Safety Policy

Indian Institute of Technology Roorkee is committed to provide a Safe & Healthy working environment and achieving an injury free workplace for students, faculty, research staff , technical personnel, visitors & associated members. it will be make certain through safe work practices and team work. IIT Roorkee also strives to continually enhance the safety performance by conducting hazard assessments, implementing safety controls, ensuring legal compliance and providing continual safety training. IIT Roorkee firmly believes that the responsibility for safety must be shared by all those involved in routine & non-routine activities.

FIRE SAFETY

INTRODUCTION:

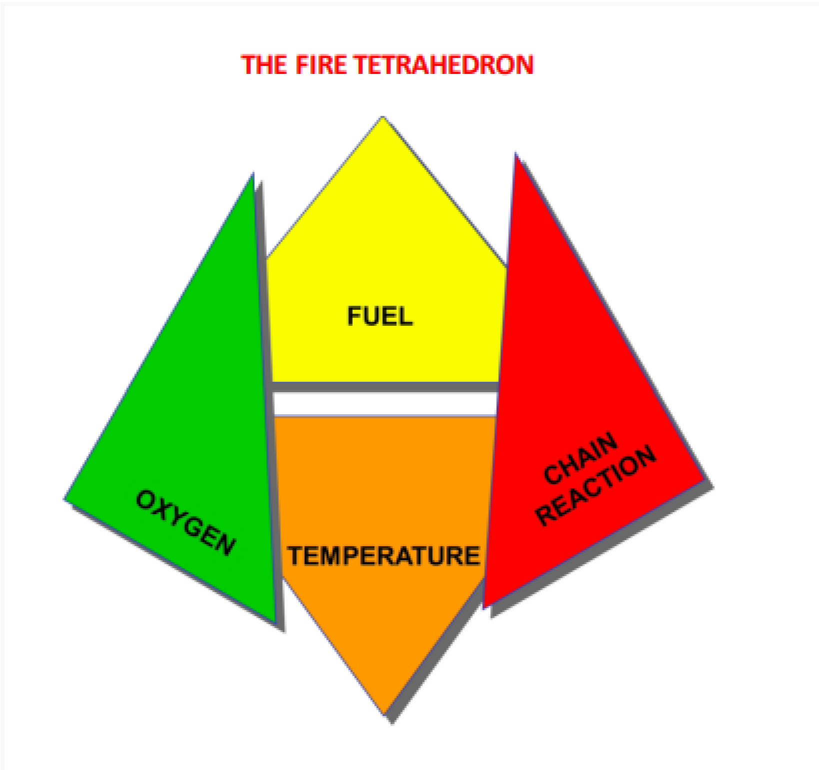
Fire safety is the set of practices intended to reduce the destruction caused by fire. Fire safety measures include those that are intended to prevent ignition of an uncontrolled fire, and those that are used to limit the development and effects of a fire after it starts. Fire safety measures include those that are planned during the construction of a building or implemented in structures that are already standing, and those that are taugh t to occupants of the building. Threatsto fire safety are commonly referred to as fire hazards. A fire hazard may include a situation that increases the likelihood of a fire or may impede escape in the event a fire occurs. Fire safety is often a component of building safety. The staff/employees should have a working knowledge of basic fire science and chemistry. A fire, or combustion, is a chemical reaction. An understanding of the chemical reaction is the basis for preventing fires, as well as extinguishing fires once they initiate. A working knowledge of basic fire science and chemistry is essential for developing and implementing a successful fire safety program.

DEFINITION OF FIRE:

A fire is a chemical reaction. There are many variables that can affect a fire. Effective fire safety management programs control the variables that can affect a fire. Therefore, it is imperati ve to understand the variables. A fire is self-sustained oxidation of a fuel that emits heat and light. A fire requires three variables to initiate: a fuel, oxygen, and heat. The fire triangle is a well-known representation of the three variables needed to initiate a fire. In order to initiate a fire, fuel, oxygen, and heat are required.

FIRE TETRAHEDRON:

Fire prevention is the concept of preventing the variables of the fire triangle from coming into contact with each other to initiate a fire. Once a fire begins, it requires four variables to sustain the combustion reaction. The four variables required to sustain a fire are fuel, oxygen, heat, and chemical chain reactions. These four variables represent the fire tetrahedron. Chemical chain reactions are a product of the combustion process. The chemical reactions ultimately produce combustion byproducts such as carbon monoxide, carbon dioxide, carbon, and other molecules, depending on the specific fuel. It is these byproducts of combustion found in the smoke that usually affect the safety and health of occupants and fire fighters. Once a fire begins and is self-sustaining, the goal is to control and extinguish the fire. Fire extinguishment is done by eliminating one of the variables of the fire tetrahedron. By removing the fuel, oxygen, or heat, or inhibiting the chemical chain reactions, a fire can be extinguished. The concept of fire protection assumes fires will occur, and focuses on controlling fires by eliminating or otherwise controlling the variables of the fire tetrahedron. The concept of fire prevention differs from fire protection because fire prevention attempts to control the variables of the fire triangle before a fire occurs.



