ELECTRICAL MOTOR CONTROLS

Automated Industrial Systems

Third Edition

Gary Rockis
Glen Mazur

an atp publication

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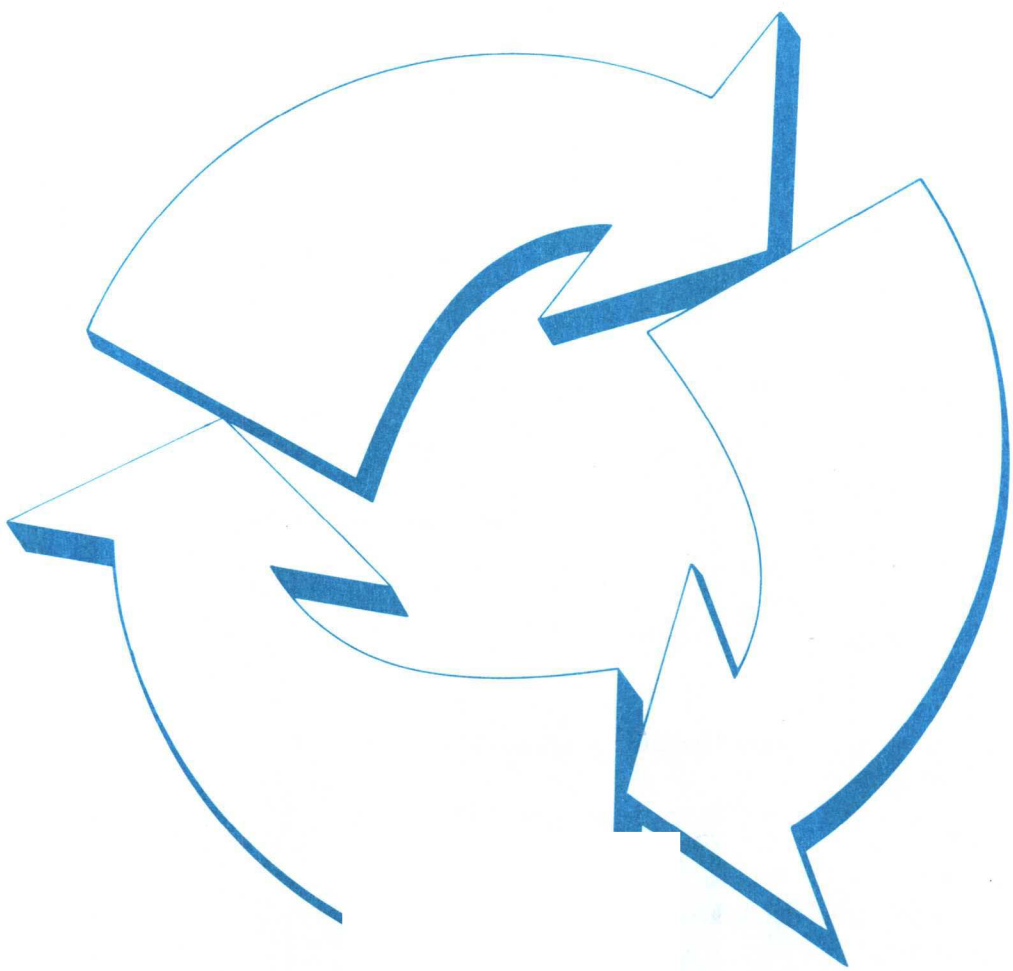

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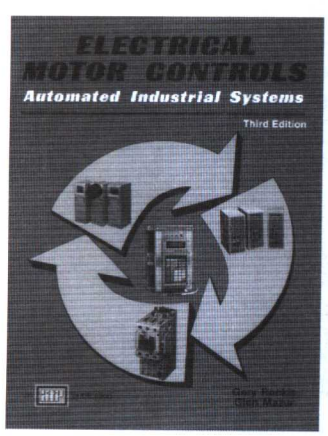
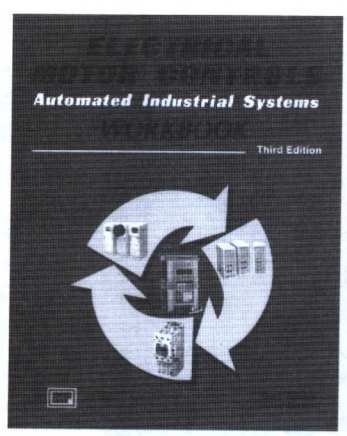
Introduction

