1 a Discuss the causes for fire. List types of fires and effects of fire.

Fire hazards are conditions that favour fire development or growth. Three elements are required to start and sustain fire:

(1) oxygen

(2) fuel and

(3) heat

Since oxygen is naturally present in most earth environments, fire hazards usually involve the mishandling of fuel or heat.

Fire, or combustion, is a chemical reaction between oxygen and a combustible fuel. Combustion is the process by which fire converts fuel and oxygen into energy, usually in the form of heat. By-products of combution include light and smoke.

Causes for fire

1> Deliberate

2> Carelessness (including smoking)

3> Burning rubbish / waste

4) poor housekeeping

5> Electrical faults

6) Mise-use of electrical installations.

Types of fire

Fire are classified according to their properties, which relate to the nature of the fuel.

Class A fires : solid materials such as wood, plastic, textiles, and their products : paper, housing, clothing.. This type of fire generally leaves Ash.

Class B fires : Flammable liquids and gases. ~~such as~~ Liquids like petrol, Diesel, Kerosene, Oil, Grease, Acetone. This type of fire involves materials that Boil or Bubble.

Class C fires : Electrical (referring to live electricity situat not including fires in other materials started by electric

Class D fires : combustible, easily oxidized metals such as aluminium, magnesium, titanium, and zirconium.

Special categories : Extremely active oxidizers or mixtures flammables containing oxygen, nitric acid, hydrogen pero. solid missile propellants. HNO_3, O_2, H_2O_2, Propellants

Effects of fire

→ Fire may damage life and property

→ The major outcomes of fire are heat and smoke.

→ Smoke causes suffocation

→ Heat Generates due to Burning of combustible mater

→ The Intensity of heat depends upon fire-load, calori value and rate of Burning

→ Production of toxic gases.

Most people die in fires from suffocating or breathing smoke and toxic fumes.

Table shows major chemical products of Combustion & their effects.

Product	Pathology (Effects)
Acrolein	Highly toxic, irritant to eyes and respiratory system.
Ammonia (NH_3)	Somewhat toxic, irritant to eyes and respiratory system.
carbon-dioxide	Not toxic, but depletes available oxygen.
carbon monoxide	can be deadly.
Hydrogen chloride (HCN)	Quickly lethal asphyxiant.
Hydrogen sulfide (H_2S)	Highly toxic gas. strong odor of rotten eggs, but quickly destroys sense of smell.
Nitrogen dioxide (NO_2)	Lung irritant, causing death or damage.
Sulfur dioxide (SO_2)	Toxic irritant

1 (b) List the do's and don'ts at the time of fire.

Do's in case of High-Rise Buildings

1) Good housekeeping must be ensured.

2) Switch off the electrical mains before fighting the fire.

3) use stair case only for evacuation.

4) Keep means of escape clear of obstructions.

5) Impart fire fighting training to occupants.

6) Conduct fire / evacuation drills regularly.

7) Keep smoke/ fire check doors close.

8) Emergency organisation must be set up.

Dont's in case of high-rise Buildings

1) Do not use lifts in times of fire.

2) Do not dispose off lighted cigarette buds carelessly.

3) Do not paint fire detector/ sprinkler heads.

4) Do not plug too many electrical appliances in one socket.

5) Do not make unauthorised electrical connections.

6) Do not store inflammable materials inside the building.

7) Do not refill the oil stoves when Burning.

8) Do not obstruct fire exist staircases with old / unused furniture.

9) Do not return to collect valuables in case of outbreak of fire.

Do's in case of Industrial Buildings

1) Make all employees 'Fire concious' and observe one day as fire safety day every year.

2) provide all fire safety measures and personal clothing/ gadgets.

3) Ensure Regular house keeping.

4) Unauthorised entries must be checked

5) Be sure all employees are familiar with the emergency alarm sounds / modes and escape routes.

6) Ensure no smoking in the workplace.

7) Store flammable liquids, Gases, Solvents properly and correctly labeled.

8) use fuses and Circuit breakers of correct capacity.

9) carry out fire drills regularly.

Don'ts in case of Industrial buildings

1) Do not smoke in Prohibited areas.

2) Do not Tamper with fire fighting and fire detection equipment.

3) Do not key exits chained or locked.

4) Do not block access to fire fighting equipment.

5) Do not keep fire extinguisher unrefilled / uncharged

<u>DO's in case of fire emergency.</u>

1) Evacuate without panic.

2) Follow the instructions conveyed through public address system.

3) Put emergency escape masks & exit from nearest exit in orderly form.

4) Assemble at the designated point outside building

<u>Don'ts in case of fire emergency</u>

1) Do not dishonour the instructions.

2) Do not panic and create chaos during evacuation

3) Do not overcrowd during evacuation.

4) Do not take refuge in toilets / pantry.

2 (a) What are fire extinguishers? Name different types of fire extinguishers and their use during fire.

A fire extinguisher is an active fire protection device used to extinguish or control a fire, often in emergency situations. Typically a fire extinguisher consists of a handled cylindrical pressure vessel containing an agent which can be discharged to extinguish a fire.

Types of extinguishing agents

Dry chemical

1) Ammonium phosphate

Used on class A, B and C fires. It receives its class A rating from the agent's ability to melt and flow at 350° to smother the fire. More corrosive then other dry chemical agents.

2) Sodium bicarbonate

Used on class B and C fires, Interrupts the fire's chemical reaction.

3) Potassium bicarbonate

Used on class B and C fires. About two times as effective on class B fires as sodium bicarbonate

Foams

1) Aqueous Film Forming Foam (AFFF)

Used on A and B fires and for vapor supression

2) Alcohol Resistant Aqueous Film Forming Foam (AR-AFFF)

Used on fuel fires containing alcohol. Forms a membrane between the fuel and the foam preventing the alcohol from breaking down the foam blanket.

3) Film Forming Fluoroprotein (FFFP)

Contains naturally occurring proteins to create a foam blanket that is more heat resistant than the synthetic AFFF foams.

4) Compressed Air Foam System (CAFS)

Any APW style extinguisher that is charged with a foam solution and pressurized with compressed air. Generally used to extend a water supply in wildland operations. Used on class A fires and with very dry foam on class B for vapor suppression.

5) Arctic Fire

Is a liquid fire extinguishing agent that emulsifies and cools heated materials quicker than water or ordinary foam. It is used extensively in the steel industry. Effective on classes A, B and D.