To further understand the fire triangle, it is necessary to analyze what influence each side of the fire triangle has in the combustion process. For the safety manager, this analysis is the key for understanding the concept of fire prevention. Fire prevention attempts to prevent fuels, oxygen, and heat from combining to start a fire. Fire prevention strategies include controlling fuels, controlling oxygen sources, and con- trolling heat sources. A discussion of fuels, oxygen, and heat sources follows.

FUEL:
A fuel is a combustible solid, liquid, or gas. Like in any chemical reaction, a source of energy is needed to sustain the heat required. The most common solid fuels are wood, paper, cloth, coal, and so forth. Flammable and combustible liquids include gasoline, fuel oil, paint, kerosene, and other similar materials. Propane, acetylene, and natural gas are some examples of gasses that are flammable. Solid and liquid fuels share a common characteristic; they must be converted into a gas in order to support combustion. Gaseous fuels can undergo direct oxidation because the molecules are already in the gas state. Some liquid fuels can undergo direct oxidation because they produce vapors at ambient temperatures and pressures. Other liquid fuels and

solid fuels, however, undergo sequential oxidation. This means that a fuel must be heated first to produce sufficient concentrations of gas to support combustion. From a fire safety standpoint, the safety manager should be aware of the different types of fuels located in the workplace. The ease of ignition of a solid fuel is dependent on several factors. The most important factor is the surface to mass ratio of the fuel. The surface to mass ratio refers to how much of a fuel's surface area is exposed to the environment in relation to its overall mass. The safety manager should be concerned with two things regarding the surface to mass ratio of a fuel. First, the more surface area that is exposed, the easier it is for a fire to initiate and the more rapidly it can burn. Second, the more mass that a solid fuel has, the more difficult it will be to initiate and sustain combustion. Consider cotton as a fuel in a textile mill. Cotton dusts and lint will burn easier and faster than a tightly bound bale of cotton. Liquid fuels are affected by several factors. The safety manager should be familiar with the terms flash point, fire point, boiling point, and specific gravity. Chapter 4 explores these factors in detail.. However, one of the most critical indicators of a liquid's flammability should be mentioned—flash point. The flash point refers to the temperature at which adequate vapors are produced to form an ignitable mixture in air. Therefore, a liquid heated to a temperature at or above its flash point will ignite in the presence of an ignition source such as a spark, cigarette, hot surface, or open flame.

OXYGEN:

The atmosphere contains approximately 21% oxygen by volume. During combustion, the oxygen necessary for oxidation is sufficiently provided from the surrounding air. When the oxygen content of the atmosphere falls below 15%, a free-burning fire will begin to smolder. When the oxygen content of the atmosphere falls below 8%, a smoldering fire will stop burning (Bryan, 1982). Oxygen can also be provided by other sources that release oxygen molecules during a chemical reaction. The safety manager should be aware of these oxidizers in the workplace and segregate them from any fuels.

HEAT:

The safety manager should be concerned with sources of heat commonly found in the workplace. This is a concern because sources of heat provide the energy necessary to initiate combustion. By preventing heat sources from contacting the ignitable fuel-air mixtures, fires can be effectively prevented from occurring. Some common sources of heat for ignition in the workplace are:

- Open flames such as from cutting and welding torches
- Cigarettes and lightning.
- Sparks such as from electrical equipment, brazing, or grinding
- Hot surfaces such as electrical motors, wires, and process pipes
- Radiated heat from boilers or portable heaters
- Static discharges such as during the transfer of flammable liquids
- Arcing from wires and electrical equipment
- Compression such as hydraulic oil under pressure on a machine
- Exothermic chemical reactions
- Spontaneous ignition from slow oxidation or fermentation combined with proper insulation of a fuel.

Heat is transferred by three methods: conduction, convection, or radiation. Conduction occurs when two bodies are touching one another and heat is transferred from molecule to molecule. Convection is the transfer of heat through a circulating medium rather than by direct contact. The medium can be either a gas or a liquid. Radiation is the transfer of electromagnetic waves through any medium. For the safety manager, recognizing how heat can be transferred in the workplace is helpful for preventing fires.

As mentioned, four fire extinguishing principles exist. They are highlighted below:

1. Control the fuel— Controlling the fuel is accomplished by two methods. First, the fuel can be physically removed or separated from the fire. For instance, a fire involving stacks of wood pallets could be controlled by removing any exposed stacks of pallets to a safe location. Another example is closing a valve feeding a gas or flammable liquid fire. Second, the fuel can be chemically affected by diluting the fuel.

2. Control the oxygen— Controlling the oxygen requires that the oxygen be inhibited, displaced, or the concentration of oxygen be reduced below 15% by volume. Smoldering fires should be diluted to an oxygen concentration below 8% by volume. The oxygen supply to a fire can be inhibited by smothering the fire. Smothering a fire places a barrier between the flame and the atmosphere. This can be accomplished with a blanket or applying a layer of foam to form a vapor barrier. Displacing and reducing the oxygen concentration involves applying an inert gas to the fire, such as carbon dioxide. The carbon dioxide displaces the oxygen thus lowering the concentration to a level that cannot sustain the fire. Applying an inert gas to a fire requires that the fire be located in a confined space. Personnel must be aware that displacing the oxygen or diluting the oxygen concentration affects their ability to breathe. Fire extinguishment using this method requires that personnel be absent from the confined area or protected by self-contained breathing apparatus.