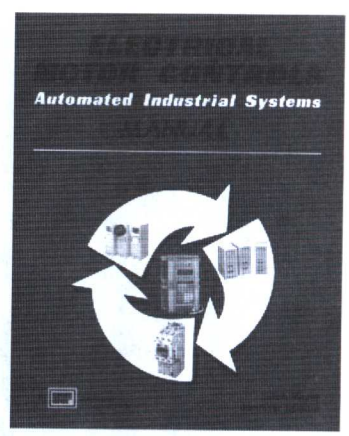
Electrical Motor Controls covers the control devices used in modern industrial electrical systems. The devices, applications, and systems are chosen to represent the broad range of uses for electricity found in different industries. The chapters are organized so the content is presented in a logical order. Each new concept builds on the information learned in the previous chapter. The book starts with basics such as tools, symbols, diagrams, and manual controls. The most common control devices and circuits from motor starters to programmable controllers are covered.

Electrical Motor Controls Workbook provides worksheets for each major concept presented in the textbook. The worksheets provide an opportunity for problem solving and circuit design. Typical applications and standard circuits provide the background required to work in the electrical field. For review, a tech-chek follows each chapter.

Electrical Motor Controls Manual provides applications and activities that show the installation and use of electrical control devices. Technical data is provided to show the proper use, sizing, and connection of control devices. Activities provide preparation for proper ordering, installation, maintenance, and troubleshooting of control devices and circuits. Manufacturing data is presented as it appears in service manuals used by industrial electricians.







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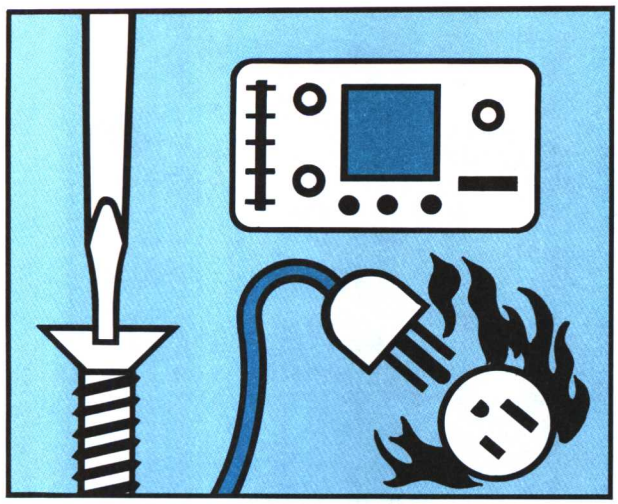


1 Electrical Tools, Instruments and Safety

Electrical tools and electrical instruments are a valuable investment and should be treated accordingly. The proper tools must be selected for each specific job. Tools must be organized and readily available for use. Before using a new tool or instrument the electrician should consult the operator's manual for correct operation.

Electrical power can be dangerous. The electrician must be aware of the dangers associated with electrical power and the potential hazards on the job. Safe work habits and proper procedures will minimize the possibility of an accident.

AN ORGANIZED TOOL SYSTEM

Since tools are expensive to replace, you need to protect your investment. Tools should be marked so that they can be easily identified as belonging to an individual or to a department in the company.

To be effective, tools must be available when needed; they must not be damaged by daily abuse. An organized tool system will provide both a central location and a means of protection for your tools.

Electrical tools can be organized in several ways, depending upon where and how frequently they are used. If the tools are used at a repair bench, a pegboard may be appropriate. If the tools are used only at the construction site, an electrician's leather pouch may be used. When the tools will be used at a bench and on the job, a portable tool box is usually best.

Pegboard. Pegboard is available in 4 feet × 8 feet sheets at most lumber yards. Usually a heavy duty tempered board is best for tools. Once the pegboard is mounted, outlines of the tools can be made to maintain an inventory. These outlines may be painted on the board or cut out of self-adhesive vinyl paper.