6) Fire Ade

A foaming agent that emulsifies burning liquids and renders them non-flammable. It is able to cool heated materi[als] and surfaces similar to CAFS. Used on A and B (Said to be effective on some Class D hazards).

7) Wet Chemical (Potassium acetate)

Extinguishes the fire by forming a crust over the burning oil. Generally class A and K only.

Water

1) Air pressurized water (APW) cools burning material by absorbing heat from burning material.

2) Water mist uses a misting nozzle to break up a stream of distilled water to the point of not conducting electricity back to the operator: class A and C rated.

Clean agents

1) Halon, a gaseous agent that smothers the fire. Classes A, B and C. (Banned from new production; replaced by Halotron).

2) CO_2, a gaseous agent that smothers the fire. Classes B and C.

Class D Fire extinguisher.

1) Sodium chloride and copper forms a crust over the burning metal and performs like a heat sink to draw heat away from the burning material, also smothers to a degree.

2(b) Write a brief note on product safety.

The role of safety instructions and warnings is to tell users about hazards that cannot be removed by design or controlled by guards and safety devices. A secondary role is to disclose a product's intended use, if this is not self-evident, as well as to recount the product's safety features and guards with the hope that understanding these features will encourage users not to remove, bypass or alter them.

3 (a) Briefly discuss the precautions to be taken at the time of fire at homes

The best way to reduce fires is to prevent their occurrence. One means of reducing a fire hazard is the isolation of the three triangle elements : fuel, oxygen and heat.

1) use a fireplace screen to prevent sparks from flying.

2) Do not store any flammable materials near the fire place.

3) Check your chimney ~~spark~~ before it is put to use.

4) Install a chimney spark arrestor to prevent roof fires.

5) when lighting a gas fireplace, strike your match first, then turn on the gas.

6) Smoke is the leading cause of home fire, It is responsible for 3 out of 4 deaths hence it is necessary to install smoke detectors on every level of house and outside of sleeping areas.

7) Test every detector atleast once a month.

8) keep smoke detectors dust free.

9) Wise to have a fire extinguisher near the kitchen.

10) Do not overload kitchen electrical outlets.

11) Clean the exhaust wood and duct over the stove regularly.

12) operate microwave only when there is food in it.

3 (b) Discuss briefly the causes and prevention of industrial fires.

Almost everything in an industrial environment will burn. metal furniture, machines, plaster, and concr block walls are usually painted. most paints and lacquers will easily catch fire.

<u>Causes of Industrial fires</u>

Although many industries have specific problems of fire prevention and control because of the type of work Performed or the materials used, the most frequent causes of industrial fires are common to all industries. most of these causes can be controlled or eliminated. The success or failure of any plant safety and fire prevention progra depends on the first-line supervisors.

Below is a list of somethings that can be done to help prevent a serious fire, which could destroy an entire Plant; the percentage identify the extent to which a specific cause has contributed to industrial fires

<u>Electrical causes - 22%</u>.. Guard against electrical defe mainly the kind that develop from lax maintenance in wiring, motors, switches, lamps & heating elements.

<u>Matches and Smoking -18%</u>. Don't relax the rules in "no smoking" areas just because a fire hasn't happen yet. Be especially careful where flammable liquids

are present, near stored combustibles, or in working areas where combustibles are used. If an area is restricted for smoking, then there can be no exceptions.

Friction -11% : Watch for hot bearings, misaligned or broken machine parts, choking or jamming material, poor adjustmen of moving parts.

Hot Surfaces -9%. Guard against exposure of combustibles to furnaces, hot ducts or flues, electric clamps or heating elements, and hot metal inprocess.

Overheated Materials - 7%. Watch out for abnormal process temperatures, overheating of materials in driers, and overheating of flammable liquids.

open flames - 6%. Gasoline or other torches, trouble with gas or oil burners.

Foreign Substances-5%. Foreign materials in stock, Tramp metal produces sparks when struck by rapidly revolving tools. Oils pans used near cutting machines are a constant hazard.

Spontaneous Heating -4%. Deposits in ducts and flues, low grade storage, Scrap waste, oily waste, and rubbish.

cutting and Welding - 4%. Dangerous operations in areas where sparks can ignite combustibles.

Combustion sparks -4%. Burning of rubbish, Foundary cupolas, furnaces & fireboxes.

Miscellaneous -10%. This includes incendiary cases (3%); fires spreading from adjoining buildings (2½%); molten metal or glass (2%); static electricity near flammable liquids as at spreading or coating rolls or where liquid flows from pipes (1½%); chemical action (½%); and lightning (½%).

The following factors should be considered in implementing a fire prevention program.

Gas : Gases of all types represent a hazard. All equipment (piping, regulators and ignitors) should receive periodic and careful inspection by a qualified person. Employees must receive thorough instruction before using these types of equipment. Matches should not be used for lighting gas-fired equipment.

Housekeeping : Rubbish, waste, and other debris must be cleaned up and removed daily and disposed of in suitable containers outside of the plant.

Electrical equipment : Inspection and maintenance of motors and other electrical devices should be done by a qualified person. All electrical equipment should be included in a periodic inspection.

Matches & smoking : Smoking and the use of matches should be permitted in designated areas only. Dust, lint, and oil collecting in ducts and flues can also ignite spontaneously

Safety containers should be provided for rags and waste. and they should be emptied daily. Employees must be instructed carefully and supervised closely to prevent fires of these types.

Open Flames. Open flames are involved in welding, forging, forming, and other heating operations. Fireproof materials around the work area and suitable clothing will aid in the prevention of most fires. However the use of portable equipment involves high fire danger and all precautions should be taken, including having an extinguisher of the proper type immediately available.

Heated Surfaces: Heated surfaces on furnaces, flues, heating devices, and light bulbs can be the cause of fires. Care should be taken to ensure that all devices are properly installed, especially with respect to clearance & barrier materials.

Molten metals: precautions should be taken to provide a flameproof envirionment in foundary areas and also to Provide flameproof clothing.

Volatile liquids: paints, varnishes, lacquers, petroleum Products, solvents, and similar volatile materials are frequent sources of fire & explosion.

Tight metal containers, flameproof cabinets, color coding, and strict storage and handling procedures ar necessary.