3. Control the heat— Controlling the heat requires that the heat be absorbed. Combustion is an exothermic chemical reaction. If the heat emitted by the reaction can be absorbed faster than the reaction can produce the heat, then the reaction cannot be sustained. Water is the most common extinguishing agent. Water is also the most efficient extinguishing agent because it has the capability to absorb immense amounts of heat.

4. Inhibit the chemical chain reactions— Inhibiting the chemical chain reactions requires that a chemical agent be introduced into the fire. Certain chemical agents can interfere with the sequence of reactions by absorbing free radicals from one sequence that are needed to complete the next sequence. Dry chemical extinguishing agents commonly used in portable fire extinguishers have this ability.

CLASSES OF FIRE

Fires are classified based upon the type of fuel that is consumed. Fires are classified into categories so personnel can quickly choose appropriate extinguishing agents for the expected fire and associated hazards. Fires are classified into five general classes. Each class is based on the type of fuel and the agents used in extinguishment. The five classes of fire are described next:

- **Class A—** Class A fires involve ordinary combustibles such as wood, paper, cloth, rubber, and some plastics. Water is usually the best extinguishing agent because it can penetrate fuels and absorb heat. Dry chemicals used to interrupt the chemical chain reactions are also effective on Class A fires.
- **Class B—** Class B fires involve flammable and combustible liquids and gasses such as gasoline, alcohols, and propane. Extinguishing agents that smother the fire or reduce the oxygen concentration available to the burning zone are most effective. Common extinguishing agents include foam, carbon dioxide, and dry chemicals.
- **Class C—** Class C fires involve energized electrical equipment. Non-conductive extinguishing agents are necessary to extinguish Class C fires. Dry chemicals and inert gasses are the most effective agents. If it can be done safely, personnel should isolate the power to electrical equipment before attempting to extinguish a fire. Once electrical equipment is de-energized, it is considered a Class A fire.
- **Class D—** Class D fires involve combustible metals such as magnesium, sodium, titanium, powdered aluminum, potassium, and zirconium. Class D fires require special extinguishing agents that are usually produced for the specific metal.
- **Class K—** Class K fires most often occur where cooking media (fats, oils, and greases) are used, and most of the time are found in commercial cooking operations. Class K fire extinguishers are required in any location that cooks oils, grease, or animal fat. Any location that fries must have a Class K fire extinguisher. Every commercial kitchen should have a Class K extinguisher located in it to supplement the suppression system.

THREE STAGES OF FIRE

Fires evolve through several stages as the fuel and oxygen available are consumed. Each stage has its own characteristics and hazards that should be understood by safety managers and fire-fighting personnel.

INCIPIENT STAGE: The incipient stage is the first or beginning stage of a fire. In this stage, combustion has begun. This stage is identified by an ample supply of fuel and oxygen. The products of combustion that are released during this stage normally include water vapor, carbon dioxide, and carbon monoxide. Temperatures at the seat of the fire may have reached 1000°F, but room temperatures are still close to normal.

FREE-BURNING STAGE: The free-burning stage follows the incipient stage. At this point, the self-sustained chemical reaction is intensifying. Greater amounts of heat are emitted and the fuel and oxygen supply is rapidly consumed. Room temperatures can rise to over 1300°F. In an enclosed compartment, the free-burning stage can become dangerous. Because of the heat intensity, the contents within a compartment are heated. At some point, if the compartment is not well ventilated, compartment contents will reach their ignition temperature. A flashover occurs when the contents within a compartment simultaneously reach their ignition temperature and become involved in flames. It is not uncommon for room temperatures to exceed 2000°F following a flashover. Human survival, even for properly protected fire fighters, is difficult if not impossible for a few seconds within a compartment following a flashover.

SMOLDERING STAGE:

The smoldering stage follows the free-burning stage. As a free-burning fire continues to burn, the chemical reaction will eventually consume the available oxygen within the compartment and ultimately convert it into carbon monoxide and carbon dioxide. This causes the oxygen concentration within the compartment to decrease. When the oxygen concentration decreases to 15% by volume, the chemical reaction will not have sufficient oxygen to support free-burning combustion. Visibly, the flames subsist and the fuel begins to glow. A smoldering fire is identified by a sufficient amount of fuels and lower oxygen concentrations. Smoldering fires, especially when insulated within a compartment, can continue the combustion process for hours. Room temperatures can range from 1000–1500°F. The byproducts of combustion also fill the compartment and human survival is impossible. During the smoldering stage, an extreme hazard, called a backdraft, can develop. A backdraft occurs when oxygen is introduced into a smoldering compartment fire. The immediate availability of sufficient oxygen in the presence of sufficient fuel, heat, and chemical chain reactions causes flaming combustion again. In some cases, the backdraft is so violent that an explosion will occur. Human survival, even of properly protected fire fighters, is usually not possible.