Electrician's Pouch. An electrician's pouch is usually made of heavy-duty leather (Figure 1-1). Pouches vary in design and size. Be sure to choose one that meets your specific needs and fits you comfortably. Some hold only a few tools, whereas others hold a wide selection. The type of pouch you need depends on the type of work you are planning to do. It is always wise to choose one that allows extra storage space for tools you may wish to add later.

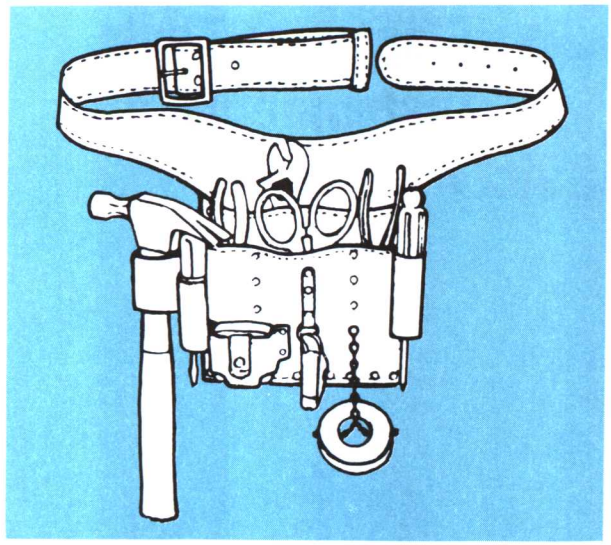


Figure 1-1 Multi-purpose electrician's pouch. (Action Leathercraft)

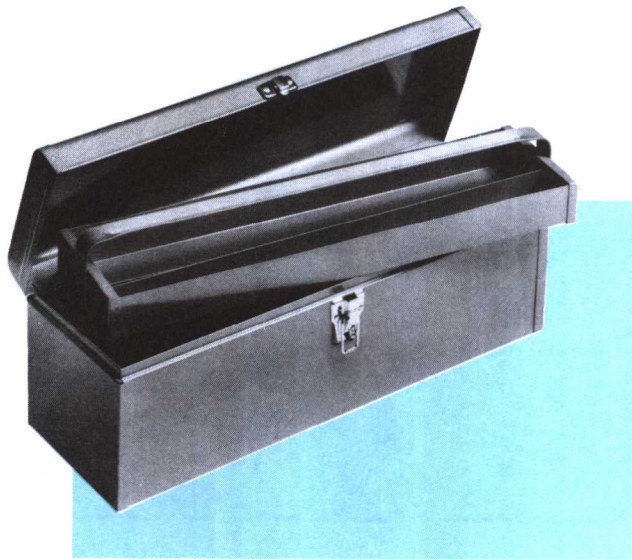


Figure 1-2 Portable tool box used by electrician. (Waterloo Industries, Inc., "Lumidor")

Portable Tool Box. Many electricians prefer to store their tools in a good portable box (Figure 1-2). A well-designed box can be locked and will keep your tools clean and dry. In addition, the tool box provides a fixed place where all the tools can be collected. To insure a complete inventory after each job, keep a list of all your tools in the box.

Whichever system you choose, organization is necessary. An organized tool system insures that you will always find clean, dry tools when and where you need them. (*Note:* Several manufacturers produce chemicals which can be placed in a tool box to keep the tools and box from rusting.)

TOOL SAFETY

Hand Tools. Use the right tools for the job. Tool safety requires tool knowledge. Use not only the proper tool but also the correct size. Use good quality tools and use them for the job they were designed to accomplish.

Learn how to use the tools properly. Study your tools—learn the safe way of working with each tool. Don't force a tool or use tools beyond their capacity. Don't be afraid to ask questions on the proper and safe use of a tool. It is often tempting to use a screwdriver for a chisel or a pair of pliers for a wrench. Remember, however, that the right tool will do the job faster and safer. The cost of the tool and the time it takes to buy it will prove far less costly than a serious accident.

Keep tools in good condition. Periodic checks on your tools will help to keep them in good condition. Always inspect a tool before using it. Do not use a tool which is in poor or faulty condition. Use only safe tools. Tool handles should be free of cracks and splinters and should be fastened securely to the working part. Damaged tools are not only dangerous but are also less productive than those in good working condition. When inspection shows a dangerous condition, repair or replace the tool immediately.