What is Fire?

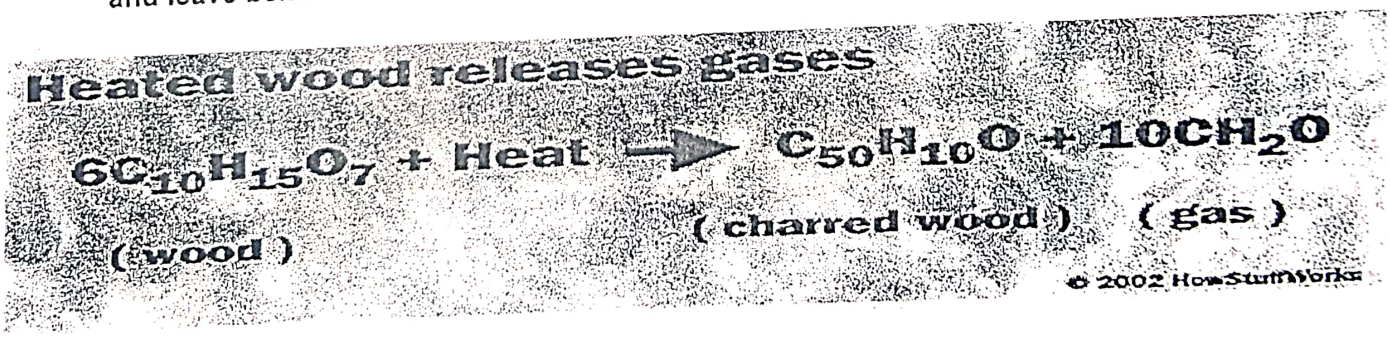
The ancient Greeks considered fire one of the major elements in the universe, alongside water, earth and air. This grouping makes intuitive sense: You can feel fire, just like you can feel earth, water and air. You can also see it and smell it, and you can move it from place to place.

But fire is really something completely different. Earth, water and air are all forms of matter -- they are made up of millions and millions of atoms collected together. Fire isn't matter at all. It's a visible, tangible side effect of matter changing form -- it's one part of a chemical reaction.

Typically, fire comes from a chemical reaction between oxygen in the atmosphere and some sort of fuel (wood or gasoline, for example). Of course, wood and gasoline don't spontaneously catch on fire just because they're surrounded by oxygen. For the combustion reaction to happen, you have to heat the fuel to its ignition temperature.

Here's the sequence of events in a typical wood fire:

- Something heats the wood to a very high temperature. The heat can come from lots of different things -- a match, focused light, friction, lightning, something else that is already burning...
- When the wood reaches about 300 degrees Fahrenheit (150 degrees Celsius), the heat decomposes some of the cellulose material that makes up the wood.
- Some of the decomposed material is released as volatile gases. We know these gases as smoke. Smoke is compounds of hydrogen, carbon and oxygen. The rest of the material forms char, which is nearly pure carbon, and ash, which is all of the unburnable minerals in the wood (calcium, potassium, and so on). The char is what you buy when you buy charcoal. Charcoal is wood that has been heated to remove nearly all of the volatile gases and leave behind the carbon. That is why a charcoal fire burns with no smoke.

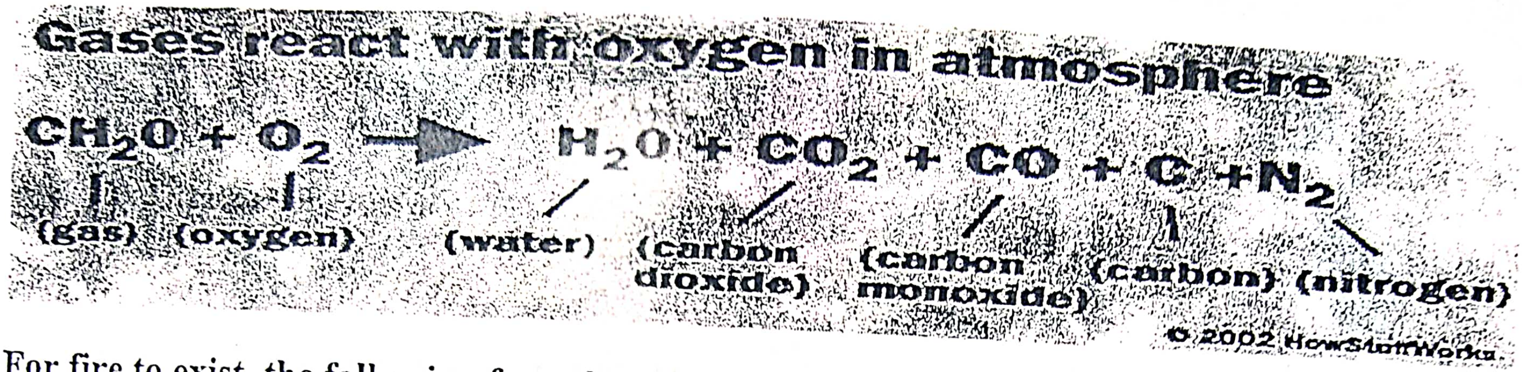


- The actual burning of wood then happens in two separate reactions:
  - When the volatile gases are hot enough (about 500 degrees F (260 degrees C) for wood), the compound molecules break apart, and the atoms recombine with the oxygen to form water, carbon dioxide and other products. In other words, they burn.
  - The carbon in the char combines with oxygen as well, and this is a much slower reaction. That is why charcoal in a BBQ can stay hot for a long time.

A side effect of these chemical reactions is a lot of heat. The fact that the chemical reactions in a fire generate a lot of new heat is what sustains the fire.

Many fuels burn in one step. Gasoline is a good example. Heat vaporizes gasoline and it all burns as a volatile gas. There is no char.

Humans have also learned how to meter out the fuel and control a fire. A <u>candle</u> is a tool for slowly vaporizing and burning wax.



For fire to exist, the following four elements must be present at the same time:

- Enough oxygen to sustain combustion,
- Enough heat to raise the material to its ignition temperature,
- Some sort of fuel or combustible material, and
- The chemical reaction that is fire.