IDENTIFICATION OF HAZARDOUS MATERIALS

In the past, chemical manufacturers labeled their products with the warnings “Caution,” “Danger,” and “Handle with Care.” The terms were vague and did not indicate specific hazards associated with particular chemicals. The U.S. The Department of Transportation labeling system contains requirements for the shipping, marking, labeling, and placarding of 1400 hazardous materials.

The objectives of this standard are to
(1) Provide an immediate warning of potential danger;
(2) Inform emergency responders of the nature of the hazard;
(3) State emergency spill or release control procedures; and
(4) Minimize potential injuries from chemical exposure.

The standard contains a hazardous materials table listing substances by name, prescribing requirements for shipping papers, package marking, labeling, and transport vehicle placarding. Table shows a comparison listing of United Nations and DOT classifications for hazardous materials. The classes of hazardous materials that must be labeled and placarded are as follows: explosives, flammable and combustible materials, oxidizers, corrosives, poisons, compressed gasses, etiologies, and radioactive materials.

TABLE 1

United Nations and Department of Transportation Classification of Hazardous Materials

United Nations Class	DOT Classification
1	Explosives: Class A, B, and C
2	Nonflammable and flammable gases
3	Flammable liquids
4	Flammable solids, spontaneously combustible substances, and water reactive substances
5	Oxidizing materials and organic peroxides
6	Poisons: Class A, B, and C
7	Radioactive I, II, and III
8	Corrosives
9	Miscellaneous materials which can present a hazard during transport, but are not covered by other classes

TABLE 2

Table of Evacuation (Isolation) Distances

1. Determine if the accident involves a *small* or *large* spill and if *day* or *night*. Generally, a *small spill* is one which involves a single, small package (i.e., up to a 208 liter [55 U.S. gallon] drum), a small cylinder, or a small leak from a large package. A *large spill* is one which involves a spill from a large package, or multiple spills from many small packages.

2. Determine the initial *isolation* distance. Direct all persons to move, in a crosswind direction, away from the spill to the distance specified in meters and feet.

3. Next, determine the initial *protective action distance*. For a given dangerous goods, spill size, and whether day or night, try to determine the downwind distance—in kilometers and miles—for which protective actions should be considered. For practical purposes, the Protective Action Zone (i.e., the area in which people are at risk of harmful exposure) is a square, whose length and width are the same as the downward distance.

4. Initiate protective actions to the extent possible, beginning with those closest to the spill site and working away from the site in the downwind direction. When a water-reactive PIH producing material is spilled into a river or stream, the source of the toxic gas may move with the current or stretch from the spill point downstream for a substantial distance.

Identification and Control of Hazardous Material

TABLE 3
Classes of Flammable Materials

Hazardous Class	Definition	Examples
Flammable Liquid	Any liquid with a flash point below 37.8°C (100°F).	Gasoline, pentane
Flammable Solid	Any solid material, other than one classified as an explosive, which is likely to cause fire by self-ignition through friction, absorption of moisture, chemical changes, or retained heat. Can be ignited readily and burn vigorously.	Phosphorus, fish meal
Flammable Solid (Dangerous when wet)	Same definition as above, with the additional fact that water will accelerate the reaction.	Magnesium scrap, lithium silicon
Flammable Gases	Any mixture or material in a container having an absolute pressure exceeding 40 psi at 70°F or any liquid flammable material having a vapor pressure exceeding 40 psi at 100°F.	Methane, methyl chloride
Combustible Liquid	Any liquid with a flash point at or above 37.8°C (100°F) and below 93.3°C (200°F).	Pine oil, ink, fuel oil

TABLE 4
Classification of Flammable and Combustible Liquids (*NFPA-30*)

Class I	Flammable Liquids—Flash point below 100°F (37.8°C)
	Volatile Class I Flammable Liquids
Class IA	Most hazardous, having flash points below 73°F (22.8°C) with boiling points below 100°F (37.8°C)
Class IB	Same flash point range but with boiling points at or above 100°F (37.8°C)
Class IC	Flash points between 73°F (22.8°C) and below 100°F (37.8°C)
Class II	Combustible Liquids—Flash points at or above 100°F (37.8°C) and below 140°F (60°C)
Class III	Liquids are included in the combustible liquid classification and are further classified
Class IIIA	Flash point between 140 and 200°F (60–93.4°C)
Class IIIB	Flash point 200°F (93.4°C) or above

NFPA CODE 704:

NFPA 704 provides an easy method of recognizing hazards. The NFPA 704 Diamond indicates the health, flammability, and reactivity (i.e., stability) hazards of chemicals by placing numbers in the three upper squares of the diamond

Health Hazards Are Indicated in the Left Square, Color-Coded Blue

4) Materials which on very short exposure could cause death or major residual injury**.**
3) Materials which on short exposure could cause serious temporary or residual injury.
2) Materials which on intense or continued, but not chronic, exposure could cause temporary incapacitation or possible residual injury.
1) Materials which on exposure would cause irritation but only minor residual injury.
0) Materials which on exposure under fire conditions would offer no hazard beyond that of ordinary combustible material.

