cap. Although wearing body jewelry has become a recent trend, you should consider removing as much as possible of this while at work. Bear in mind that body jewelry is often made of conductive metals, so you should consider both the possibility of snagging jewelry and creating some unwanted electrical short circuits.

## Safety Helmets

Safety helmets are essential in shops servicing and repairing large off-road equipment, especially when working under the equipment. The helmet should be adjusted to fit snug to the head and certified to meet UL, AS, and CSA certification standards.

## Spill Response

Liquids spilled onto the shop floor are a fact of life in a shop environment. However, they should be

regarded as an avoidable hazard. Make a point of immediately attending to and cleaning up any liquids spilled onto the shop floor. Ground-up absorbents are available in all shops and should be used. They are manufactured from wood bark, clay, and artificial substances. Until they become saturated with liquid, the absorbents can be regarded as harmless. Once used, absorbents must be disposed of in an environmentally responsible manner.

## FIRE SAFETY

Service and repair facilities are usually subject to regular inspections by fire departments. This means that obvious fire hazards are identified and neutralized. Although it should be stressed that fire fighting is a job for trained professionals, any person working in a service shop environment should be able to appropriately respond to a fire in its early stages. This requires some knowledge of the four types of fire extinguisher in current use.

### Fire Extinguishers

Fire extinguishers are classified by the types of fire they are designed to suppress. Using the wrong type of fire extinguisher on certain types of fire can be extremely dangerous and actually accelerate the spread of the fire you are attempting to control. Every fire extinguisher will clearly state the types of fire it is designed to suppress using the following class letters. In suppressing a fire, your role as a technician is to assess the risk required and intervene only if there is minimal risk.

**Class A.** A Class A fire is one involving combustible materials such as wood, paper, natural fibers, biodegradable waste, and dry agricultural waste. A Class A fire can usually be extinguished with water. Fire extinguishers designed to suppress Class A fires use foam or multipurpose dry chemical, usually sodium bicarbonate.

**Class B.** Class B fires are those involving fuels, oil, grease, paint, and other volatile liquids, flammable gases, and some petrochemical plastics. Water should not be used on Class B fires. Fire extinguishers designed to suppress Class B fires make use of smothering: they use foam, dry chemical, or carbon dioxide. Trained fire personnel may use extinguishers such as Purple K (potassium bicarbonate) or halogenated agents to control fuel and oil fires.

**Class C.** Class C fires are those involving electrical equipment. First intervention with this type of fire should be to attempt to shut off the power supply; assess the risk before handling any switching devices. When a Class C fire occurs in a vehicle harness, combustible insulation and conduit can produce highly toxic fumes. Great care is required when making any kind of intervention in vehicle chassis or building electrical fires. Fire extinguishers designed to suppress electrical fires use carbon dioxide, dry chemical powder, and Purple K.

**Class D.** Class D fires are those involving flammable metals. Some metals, when heated to their fire point, begin to vaporize and combust. These metals include magnesium, aluminum, potassium, sodium, and zirconium. Dry powder extinguishers should be used to suppress Class D fires. **Figure 1-6** provides a visual guide to selecting fire suppression equipment, and **Figure 1-7** shows a cabinet used to safely store combustibles.

## SHOP EQUIPMENT

Technicians must become familiar with an extensive assortment of shop equipment. Some items can be dangerous if you are not trained how to use them. Make a practice of asking for help if you are not familiar with how to operate any equipment.

### Lifting Devices

Many different types of hoists and jacks are used in heavy equipment shops. These can range from simple pulley and chain hoists to a variety of hydraulically actuated hoists. Weight-bearing chains on hoists should be routinely inspected (this is usually required by law): abrasive wear, deformed links, and nicks are reasons to place the equipment out of service. Hydraulic hoists should be inspected for external leaks before using, and any drop-off while in operation should be reason to take the equipment out of service. Never rely on the hydraulic circuit alone when working under equipment on a hoist. After lifting, support the equipment using a mechanical sprag or stands. Remember that this also applies when working on any kind of hydraulically actuated devices on heavy equipment.