Cutting tools should be sharp and clean. Dull tools are dangerous. The extra force exerted in using dull tools often results in losing control of the tool. Dirt or oil on a tool may cause it to slip on the work and thus cause injury.

Keep tools in a safe place. Even good tools can be dangerous when left in the wrong place. Many accidents are caused by tools falling off ladders, shelves and scaffolds that are being moved.

Each tool should have a designated place in the tool box. Do not carry tools in your pockets unless the pocket is designed for that tool. Keep pencils in the pocket designed for them. Do *not* place pencils behind your ear or under your hat or cap.

Keep sharp-edged tools away from the edge of a bench or work area. Brushing against the tool may cause it to fall and injure a leg or foot. When carrying edged and sharply pointed tools, carry with the cutting edge or the point down and outward from your body. Be sure the place you choose to set down a tool is safe.

Power Tools. Do not attempt to use any power tools without knowing their principles of operation, methods of use, and safety precautions.

Obtain authorization from your job supervisor before you use power tools.

Grounding. All power tools should be grounded (unless they are approved double-insulated). Power tools must have a three-wire conductor cord. A three-prong plug connects into a grounded outlet (receptacle). See Figures 1-3 and 1-4 for approved receptacles and consult OSHA (Occupational Safety Health Act) and local codes for proper grounding specifications. It is very dangerous to use an adapter to plug a three-prong plug into a two-hole conductor outlet unless a separate ground wire or strap is connected to an approved type of ground. The ground insures that any short will trip the circuit breaker or blow the fuse. WARNING: An ungrounded power tool can kill you.

Double-insulated tools have two prongs and will have a notation on the specification plate that they are double-insulated. They are safe but are not often used on the job. Electrical parts in the motor of a double-insulated tool are surrounded by extra insulation to help prevent shock; therefore, the tool does not have to be grounded. Both the interior and exterior should be kept clean of grease and dirt that might conduct electricity.

Safety Rules. Study the following rules carefully and keep them in mind when you handle power tools.

1. You must be smarter than the tool you are operating.
2. Know and understand all of the manufacturer's safety recommendations.
3. Be sure that all safety guards are properly in place and in working order.
4. Wear safety goggles and a dust mask when the work requires it.
5. Be sure that the material to be worked is free of obstructions and securely clamped.
6. Before connecting a tool to a power source, be sure that the switch is in the OFF position.
7. Keep your attention focused on the work.
8. A change in sound during tool operation normally indicates trouble. Investigate immediately.
9. Power tools should be inspected and serviced by a qualified repair person at regular intervals as specified by the manufacturer or by OSHA.
10. Inspect electrical cords to see that they are in good condition.

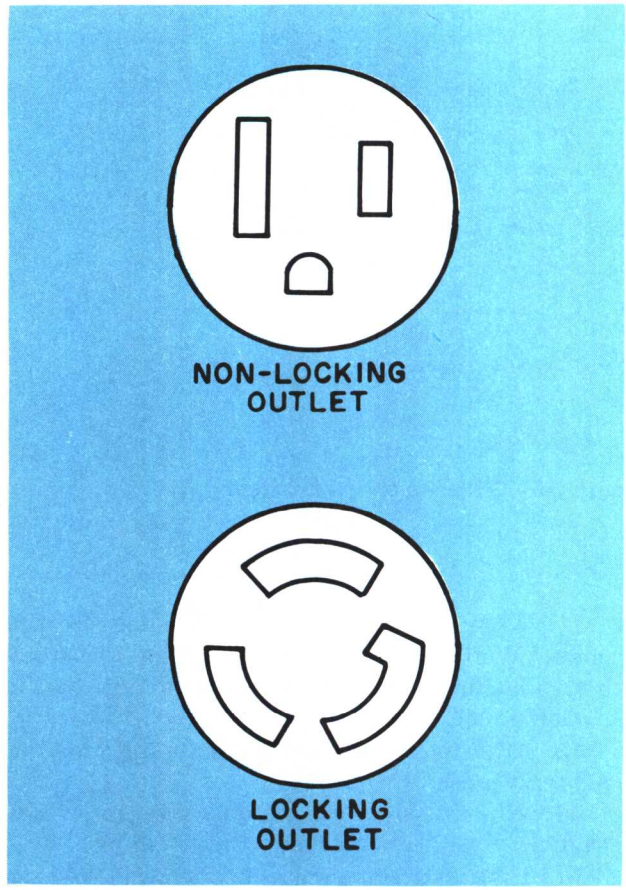


Figure 1-3 Approved electrical outlets (receptacles) commonly used for 110-volt tools and equipment. *Non-locking outlet* for indoor use only in remodeling work in existing structures. *Locking outlet* for exterior use and new construction.