FIRE PREVENTION AND PROTECTION

TYPES OF FIRE

CLASSIFIED ACCORDING TO THE TYPE OF FUEL USED

1) CLASS A
   - SOLID COMBUSTIBLE MATERIALS THAT ARE NOT METALS
   - THIS TYPE OF FIRE GENERALLY LEAVES ASH

   (FUEL – WOOD, PAPER, CLOTH, TRASH, PLASTIC)

2) CLASS B
   - ANY NON-METAL IN A LIQUID STATE ON FIRE
   - THIS TYPE OF FIRE INVOLVES MATERIALS THAT BOIL OR BUBBLE

   (FLAMMABLE LIQUIDS LIKE PETROL, DIESEL, KEROSENE, OIL, GREASE, ACETONE)

3) CLASS C
   - THIS TYPE OF FIRE GENERALLY DEALS WITH ELECTRICAL CURRENT

   (ENERGISED ELECTRICAL EQUIPMENT)

4) CLASS D
   - METALS SUCH AS SODIUM, ALUMINIUM, POTASSIUM, MAGNESIUM, ZIRCONIUM, ETC.

Basic Envl Technology
Water supply, W/ management,
& Poll^n ctrl.
Jerry A. Nathanson
- Third Edition)

EFFECTS OF FIRE

- FIRE MAY DAMAGE LIFE AND PROPERTY
- THE MAJOR OUTCOMES OF FIRE ARE HEAT AND SMOKE
- SMOKE CAUSES SUFFOCATION
- HEAT GENERATES DUE TO BURNING OF COMBUSTIBLE MATERIAL
- THE INTENSITY OF HEAT DEPENDS UPON FIRE-LOAD, CALORIFIC VALUE AND RATE OF BURNING
- PRODUCTION OF TOXIC GASES

TYPES OF FIRE EXTINGUISHERS

THREE MOST COMMON TYPES ARE

1) WATER (AIR PRESSURISED WATER)
   THIS IS DESIGNED FOR CLASS A FIRES ONLY

2) CARBON-DI-OXIDE (CO_2)
   THIS IS USED FOR CLASS B AND CLASS C FIRES ONLY

3) DRY CHEMICAL (ABC, BC, DC)
   ABC – DESIGN TO EXTINGUISH CLASS A, B AND C FIRES
   BC – DESIGN TO EXTINGUISH CLASS B AND C FIRES
   DC – DRY CHEM

fire
ISO
STP/SWM
[illegible]
Right to know law
CTA

FIRE PREVENTION

- ➔ USE OF FIRE RESISTENT DOORS
- ➔ USE OF FIRE RETARDENT PAINTS
- ➔ USE OF FIRE RESISTENT MATERIALS
- ➔ USE OF GEORGIAN WIRED GLASS
- ➔ INSULATION OF SURFACE WITH FIRE PROOF MATERIALS

GENERAL TIPS DURING FIRE

- ✓ RAISE ALARM AND INFORM THE FIRE BRIGADE IMMEDIATELY
- ✓ ATTACK THE FIRE WITH AVAILABLE EQUIPMENT IF YOU CAN WITHOUT TAKING UNDUE RISK
- ✓ LEAVE THE PREMISES BY NEAREST EXIT
- ✓ DO NOT USE LIFT TO ESCAPE FROM THE FIRE
- ✓ DO NOT SHOUT OR RUN, THIS CAUSES PANIC
- ✓ GIVE WAY TO FIRE ENGINES
- ✓ GUIDE FIREMEN TO WATER RESOURCES
- ✓ NON-INFORMING TO FIRE SERVICE ABOUT THE FIRE INCIDENT IS A COGNISABLE AFFENCE
- ✓ DO NOT MISUSE FIRE SERVICE BY FALSE CALLS

FIRE IN HIGH-RISE BUILDINGS

DO's

- ✓ GOOD HOUSEKEEPING MUST BE ENSURED
- ✓ SWITCH OFF THE ELECTRICAL MAINS BEFORE FIGHTING THE FIRE
- ✓ USE STAIR CASE ONLY FOR EVACUATION
- ✓ KEEP MEANS OF ESCAPE CLEAR OF OBSTRUCTIONS
- ✓ IMPART FIRE FIGHTING TRAINING TO OCCUPANTS
- ✓ CONDUCT FIRE / EVACUATION DRILLS REGULARLY
- ✓ KEEP SMOKE / FIRE CHECK DOORS CLOSE
- ✓ EMERGENCY ORGANISATION MUST BE SET UP

FIRE IN HIGH-RISE BUILDINGS

DON'Ts

- ☞ DO NOT USE LIFTS IN TIMES OF FIRE
- ☞ DO NOT DISPOSE OFF LIGHTED CIGARETTE BUDS CARELESSLY
- ☞ DO NOT PAINT FIRE DETECTOR / SPRINKLER HEADS
- ☞ DO NOT PLUG TOO MANY ELECTRICAL APPLIANCES IN ONE SOCKET
- ☞ DO NOT MAKE UNAUTHORISED ELECTRICAL CONNECTIONS
- ☞ DO NOT STORE INFLAMMABLE MATERIALS INSIDE THE BUILDING
- ☞ DO NOT REFILL THE OIL STOVES WHEN BURNING
- ☞ DO NOT OBSTRUCT FIRE EXIT STAIRCASES WITH OLD / UNUSED FURNITURE
- ☞ DO NOT RETURN TO COLLECT VALUABLES IN CASE OF OUTBREAK OF FIRE

FIRE IN INDUSTRIAL BUILDINGS

DO's

- MAKE ALL EMPLOYEES 'FIRE CONCIOUS' AND OBSERVE ONE DAY AS FIRE SAFETY DAY EVERY YEAR
- PROVIDE ALL FIRE SAFETY MEASURES AND PERSONAL CLOTHING / GADGETS
- ENSURE REGULAR HOUSE KEEPING
- UNAUTHORISED ENTRIES MUST BE CHECKED
- BE SURE ALL EMPLOYEES ARE FAMILIAR WITH THE EMERGENCY ALARM SOUNDS / MODES AND ESCAPE ROUTES
- ENSURE NO SMOKING IN THE WORKPLACE
- STORE FLAMMABLE LIQUIDS, GASES, SOLVENTS PROPERLY AND CORRECTLY LABELED
- USE FUSES AND CIRCUIT BREAKERS OF CORRECT CAPACITY
- CARRYOUT FIRE DRILLS REGULARLY