Flammability Hazards Are Indicated in the Top Square, Color-Coded Red

4) Materials which will evaporate rapidly or completely at atmospheric pressure and normal ambient temperature, or which are dispersed readily and which will burn readily.
3) Liquids and solids which can be ignited under almost all ambient temperature conditions.
2) Materials which must be heated moderately or exposed to relatively high ambient temperatures before ignition can occur.
1) Materials which must be preheated before ignition can occur.
0) Materials that will not burn.

Reactivity (Stability) Hazards Are Indicated in the Right Square, Color-Coded Yellow

4) Materials which in themselves are readily capable of detonations or of explosive decomposition or reaction at normal temperatures and pressures.
3) Materials which in themselves are capable of detonation or explosive decomposition or reaction, but require a strong initiating source, or which must be heated under confinement before initiation, or which react explosively with water.
2) Materials which readily undergo violent chemical change at elevated temperatures, or which react violently with water, or which may form explosive mixtures with water.
1) Materials which in themselves are normally stable, but which can become unstable at elevated temperatures and pressures. 0. Materials which in themselves are normally stable, even under fire expo- sure conditions, and which are not reactive with water.

Special Information Is Indicated in the Bottom Square, Color-Coded White

0) The letter W with a bar through it indicates a material may have a hazardous reaction with water. This does not mean “**use no water**,” but rather “**avoid the use of water**.” Note that some forms of water (e.g., fog or fine spray) may be used. Because water may cause a hazard, it is advised that water be used very cautiously until firefighters have proper information.
1) The radioactive “pinwheel” indicates radioactive materials.
2) The letters “OX" indicate an oxidizer.

HAZARD DIAMOND

TABLE 5
Classes of Oxidizing Materials

Hazardous Class	Definition	Examples
Oxidizer	A substance that yields O_2 readily to stimulate the combustion of organic matter.	Silver nitrate
Organic Peroxide	An organic derivative of the inorganic compound, hydrogen peroxide.	Lauroyl peroxide
Oxygen	An odorless, colorless, gaseous chemical element that supports combustion. At low temperatures the gas liquefies.	Oxygen

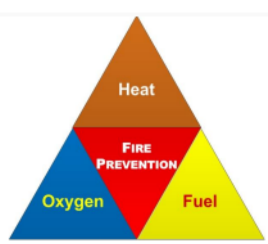
TABLE 6
Classes of Explosives

Hazardous Class	Definition	Examples
Explosive	Any chemical compound, mixture, or device, the purpose of which is to function by explosion, that is, with substantial instantaneous release of gas or heat.	
Class A	A detonating or otherwise maximum hazard.	Black powder, dynamite, blasting caps
Class B	Function by rapid combustion rather than detonation.	Special fireworks, flash powders
Class C	Materials that do not ordinarily detonate in restricted quantities—minimum explosion hazard.	Flares, small arms

FIRE PREVENTION & PROTECTION:

FIRE PREVENTION

Fire prevention requires segregating the three elements of the fire triangle. A fire needs three elements - heat, oxygen and fuel. Without heat, oxygen and fuel a fire will not start or spread. A key strategy to prevent fire is to remove one or more of heat, oxygen or fuel.



HEAT

Heat can be generated by work processes and is an essential part of some processes such as cooking. This heat must be controlled and kept away from fuel unless carefully controlled. Heat generated as a by -product of a process must be dealt with properly.

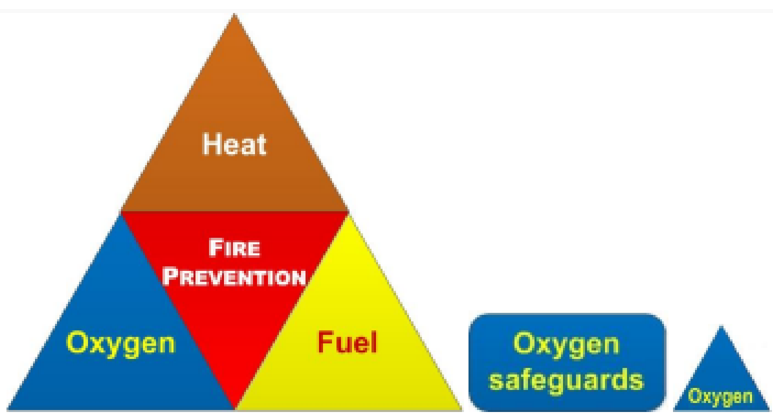
Heat Safeguards:

- Ensure employees are aware of their responsibility to report dangers
- Control sources of ignition
- Have chimneys inspected and cleaned regularly
- Treat independent building uses, such as an office over a shop as separate purpose groups and therefore compartmentalize from each other
- Ensure cooking food is always attended
- Use the Electricity Supply Board's Safety webpage
- Have regard to relevant AuthoritySafety Alerts, e.g. Mobile Phone "Expert XP-Ex-1", Filling LPG Cylinders
- Use the Code of Practice For Avoiding Danger From Underground Services