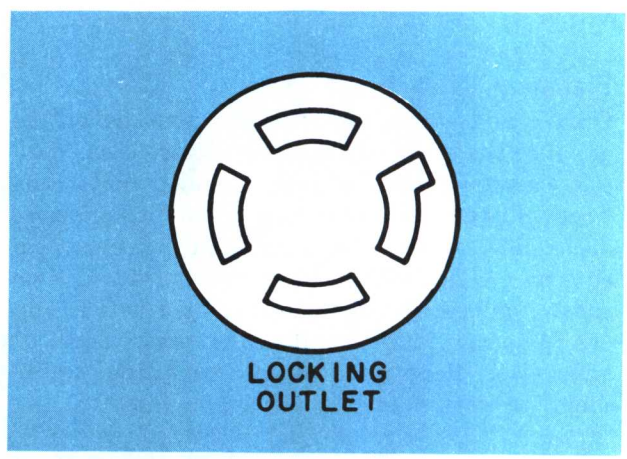


Figure 1-4 Approved electrical outlets (receptacles) commonly used for 220-volt tools and equipment. Locking outlets are required for exterior job use and for new construction.

OSHA SAFETY COLOR CODES.

Red	Fire protection equipment and apparatus Portable containers of flammable liquids Emergency stop buttons and switches
Yellow	Caution and for marking physical hazards Waste containers for explosive or combustible materials Caution against starting, using, or moving equipment under repair Identification of the starting point or power source of machinery
Orange	Dangerous parts of machines Safety starter buttons The exposed parts (edges) of pulleys, gears, rollers, cutting devices, power jaws
Purple	Radiation hazards
Green	Safety Location of first aid equipment (other than fire fighting equipment)

Figure 1-5 OSHA safety color codes.

11. When work is completed, shut off the power. Wait until all movement of the tool stops before leaving a stationary tool or laying down a portable tool.
12. After use, clean and lubricate tools for the next day's use.
13. When a power tool is defective, remove it from service. Alert others to the situation.
14. Take extra precautions when working on damp or wet surfaces. If necessary, use additional insulation to prevent any part of your body from coming into contact with the wet or damp surface.
15. Whenever working conditions are hazardous, at least two people should work together.

Electrical Safety

OSHA and state safety laws have helped to advance the cause of safety for electricians. With today's safeguards and recommended work practices, plus an understanding of the principles of electricity, people can work safely on electrical equipment. Remember, if you disregard your own safety, you are also disregarding the safety of others. When in doubt about a procedure, ask your supervisor. Report any unsafe condition, equipment, or work practices as soon as possible.

Fuses. Before removing any fuse from a circuit, be sure the switch for that circuit is open or disconnected. When removing fuses, use an approved type fuse puller and break contact on the hot side of the circuit first. When replacing fuses, install the fuse first into the load side of the fuse clip, then into the line side.

Electrical Shock. Electrical shock occurs when a person comes in contact with two conductors of a circuit or when his body becomes a part of the electrical circuit. In either case, a severe shock can cause the heart and lungs to stop functioning. Also, severe burns may occur where current enters and exits the body.

Prevention is the best medicine for electrical shock. Respect all voltages, have a knowledge of the principles of electricity and follow safe work procedures. Do not take chances. All electricians should be encouraged to take a basic course in Cardiac Pulmonary Resuscitation (CPR) so that they can come to the aid of a co-worker in emergency situations.

When using portable electric tools, always make sure they are in safe operating condition. Make sure there is a third wire on the plug for grounding in case of shorts. Theoretically, if electric power tools are grounded and if an insulation breakdown occurs, the fault current should flow through the third wire to ground instead of through the operator's body to ground.