FIRE IN INDUSTRIAL BUILDINGS

DON'Ts

⇒ DO NOT SMOKE IN PROHIBITED AREAS

⇒ DO NOT TAMPER WITH FIRE FIGHTING AND FIRE DETECTION EQUIPMENT

⇒ DO NOT KEEY EXITS CHAINED OR LOCKED

⇒ DO NOT BLOCK ACCESS TO FIRE FIGHTING EQUIPMENT

⇒ DO NOT KEEP FIRE EXTINGUISHER UNREFILLED / UNCHARGED

IN CASE OF FIRE EMERGENCY

DO's

- ⇨ EVACUATE WITHOUT PANIC
- ⇨ FOLLOW THE INSTRUCTIONS CONVEYED THROUGH PUBLIC ADDRESS SYSTEM
- ⇨ PUT EMERGENCY ESCAPE MASKS AND EXIT FROM NEAREST EXIT IN ORDERLY FORM
- ⇨ ASSEMBLE AT THE DESIGNATED POINT OUTSIDE BUILDING

DON'Ts

- DO NOT DISHONOUR THE INSTRUCTIONS
- DO NOT PANIC AND CREATE CHAOS DURING EVACUATION
- DO NOT OVERCROWD DURING EVACUATION
- DO NOT TAKE REFUGE IN TOILETS / PANTRY

FIRE PREVENTION IN THE HOME

CAUSES OF FIRE AT HOME

- SMOKING IS THE LEADING CAUSE OF HOME FIRE
- HEATING EQUIPMENT IS THE SECOND MAJOR CAUSE OF HOME FIRE

FIRE PREVENTION

SMOKE DETECTORS

SMOKE IS RESPONSIBLE FOR 3 OUT OF 4 DEATHS

1) INSTALL SMOKE DETECTORS ON EVERY LEVEL OF HOUSE AND OUTSIDE OF SLEEPING AREAS
2) TEST EVERY DETECTOR ATLEAST ONCE A MONTH
3) KEEP SMOKE DETECTORS DUST FREE
4) INEXPENSIVE SMOKE DETECTORS ARE AVAILABLE FOR THE HEARING IMPAIRED

FIRE EXTINGUISHERS

- THEY REMAIN YOUR BEST BET, IF YOU ARE ON THE SPOT WHEN A FIRE BEGINS

- FIRE EXTINGUISHERS SHOULD BE MOUNTED IN THE KITCHEN, GARAGE AND WORKSHOP

- PURCHASE AN 'ABC' TYPE EXTINGUISHER FOR ALL TYPES OF FIRE

- LEARN WELL HOW TO USE YOUR FIRE EXTINGUISHER

- REMEMBER, USE AN EXTINGUISHER ON SMALL FIRES ONLY. IF THERE IS A LARGE FIRE, GET OUT IMMEDIATELY AND CALL FIRE SERVICES

FIREPLACE

REMEMBER, YOU ARE DELIBERATELY BRINGING FIRE INTO YOUR HOME

1) USE A FIREPLACE SCREEN TO PREVENT SPARKS FROM FLYING

2) DO NOT STORE ANY FLAMMABLE MATERIALS NEAR THE FIREPLACE

3) CHECK YOUR CHIMNEY BEFORE IT IS PUT TO USE

4) INSTALL A CHIMNEY SPARK ARRESTOR TO PREVENT ROOF FIRES

5) WHEN LIGHTING A GAS FIREPLACE, STRIKE YOUR MATCH FIRST, THEN TURN ON THE GAS

FURNACE / SPACE HEATERS

USED IMPROPERLY, A SPACE HEATER CAN BE THE MOST DANGEROUS APPLIANCE

1) INSTALL AND MAINTAIN HEATING EQUIPMENT CORRECTLY

2) DO NOT LEAVE SPACE HEATERS OPERATING WHEN YOU ARE NOT IN THE ROOM

3) KEEP A SUFFICIENT DISTANCE FROM THE SPACE HEATER INCLUDING THE WALL

4) DON'T USE EXTENTION CORDS WITH ELECTRICAL SPACE HEATERS

5) NEVER USE A GAS RANGE AS A SUBSTITUTE FOR A FURNACE OR SPACE HEATER

CLOTHES DRIER

- UNDER SOME CIRCUMSTANCES, DANGEROUS HEAT CAN BUILD UP IN A DRIER
- NEVER LEAVE HOME WITH THE CLOTHES DRIER RUNNING
- DRIERS MUST BE VENTED TO THE OUTSIDE NOT INTO A WALL OR ATTIC
- CLEAN THE LINT SCREEN FREQUENTLY TO KEEP THE AIR AWAY
- NEVER PUT IN SYNTHETIC FABRICS, PLASTIC, RUBBER OR FOAM BECAUSE THEY RETAIN HEAT

ELECTRICAL HAZARDS

- ELECTRICITY, THE SILENT SERVENT, CAN BECOME A SILENT ASSASSIN
- BETTER NOT TO USE EXTENSION CORDS
- NEVER OVERLOAD A SOCKET
- ALLOW AIR SPACE AROUND THE TV TO PREVENT OVERHEATING
- BE SURE ALL ELECTRICAL EQUIPMENT BARES THE STANDARD LABEL
- CHECK PERIODICALLY FOR LOOSE WIRES, LOOSE FITTINGS, CONNECTIONS, ETC.

KITCHEN

- CARELESS COOKING IS THE NUMBER ONE CAUSE OF RESIDENTIAL FIRES
- WISE TO HAVE A FIRE EXTINGUISHER NEAR THE KITCHEN
- NEVER POUR WATER ON A GREASE FIRE
- DO NOT STORE ITEMS ON THE STOVE TOP AS THEY COULD CATCH FIRE
- DO NOT OVERLOAD KITCHEN ELECTRICAL OUTLETS
- WEAR TIGHT FITTING CLOTHING WHEN YOU COOK
- OPERATE YOUR MICROWAVE ONLY WHEN THERE IS FOOD IN IT
- CLEAN THE EXHAUST WOOD AND DUCT OVER THE STOVE REGULARLY

CHILDREN AND GRAND CHILDREN

1/4th OF ALL FIRE DEATHS OF CHILDREN ARE FROM FIRES STARTED BY CHILDREN

1) KEEP LIGHTERS AND MATCHES OUT OF REACH FROM CHILDREN

2) NEVER LEAVE CHILDREN UNATTENDED WITH FIRE OR SPACE HEATERS

3) IF YOUNGSTERS LIVE WITH YOU OR STAY OVERNIGHT OCASSIONALLY, BE SURE THAT THEY KNOW HOW TO ESCAPE AND ARE PART OF YOUR EMERGENCY EXIT PLAN