OXYGEN

Oxygen gas is used:

- in welding, flame cutting and other similar processes
- for helping people with breathing difficulties
- in hyperbaric chambers as a medical treatment
- in decompression chambers for food preservation and packaging
- in steelworks and chemical plants



The air we breathe contains about 21% oxygen. Pure oxygen at high pressure, such as from a cylinder, can react violently with common materials such as oil and grease. Other materials may catch fire spontaneously. Nearly all materials including textiles, rubber and even metals will burn vigorously in oxygen. With even a small increase in the oxygen level in the air to 24%, it becomes easier to start a fire, which will then burn hotter and more fiercely than in normal air. It may be almost impossible to put the fire out. A leaking valve or hose in a poorly ventilated room or confined space can quickly increase the oxygen concentration to a dangerous level. The main causes of fires and explosions when using oxygen are:

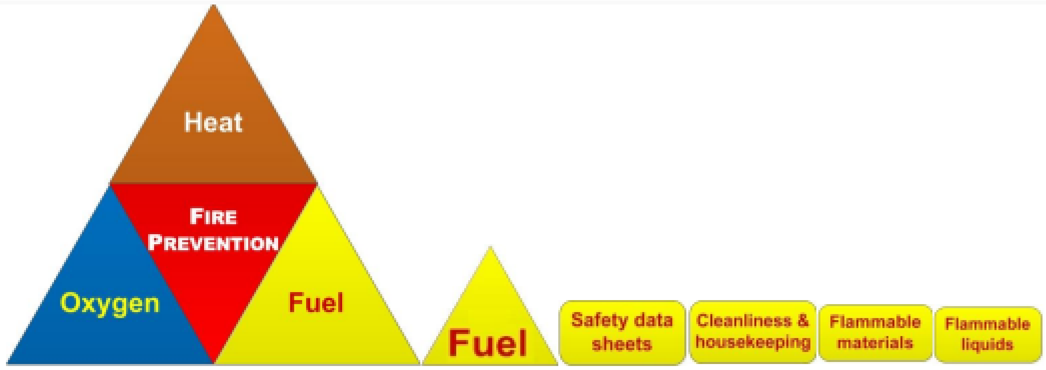
- oxygen enrichment from leaking equipment
- use of materials not compatible with oxygen
- use of oxygen in equipment not designed for oxygen service
- incorrect or careless operation of oxygen equipment

Oxygen Safeguards

- Ensure employees are aware of their responsibility to report dangers
- See safeguards in the Code of Practice for Working in Confined Spaces
- Oxygen should never be used to “sweeten” the air in a confined space
- Where oxygen is used:
    1) follow safety advice from the supplier
    2) follow the safeguards on the safety data sheet
    3) keep the safety data sheet readily available
- Be aware of the dangers of oxygen if in doubt, ask Prevent oxygen enrichment by ensuring that equipment is leak-tight and in good working order
- Check that ventilation is adequate
- Always use oxygen cylinders and equipment carefully and correctly
- Always open oxygen cylinder valves slowly
- Do not smoke where oxygen is being used
- Never use replacement parts which have not been specifically approved for oxygen service Never use oxygen equipment above the pressures certified by the manufacturer
- Never use oil or grease to lubricate oxygen equipment
- Never use oxygen in equipment which is not designed for oxygen service
- Operators of locations storing large amounts of oxidizing substances

FUEL

Workplaces in which large amounts of flammable materials are displayed, stored or used can present a greater hazard than those were the amount kept is small. In relation to fire, fuel consists of flammable material. Flammable material is material that burns readily in a normal atmosphere. Flammable materials include flammable liquids (e.g. petrol), flammable gasses (e.g. propane and butane) and flammable solids (e.g. charcoal, paper). It is important to identify all flammable materials that are in your workplace so that proper controls can be put in place.



Great care is required in the storage, handling and use of flammable materials. Safety Data sheets may provide detailed advice.

Fuel Safeguards

- Identify all flammable materials so that proper controls can be put in place
- Identify use of substances with flammable vapors (e.g. some adhesives)
- Reduce quantities of flammable materials to the smallest amount necessary for running the business and keep away from escape routes
- Replace highly flammable materials with less flammable ones
- Store remaining stocks of highly flammable materials properly outside, in a separate building, or separated from the main workplace by fire-resisting construction
- Provide clearly marked separate storage for flammable chemicals, gas cylinders, and waste materials
- Train employees on safe storage, handling and use of flammable materials
- Keep stocks of office stationery and supplies and flammable cleaners' materials in separate cupboards or stores. They should be fire-resisting with a fire door if they open onto a corridor or stairway escape route.
- This is highly specialized work and a detailed risk assessment must be conducted
- Detailed work instructions must be put in place
- Advice should be sought from the gas supplier as needed Workers must be properly trained and supervised
- The quantity of flammable liquids in workrooms should be kept to a minimum, normally no more than a half-day's or half a shifts supply
- Flammable liquids, including empty or part-used containers, should be stored safely.
- Small quantities (Tens of Liters) of flammable liquids can be stored in the workroom if in closed containers in a fire-resisting (e.g. metal), bin or cabinet fitted with means to contain any leaks Flammable liquids should not be decanted within the store.
- Decanting should take place in a well-ventilated area set aside for this purpose, with appropriate facilities to contain and clear up any spillage
- Container lids should always be replaced after use, and no container should ever be opened in such a way that it cannot be safely resealed
- Flammable liquids should be stored and handled in well ventilated conditions.
- Where necessary, additional properly designed exhaust ventilation should be provided to reduce the level of vapor concentration in the air