Out of Service Protection. Before any repair is to be performed on a piece of electrical equipment, be absolutely certain the source of electricity is open and *carded* (out of service). Carding is the process of padlocking in the off position the power source and indicating on an appropriate card the procedure which is taking place.

Whenever you leave your job for any reason, or whenever the job cannot be completed the same day, be sure the source of electricity is still open or disconnected when you return to continue the work.

Safety Color Codes

Federal law (OSHA) has established specific colors to designate certain cautions and dangers. Figure 1-5 shows these accepted usages. Study these colors until you are familiar with all of them.

SAFE WORK CLOTHES ON THE JOB

1. Supervisory forces must see that employees do not wear clothing that will create a hazard on their jobs.

a. Oil-or grease-soaked clothing is prohibited as it may catch fire from a match, cigarette, sparks, or any open flame. Overalls or work clothing should be washed regularly.

b. Approved flame resistant clothing must be worn, as specified, on jobs involving exposure to molten metal hazards.

c. A state of partial undress (such as stripping to the waist) on the job is prohibited.

d. Ragged or flapping shoe soles, worn heels, that might become a slipping, tripping, or stumbling hazard, are prohibited. (Shoes should be kept in good repair.)

e. Sneakers, moccasins, canvas or loafer type street shoes are prohibited in the plant.

f. Safety (hard) hats must be worn in areas or departments specified. Conventional head cover must be worn in other areas within the plant where required by District or Division safety policy.

2. Employees working with or around moving machinery or high places are prohibited from wearing:

a. Loose hanging neckties,

b. Long flowing coats, open sweaters,

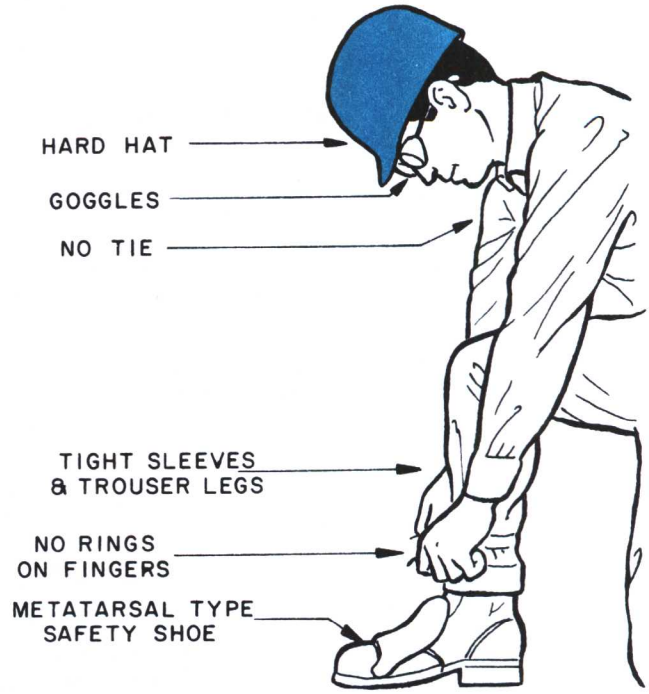
c. Dusters or aprons,

d. Long belt ends projecting from buckles,

e. Rings, watch chains, fobs, key chains,

f. Baggy, loose or unbuttoned sleeves, loose trouser bottoms, or torn clothing,

g. Gloves, except where authorized by District or Division Safety Committee.



Clothing should be kept tight as is comfortable and should fit snugly to avoid danger of becoming entangled in moving machinery, or creating a tripping or stumbling hazard.

3. Finger rings shall not be worn by:
ANY employee . . . other than regular office workers whose duties do not require them to operate machines such as multilith, mimeograph machines, etc.

4. Safety shoes are recommended for all supervision and employees. Safety shoes incorporating metatarsal guards afford additional protection to the feet and are particularly recommended.

Clothing and Personal Protective Equipment (Figure 1-6)

1. Wear thick-soled work shoes for protection against sharp objects such as nails. Wear work shoes with safety toes if the job requires. If your shoes are subject to oils and grease, make sure the soles are oil resistant.
2. Wear rubber boots in damp locations.
3. Wear a hat or cap. Wear an approved safety helmet (hard hat) if the job requires. Confine long hair or keep your hair trimmed and avoid placing your head too near rotating machinery.
4. Leave your jewelry in your locker; gold and silver are excellent conductors of electricity.