GASOLENE AND OTHER FLAMMABLE LIQUIDS

MUST BE LABELED PROPERLY AND STORED PROPERLY

SMOKING

IF YOU ACTUALLY BELIEVE THAT YOU ARE IMMUNE TO CANCER, HEART DISEASE AND OTHER ILLS, ATLEAST WORRY ABOUT BURNING TO DEATH

1) NEVER SMOKE IN BED

2) DO SMOKE WHEN YOU ARE DRINKING OR ABNORMALLY TIRED

3) USE LARGE / DEEP ASHTRAYS AND EMPTY THEM FREQUENTLY

4) NEVER DUMP AN ASHTRAY INTO THE TRASH WITHOUT WETTING THE BUDS AND ASH FIRST

THINKING AHEAD - YOUR EXIT PLAN

- THE BEST MOTTO IS 'BE PREPARED'
- PREPARE A FLOOR PLAN OF YOUR HOME SHOWING ATLEAST TWO WAYS OUT OF EACH ROOM
- SLEEP WITH YOUR BED ROOM DOOR CLOSED
- EASY-TO-USE WINDOW ESCAPE LADDERS ARE AVAILABLE, USE THEM
- AGREE ON A FIXED LOCATION OUT OF DOORS WHERE TO ASSEMBLE (POINT OF ASSEMBLY)
- STAY TOGETHER AWAY FROM THE FIRE
- CALL FIRE EMERGENCY FROM ANOTHER LOCATION
- CHECK CORRIDORS AND STAIRWAYS TO MAKE SURE THEY ARE FREE FROM OBSTRUCTIONS AND COMBUSTIBLES

If we examine what ignites most fires, electrical faults rank highly, along with careless smoking, heating and cooking. Electrical causes include distribution wiring, appliances and portable tools and even static electricity which can directly ignite fires by producing sparks. They also include electrical processes which produce other ignition sources, such as arc welding where molten metal and/or slag formed by the arc is the source of ignition. This was the ignition source in Case History 10.2, the cold storage warehouse fire.

Electrical safety involves much more than concern for igniting fires. Accidental contact with energized circuits can cause shock, burns and even death. We cannot neglect the element of surprise, either, because many a fall from a ladder has been caused by a surprise shock while working on electrical repairs. But what do we have to know about electrical distributions and electronics to assure safe working conditions? Most people know little more than how to turn switches on or off, plug in an electrical device and maybe where the fuse box or circuit breakers are. Fortunately, electrical circuits may be complex and electronics even mystifying, but the hazards associated with them are not. In most cases, competent electrical engineers are needed only to ensure functional design.

If we examine the consequences of electrical hazards—fire ignition, contact and surprise—we need only to determine the aspects of electrical circuits which are related to these phenomena. Fire can be ignited by overheating or by sparks created by arcing. Contact injuries arise if we accidentally become part of the circuitry and surprise can be caused by contact or by arcing. These conditions all relate to the most fundamental laws of electricity—those which describe flow, power and resistance to flow.

Electrical equipment operates because electrical energy flows through a circuit. The potential energy of the circuit is described as the voltage, the flow is described as the current and how much flow occurs is determined by the resistance. These parameters are related by Ohm's Law, which states:

$$E = IR \tag{10.1}$$

where E is the voltage or potential (in volts), I is the current, measured in amperes, and R is the resistance, measured in ohms. The power P, represented in any circuit is measured in watts and is given by:

$$P = IE = I^2R \tag{10.2}$$

Heat is generated within the wires of a circuit when current flows and can be described by:

$$H = I^2Rt \tag{10.3}$$

where H is the heat and t is time.

These relationships show that our safety concerns, whether they are contact, surprise or fire, all involve electrical resistance. Resistance results both from geometric considerations and from fundamental properties. This relationship for a wire is:

$$R = \rho l/A \tag{10.4}$$

where ρ is material resistivity (usually in ohm-cm), l is the length in cm, and A is the area in cm^2. Resistivity is the inverse of conductivity, and therefore it is a simple matter for us to think in terms of high conductivity and low resistivity for conducting materials and low conductivity and high resistivity for insulating materials. The resistivity values of common materials used in electrical applications are given in Table 10.7.

All materials will conduct electricity if the conditions are right. There has to be sufficient potential difference and sufficient conductivity of the path. Lightning strikes, for example, when the potential difference between the clouds and earth is high and the air path becomes sufficiently conductive to conduct the electricity between them. This uncontrolled flow of electricity between two conductors is a discharge or arc which occurs whenever the potential difference

TABLE 10.7 Electrical Resistance of Common Materials Used in Electrical Applications

Material	Typical Application	Resistivity (ohm-cm)
Conductors		
Copper	Wire conductor	1.67×10^{-6}
Aluminum	Wire conductor	2.65×10^{-6}
Gold	Microelectronics	2.35×10^{-6}
NiChrome	Heating element	116.0
Lead-tin solder	Printed circuit boards	15.0
Graphite	Susceptor	1000
Insulators		
PVC	Wire insulation	10^{14}
Glass	Light bulbs, transistors	10^{7}
Porcelain	Power lines	10^{14}
Mica	Power circuits	10^{13}–10^{17}

exceeds a value known as the breakdown voltage where the medium between them will conduct the electricity. Arcing is most common for movable parts of electrical circuits, such as switches and relays, which come together and separate, and in static electricity where a charge is accumulated and then discharged suddenly when nearing a conductor.

Resistance is also important when determining how damaging accidental contact with electricity can be. The hazards of using electric appliances in the bathroom relate to the decrease ($\approx$100-fold) in resistance of our skin when wet as opposed to dry and to the conducting characteristics of water. It is the current, however, which injures people in contact with electricity. Once skin resistance is overcome, current flows readily through our blood and body tissues. The effects can vary from slight sensations through painful muscle contractions, burns, ventricular fibrillation and death. Death can result from asphyxiation caused by respiratory interference, either from muscular contraction or paralysis of the central nervous system and from ventricular fibrillation, affecting the heart directly. Electrical burns arising from arcs are usually deep, very painful and slow to heal.