- Storage containers should be kept covered and proprietary safety containers with self-closing lids should be used for dispensing and applying small quantities of flammable liquids
- There should be no potential ignition sources in areas where flammable liquids are used or stored and flammable concentrations of vapor may be present at any time.
- Any electrical equipment used in these areas, including fire alarm and emergency lighting systems, needs to be suitable for use in flammable atmospheres
- Avoid accumulations of combustible rubbish and waste and remove at least daily and store away from the building
- Never store flammable or combustible rubbish, even temporarily, in escape routes, or where it can contact potential sources of heat
- Position skips so that a fire will not put any structure at risk
- Clean cooking surfaces on a regular basis to prevent grease build-up
- Rags and cloths which have been used to mop up or apply flammable liquids should be disposed of in metal containers with well-fitting lids and removed from the workplace at the end of each shift or working day
- Handle material in accordance with the advice on the safety data sheet
- Keep safety data sheets readily available
- Keep safety data sheets safely available in the event of a fire so that the information is available for emergency services.

FIRE PROTECTION

Fire is a chemical reaction that requires three elements to be present for the reaction to take place and continue.
The three elements are:

- Heat, or an ignition source
- Fuel
- Oxygen

These three elements typically are referred to as the “fire triangle.” Fire is the result of the reaction between the fuel and oxygen in the air. Scientists developed the concept of a fire triangle to aid in understanding of the cause of fires and how they can be prevented and extinguished. Heat, fuel and oxygen must combine in a precise way for a fire to start and continue to burn. If one element of the fire triangle is not present or removed, fire will not start or, if already burning, will extinguish. Ignition sources can include any material, equipment or operation that emits a spark or flame—including obvious items, such as torches, as well as less obvious items, such as static electricity and grinding operations. Equipment or components that radiate heat, such as kettles, catalytic converters and mufflers, also can be ignition sources. Fuel sources include combustible materials, such as wood, paper, trash and clothing; flammable liquids, such as gasoline or solvents; and flammable gases, such as propane or natural gas. Oxygen in the fire triangle comes from the air in the atmosphere. Air contains approximately 79 percent nitrogen and 21 percent oxygen. OSHA describes a hazardous atmosphere as one which is oxygen-deficient because it has less than 19.5 percent oxygen, or oxygen enriched because it has greater than 23.5 percent oxygen. Either instance is regarded by OSHA as an atmosphere immediately dangerous to life and health (IDLH) for reasons unrelated to the presence of fire. Depending on the type of fuel involved, fires can occur with much lower volume of oxygen present than needed to support human respiration. Every roofing project has all three of the fire triangle elements present in abundance. The key to preventing fires is to keep heat and ignition sources away from materials, equipment and structures that could act as fuel to complete the fire triangle.

Fire Classifications Fires are classified as A, B, C, D or K based on the type of substance that is the fuel for the fire, as follows:

Class A—
fires involving ordinary combustibles, such as paper, trash, some plastics, wood and cloth. A rule of thumb is if it leaves an ash behind, it is a Class A fire.

Class B—
fires involving flammable gasses or liquids, such as propane, oil and gasoline