Figure 1-6 Recommendations for safe working clothes. (Illinois Department of Labor, Division of Safety Inspection and Education)

Fire Safety

The chance of fire is greatly decreased by good housekeeping. Keep rags containing oil, gasoline, alcohol, shellac, paint, varnish, or lacquer in a covered metal container. Keep debris in a designated area away from the building. If a fire occurs, first give an alarm. Alert all workers on the job, and call the fire department. Then make a reasonable effort to contain the fire.

TYPES AVAILABLE BY CLASSIFICATION

CLASS A FIRES . . . ordinary combustible materials, such as wood, cloth, paper, rubber, and many plastics.

CLASS B FIRES✱ . . . flammable liquids/gases, and greases.

CLASS C FIRES . . . energized electrical equipment where the electrical nonconductivity of the extinguishing media is of importance.

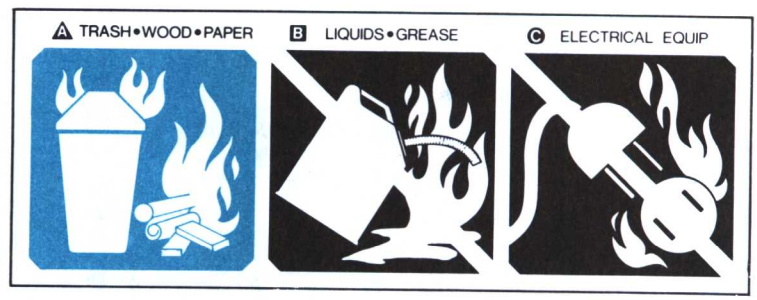
CLASS D FIRES . . . combustible metals, such as magnesium, titanium, zirconium, sodium and potassium.

✱ NOTE: O-n-l-y Dry Chemical types effective on ***pressurized*** flammable gases/liquids; for deep fat fryers, Multipurposes A/B/C dry chemicals NOT acceptablie.

▲ NOTE: Protection required below 40° F.

A					
WATER TYPES		**MULTIPURPOSE DRY CHEMICAL**		**AFFF FOAM**	**HALON 1211**
STORED PRESSURE	**PUMP TANK**	**STORED PRESSURE**	**CARTRIDGE OPERATED**	**STORED PRESSURE**	**STORED PRESSURE**
 ▲	 ▲			 ▲	
SIZES AVAILABLE	2½ Gal.	2½ and 5-Gal.	2½-30 lb. ***ALSO*** Wheeled 150-350 lb.	5-30 lb. ***ALSO*** Wheeled 50-350 lb.	2½ Gal. ***ALSO*** Wheeled 33 Gal.	9 to 22 lb.
HORIZONTAL RANGE (APPROX.)	30 to 40 ft.	30 to 40 ft.	10-15 ft., (Wheeled-15-45 ft.)	10-20 ft., (Wheeled-15-45 ft.)	20-25 ft., (Wheeled-30 ft.)	14 to 16 ft.
DISCHARGE TIME (APPROX.)	1 Min.	1 to 3 Min.	8-25 Sec., (Wheeled-30-60 Sec.)	8-25 Sec., (Wheeled-20-60 Sec.)	50 sec., (Wheeled-60 sec.)	10 to 18 Sec.