**CAUTION** *Never rely on a hydraulic circuit alone when working underneath raised equipment. Before going under anything raised by hydraulics, make sure it is mechanically supported by stands or a mechanical lock.*

| Class of Fire | | Typical Fuel Involved | Type of Extinguisher |
|---|---|---|---|
| Class A Fires (green) | **For Ordinary Combustibles** Put out a Class A fire by lowering its temperature or by coating the burning combustibles. | Wood<br>Paper<br>Cloth<br>Rubber<br>Plastics<br>Rubbish<br>Upholstery | Water*[1]<br>Foam*<br>Multipurpose dry chemical[4] |
| Class B Fires (red) | **For Flammable Liquids** Put out a Class B fire by smothering it. Use an extinguisher that gives a blanketing, flame-interrupting effect; cover whole flaming liquid surface. | Gasoline<br>Oil<br>Grease<br>Paint<br>Lighter fluid | Foam*<br>Carbon dioxide[5]<br>Halogenated agent[6]<br>Standard dry chemical[2]<br>Purple K dry chemical[3]<br>Multipurpose dry chemical[4] |
| Class C Fires (blue) | **For Electrical Equipment** Put out a Class C fire by shutting off power as quickly as possible and by always using a nonconducting extinguishing agent to prevent electric shock. | Motors<br>Appliances<br>Wiring<br>Fuse boxes<br>Switchboards | Carbon dioxide[5]<br>Halogenated agent[6]<br>Standard dry chemical[2]<br>Purple K dry chemical[3]<br>Multipurpose dry chemical[4] |
| Class D Fires (yellow) | **For Combustible Metals** Put out a Class D fire of metal chips, turnings, or shavings by smothering or coating with a specially designed extinguishing agent. | Aluminum<br>Magnesium<br>Potassium<br>Sodium<br>Titanium<br>Zirconium | Dry powder extinguishers and agents only |

**Cartridge-operated water, foam, and soda-acid types of extinguishers are no longer manufactured. These extinguishers should be removed from service when they become due for their next hydrostatic pressure test.*

*Notes:*

*(1) Freezes in low temperatures unless treated with antifreeze solution, usually weighs over 20 pounds (9 kg), and is heavier than any other extinguisher mentioned.*

*(2) Also called ordinary or regular dry chemical (sodium bicarbonate).*

*(3) Has the greatest initial fire-stopping power of the extinguishers mentioned for class B fires. Be sure to clean residue immediately after using the extinguisher so sprayed surfaces will not be damaged (potassium bicarbonate).*

*(4) The only extinguishers that fight A, B, and C classes of fires. However, they should not be used on fires in liquefied fat or oil of appreciable depth. Be sure to clean residue immediately after using the extinguisher so sprayed surfaces will not be damaged (ammonium phosphates).*

*(5) Use with caution in unventilated, confined spaces.*

*(6) May cause injury to the operator if the extinguishing agent (a gas) or the gases produced when the agent is applied to a fire is inhaled.*



**Figure 1-6** Guide to fire extinguisher selection.

**Jacks.** Many types of jack are used in heavy equipment service facilities. Before using a jack to raise a load, make sure that the weight rating of the jack exceeds the supposed weight of the load. Most jacks used in service-repair shops are hydraulic, and most use air-over-hydraulic actuation because this is faster and requires less effort. Bottle jacks are usually hand-actuated and designed to lift loads of up to 10 tons; they are so named because they have the appearance of a bottle. Air-over-hydraulic jacks capable of lifting up to 30 tons are also available.

Using hydraulic piston jacks should be straightforward: they are designed for a perpendicular lift only. The jack base should be on a level floor and the lift piston should be located on a flat surface on the equipment to be lifted. Never place the lift piston on the arc of a leaf spring or the radius of any suspension device on the mobile equipment. After lifting the equipment, it should be supported mechanically using steel stands. It is acceptable practice to use a hardwood spacer in conjunction with a shop jack: make sure it is exactly level. Whenever using a jack, ensure that the vehicle being jacked can roll either forward or backward: parking brakes should be applied and wheel chocks used on the axles not being raised.