Safe Electrical Circuits

The consequences of electrical hazards are fires and injuries—injuries which are quite different to crushing, lacerations or those needing an amputation. The engineering methods with which we can combat electrical consequences are also quite different. We can protect equipment and, to a lesser extent, eliminate fires and protect people by overload protection and by grounding. Overload protection includes fuses and/or circuit breakers which trip at a predetermined current load, de-energizing the circuit before damage can occur. A ground is a conducting connection to the earth which provides safe equalization of large voltage differences, such as lightning surges. Grounding applies to both equipment and the electrical system. Equipment is grounded by joining all conducting materials which normally do not carry current, but enclose current-carrying parts, such as the casing of a portable drill. Joining prevents a difference in voltage between the enclosure and the system ground. If a short-circuit between the energized portion and the ground occur, the overload protection will trip.

There are many instances where the grounds are improperly installed or the fault does not lead to current overload, thus leading to enclosures being raised to live voltage. Such situations are extremely hazardous to personnel. Although grounding helps protect workers and equipment, it is not foolproof. For these reasons, ground fault circuit interruptors (GFCIs) are required in many applications. A ground fault circuit interrupter, such as that shown in Fig. 10.9, provides better personnel protection. The interrupter is designed to sense currents leaking to the ground of as little as 5 mÅ, which will trip the circuit, preventing any possible injury to personnel.

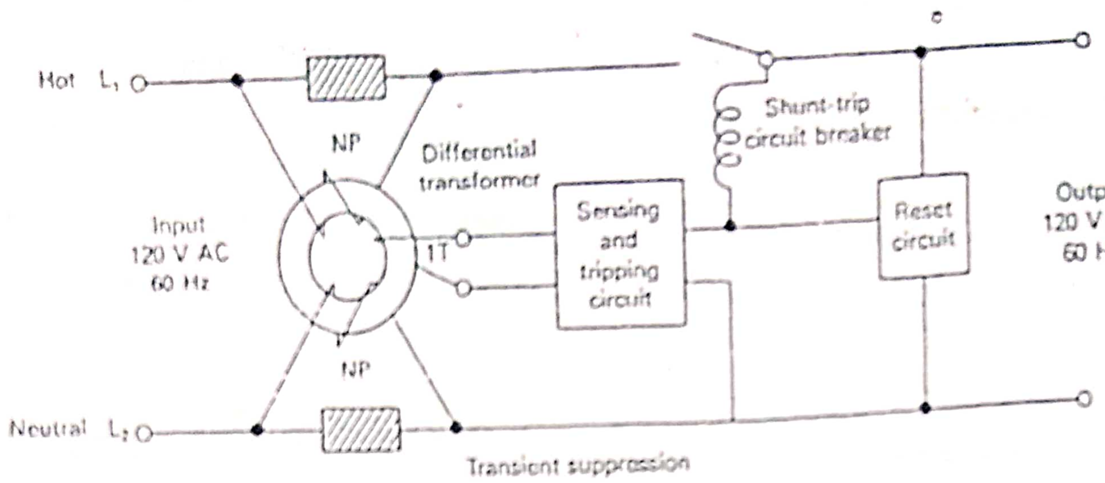


Figure 10.9 A ground fault circuit interrupter. If differential transformer senses any current flow to ground, the circuit breaker is tripped.

Management of Electrical Safety

The technical requirements for providing electrical safety can be ascertained from such sources as NFPA 70, the National Electrical Code. There is much more, however, required to ensure electrical safety in any plant operation. All of the factors which make for good management also apply here to good management of electrical safety. Because of the technical nature, training must be well thought out, and must include maintenance as well as operating personnel, covering topics such as lock-out procedures and inspection procedures. Just how far-reaching management and hazard identification processes are in electrical safety can be ascertained from the last two case histories which end this chapter.

Case History 10.6 What Can You Suspect?

Walkinshaw Shoe Company, like many shoe manufacturers, has had to reexamine their product line because of the increase in foreign competition. The company decided in 1983 to reduce the product line to specialty outdoor sporting boots. As part of the reorganization, Walkinshaw consolidated their manufacturing area to an area used principally for storage beforehand, vacating the large section of the building which was expected to be leased. Extensive rewiring was required for the move and work was contracted out to a reputable local firm.

In 1987, construction plans for a new high-rise office building adjacent to the Walkinshaw plant were approved and the one-story brick garage located only 12 feet from the Walkinshaw plant was razed. The property up to the Walkinshaw line, 3 feet from the plant, was to be converted to a parking area, and guard-rails were constructed right along the property line; these guard rails were 30 inches from ground level.

Although Walkinshaw management were aware of the construction next door, they paid no heed to its progress, simply because it was not on their property. Unfortunately, Walkinshaw Shoe Company has been named as a defendant in the wrongful death suit of a young 9-year-old boy who had lived in the neighborhood. The boy, along with two friends, had been playing ball in the new parking area until dusk. When it was too dark to play anymore, but before they disbanded to go home, they began walking along the guard rail. The unfortunate victim lost his balance and fell toward the Walkinshaw plant. He grabbed at anything to prevent his fall, unfortunately grabbing and holding the metal conduit for the electrical service into the building. His weight bent the conduit causing it to bend and break through the insulation, thus energizing the conduit and electrocuting the victim.

A post-accident inspection showed the conduit brought power from the corner of the building, with a horizontal run of 48 feet located 8 ft above the ground, where it entered the building. There were only two support straps in the 48-foot horizontal length, in direct violation of the NFPA 70 which requires a maximum distance of 10 feet between rigid-metal supports. The tragedy of the incident and accidental death were bad enough, but to learn that their safety program had been lax enough to permit the obvious violation to go unnoticed for almost 5 years devastated Walkinshaw Shoe Company. ■

Case History 10.7 The Wrong Wire

In the Northeast, mountains and lakes lend themselves to boating, swimming, fishing, hiking and skiing at different times of the year. This has led to the development of weekend homes, cottages and camps. It gets very cold in January and February and weekend residents like to be able to heat their recreational homes fast and efficiently. This has led to the need for radiant heating, the sole product of Radiant Panels, Inc.