USE ON "A" TYPES



USE ON "A/B" TYPES

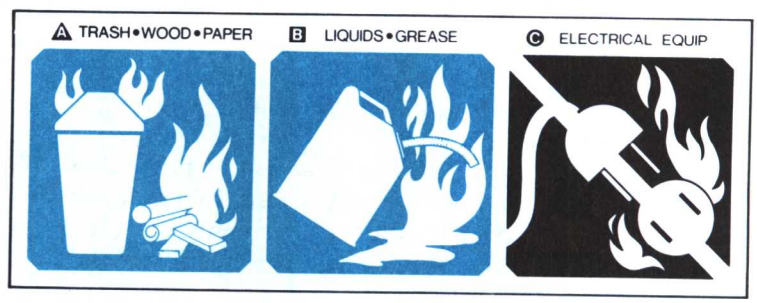
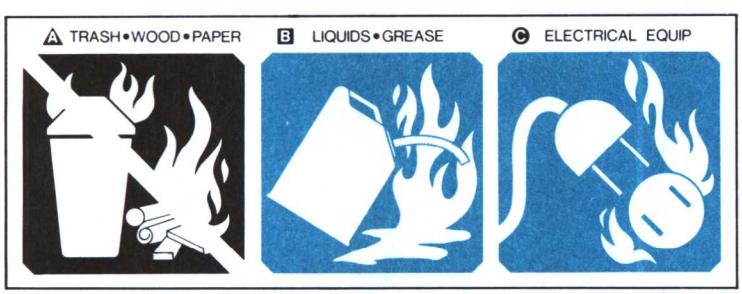


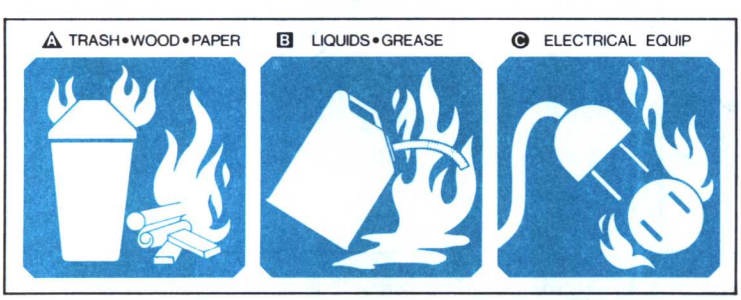
Figure 1-7 Common fire extinguishers and their applications. (National Association of Fire Equipment Distributors)

Fire Extinguishers. Always read instructions before using a fire extinguisher. Figure 1-7 illustrates some of the common fire extinguishers and their uses. Careful study of this chart will familiarize you with the types of fires normally encoun-

A/B	B/C				A/B/C			D
AFFF FOAM	CARBON DIOXIDE	DRY CHEMICAL TYPES		HALON 1211	MULTIPURPOSE DRY CHEMICAL		HALON 1211	DRY POWDER
STORED PRESSURE	SELF EXPELLING	STORED PRESSURE	CARTRIDGE OPERATED	STORED PRESSURE	STORED PRESSURE	CARTRIDGE OPERATED	STORED PRESSURE	CARTRIDGE OPERATED
								
2½ Gal. *ALSO* Wheeled 33 Gal.	5-20 lb. *ALSO* Wheeled 50-100 lb.	2½-30 lb. *ALSO* Wheeled 150-350 lb.	4-30 lb. *ALSO* Wheeled 50-350 lb.	2 to 22 lb.	2½-30 lb. *ALSO* Wheeled 150-350 lb.	5-30 lb. *ALSO* Wheeled 50-350 lb.	9 to 22 lb.	30 lb. *ALSO* Wheeled 150-350 lb.
20-25 ft., (Wheeled-30 ft.)	3-8 ft., (Wheeled-10 ft.)	10-15 ft., (Wheeled-15-45 ft.)	10-20 ft., (Wheeled-15-45 ft.)	10 to 16 ft.	10-15 ft., (Wheeled-15-45 ft.)	10-20 ft., (Wheeled-15-45 ft.)	14 to 16 ft.	5 ft., (Wheeled-15 ft.)
50 sec., (Wheeled-60 sec.)	8-15 Sec., (Wheeled-8-30 Sec.)	8-25 Sec., (Wheeled-30-60 Sec.)	8-25 Sec., (Wheeled-20-60 Sec.)	8 to 18 Sec.	8-25 Sec., (Wheeled-30-60 Sec.)	8-25 Sec., (Wheeled-20-60 Sec.)	10 to 18 Sec.	20 Sec., (Wheeled-150 lb. 70 Sec., 350 lb. 1¾ Min.)



USE ON "B/C" TYPES



USE ON "A/B/C" TYPES

tered and the best type of extinguisher used to combat that type of fire.

Fire extinguishers are normally red. If they are not red, they should have a red background so they can be easily located.

If firemen are called, be ready to direct them to the fire. Also inform them of any special problems or conditions that exist, such as downed electrical wires or leaks in gas lines.

A final thought: report to your supervisor any