Courtesy of the Protectoseal Company

**Figure 1-7** Store combustible materials in approved safety cabinets.

**Cherry Pickers.** **Cherry pickers** come in many shapes and sizes. Light-duty cherry pickers can be used to raise a heavy component, such as a cylinder head, from an engine whereas heavy-duty cherry pickers (see **Figure 1-8**) can lift a large-bore diesel engine out of a chassis. Most cherry pickers have extendable arms.

**CAUTION** *As the arm of a cherry picker is lengthened, the weight it can lift reduces significantly. Ensure that the weight you are about to lift can be sustained without toppling the cherry picker.*

**Scissor Jacks.** The popularity of **scissor jacks** has increased recently because of their versatility. Scissor jacks should only be used at one end of a vehicle: the end not being lifted has to be skidded as the lift angle increases, so it is important that the brakes not be applied during the lifting procedure. When the vehicle or equipment has been hoisted to the required height, engage the mechanical lock on the jack, and then chock the set of wheels at the end of the vehicle still on the floor. Never chock the wheels of a vehicle being lifted on a scissor jack until after the lift is completed.

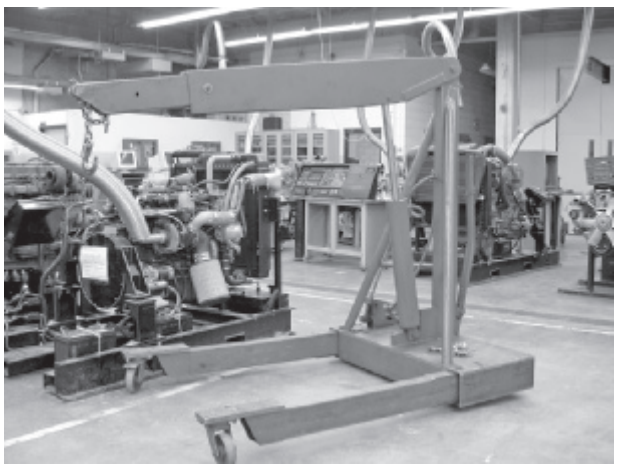
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**Figure 1-8** Typical heavy-duty cherry picker.

**Chain Hoists.** These are often called chain falls. **Chain hoists** can be suspended from a fixed rail or a beam that slides on rails or be mounted on any number of different types of A-frames. Chain hoists in shops in most jurisdictions are required to be inspected periodically. An inspection on a mechanical chain hoist will check for chain link integrity and the ratchet teeth and lock. Electromechanical units will require an inspection of the mechanical and electrical components. Where a chain hoist beam runs on rails, brake operation becomes critical. Some caution is required when braking on the beam because this can cause a pendulum effect on the object being lifted.

**Come-alongs.** **Come-alongs** describe a number of different types of cable and chain lifting devices that are hand-ratchet actuated. They are used both to lift objects and to apply linear force to them. When used as a lift device, come-alongs should be simple to use, providing the weight being lifted is within rated specification. However, come-alongs are more often used in service shops to apply linear force to an object or component. Great care should be taken, ensuring that the anchor and load are both secure and that the linear force does not exceed the weight rating of the device.

## GENERAL SHOP PRECAUTIONS

Because every service facility is different, the potential dangers faced in each shop will differ. In this section, we will outline some general rules and safety strategies to be observed in service and repair shops.

### Exhaust Extraction

Diesel engines should be run in a shop environment using an exhaust extraction system. In most cases this will be a flexible pipe or pipes that fit over the exhaust stack(s). Take care when climbing up to fit an exhaust extraction pipe over the vertical exhaust stack(s); use a ladder when you cannot get a secure foothold elsewhere. When parking mobile heavy equipment in and