Radiant Panels began operations in 1972, making 4 × 8 foot gypsum panels which were inlaid with resistive heating wires connected electrically in series to a 220-volt source. The concept of the product, being installed mainly in ceilings, but occasionally in walls, caught on gradually and then grew rapidly as the building of new units flourished. The panels were made by cutting slots lengthwise in standard gypsum board, inserting insulated Nichrome wires in these slots, filling with gypsum slurry and adhesively bonding a new surface to the board. Nichrome wire was selected because it was a known resistance heating wire; purchase conditions specified only a certain resistance per foot.

Radiant Panels were conscious of their production costs, because the cost of purchasing and installing their product hindered the development of their market share. When the metal supplier sales representative met with Joe Daigle, the President of Radiant Panels, and recommended he buy a copper-nickel alloy wire with the same resistance per foot, which was half the price of Nichrome, Joe was delighted. Tests conducted with the new alloy wires implanted in panels were satisfactory, and therefore a limited production run was made using the new copper-nickel alloy wire.

The first hints of a problem appeared innocuous because small loops of the wire popped out of the paneling, usually near the end of the panel. Little attention was initially paid to this problem because it was only of minor, cosmetic consequence. Four months after the first installation of these special panels, however, two fires were reported, both demonstrating that fires could be initiated at the panels. Radiant Panels worked closely with fire investigators examining the remnants of panels from both fires. Evidence of several exposed small loops were found near where each fire started.

These observations led to an extensive study of the heat transfer process in the radiant heating panels. It was the metallurgist from the wire manufacturer who finally solved the problem, pointing out that the copper-nickel alloy wire was not suitable for the application. The reasoning was simple:

1. Radiant heating panels heat the room by radiation, but the panels are heated in turn by conduction from the implanted wires. Heat transfer from the wires by conduction is a function of the surface area of the wire.
2. Nichrome wires were replaced by copper-nickel alloy wires having the same resistance per foot. The resistivity of Nichrome, however, is twice that of the copper-nickel alloy. The specification could only be satisfied if the copper-nickel alloy wire diameter had been 30% smaller than the Nichrome wire.
3. Heat transfer from the smaller diameter copper-nickel alloy wire is therefore about 50% less than from the equivalent resistance Nichrome wire. Therefore, the internal temperature of the copper-nickel alloy wire was higher.
4. All metals expand when heated, with the expansion proportional to the temperature difference. When constrained at the ends, a metal which expands can fail by buckling. The copper-nickel alloy wires, expanding more because of a higher temperature, probably buckled near voids in the gypsum, forming the exposed loops.
5. The hot, exposed loops probably ignited combustible dusts which in turn ignited more substantial fuel in the room areas.

Radiant Panels has recalled all of the paneling which used the copper-nickel alloy wire, replacing the product and allowing for installation. ■

MANAGEMENT OF PRODUCT SAFETY PROGRAMS

For the same reasons that a written policy for safety in an industrial operation is needed, so is there a need for a written policy for product safety. That policy should convey commitment of the corporation to product safety and the reasons for the commitment. In most cases, it pays to be frank and convey selfish interests such as legal and insurance costs as well as customer considerations. This written commitment needs to be effectively reinforced by our innovative, participative management personnel. We do not need to study management functions further, but simply state that the management of product safety adds only one more function to our safety management responsibilities.

One area of management is worthy of mention, though, particularly for organizations that have not been formally concerned with product safety in the past, i.e. training. The basic purpose of product safety training is to broaden each employee's understanding of the meaning and significance of product safety and provide them with information and tools to utilize in the program. CPSC suggests the following elements in a training program:

1. Review of the corporate program and relationships of each employee's work to the program.
2. Regulations and standards applicable to corporate products.
3. Manufacturing processes.
4. Inspection and test procedures.
5. Record-keeping and reporting requirements.

HNICAL REQUIREMENTS OF PRODUCT SAFETY PROGRAMS

Design Review

Product design is rarely the effort of a single individual; rather, the process of product development involves a wide range of technical and managerial skills. Many authors such as Eads and Reuter, Anderson, or Kolb and Ross have divided this product design process into three stages: the conceptual stage, the intermediate stage and the final preproduction stage. We can see what considerations have to be made by examining Table 12.2. What is important is that a design review should be conducted after the completion of each stage.

TABLE 12.2 Considerations Made in Design Stages

Stage	Tasks to be Considered
Conceptual	Functional performance features cost to produce, reliability/life expectancy, environment for use, special characteristics such as safety, instructions
Intermediate	Layouts, electrical schematics specifications, initial tooling needs
Final (preproduction)	Detailed, schematics and drawings, with tolerances, materials, manufacturing processes

The CPSC suggests that persons representing production, quality control, and consumer services in addition to management personnel comprise the design review committee. The CPSC also suggests that the committee address product design safety which takes into account hazards not only of the product, but hazards developing because of user ergonomics, record-keeping of hazard identification procedures and remedial actions, and designer defense to committee questioning. Surveys reported by Eads and Reuters indicate that about 80% of respondents had product liability individuals or committees, most of which operated only part-time. Of these, 57% exercised approval of product design. The representation of specialists on the committees is diverse, but included management, engineering, manufacturing and quality control, legal, safety and risk management, and marketing functions on a majority of committees.

The make-up of the safety design review committee does not represent the starting place for safety in any new design, however. Most executives would argue that safety is incorporated as soon as design work is begun on a new project. One designer requires new designs to satisfy six fundamental concepts—function, structure, cost, environment, safety and health, and statutory requirements. From the safety viewpoint only, the design team should conduct a preliminary hazards analysis.

Some authors suggest the first need in design safety review is to make up a hazards control checklist. Most, however, are wary of using such checklists because they tend to be depended on too heavily. From our viewpoint, such checklists are important, but if compiled at the initial design stages bias errors can be overlooked and continued, and the innovation and creativity of others performing design reviews at later stages can be stifled. In the same context, standards should not be incorporated into the early design considerations to avoid absolute dependence.

Once the preliminary hazards analysis has been completed and the initial design has been established, we should begin the formal design review process. Because of the technical nature and complicated analysis involved, several reviews are always necessary, with 1–2 weeks between them to allow for individual analysis of all aspects affecting the safety of the proposed products. Typical review agendas and the critical times for reviews are summarized in Table 12.3.

The most important aspect of design reviews that we are concerned with—hazard analysis—has not been addressed because the methods are the same as those discussed in Chapter 5.