Class C—
fires involving energized electrical components

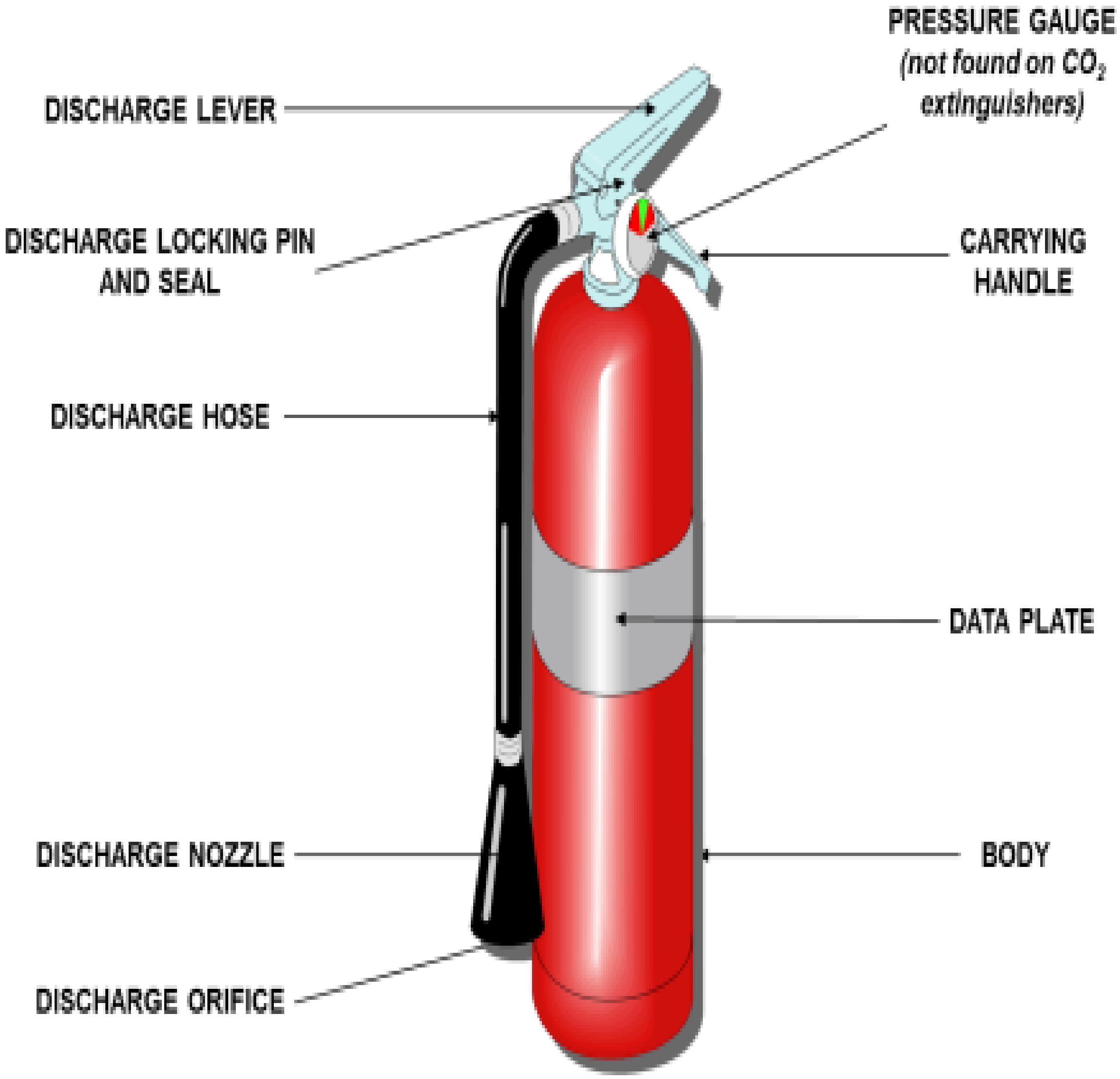
Class D—
fires involving metal. A rule of thumb is if the name of the metal ends with the letters "um," it is a Class D fire. Examples of this are aluminum, magnesium, beryllium and sodium. Class D fires rarely occur in the roofing industry.

Class K—
fires involving vegetable or animal cooking oils or fats; common in commercial cooking operations using deep fat fryers.

Fire Extinguishers There are different types of fire extinguishers designed to put out the different classes of fire. Selecting the appropriate fire extinguisher is an important consideration for a roofing contractor.

The wrong extinguisher actually may make a fire emergency worse. For example, failing to use a Crated extinguisher on energized electrical components may endanger workers by causing the extinguishing material to be electrified by the energized components that are on fire. C-rated fire extinguishers put out the fire by using a chemical that does not conduct electricity.

Fire Extinguisher Anatomy

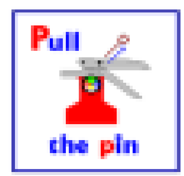


The following table illustrates the types of extinguishers, fire classes for which each is used and the limitations of each extinguisher.

Fire Extinguisher Type	*Class of Fire It Extinguishes*	*Extinguisher Limitations/ Comments*
Dry Chemical (multipurpose)	*A, B, C*	*Generally good for use in roofing industry*
Foam—alcohol-resistant and aqueous film-forming foam (AFFF) types	*B*	*Expensive; effective on Class B only; limited shelf life; generally not needed in roofing industry*
Water	*A*	*Good only for Class A fires*
Metal X	*D B, C;*	*Expensive; must be kept dry; ineffective on A, typically not needed in roofing industry*
Carbon Dioxide	*B, C*	*If used in confined areas, will create oxygen deficiency; not effective in windy conditions; can cause frostbite during discharge; typically not used in roofing industry*
Halon	*B, C*	*Expensive; not effective in windy conditions; toxic gases may be released in extremely hot fires because of decomposition; generally not used in roofing industry*
Potassium Acetate	*K*	*Expensive, wet chemical extinguisher for commercial cooking operations using oils and fats*

Remember this easy acronym when using an extinguisher - P.A.S.S.

Pull the pin.



Aim the nozzle.

Squeeze the handle.

Sweep side to side at the base of the fire.

Employees should be instructed that if a fire cannot be extinguished using one full extinguisher, they should evacuate the site and let the fire department handle the situation.

EMERGENCY EVACUATION

Emergency evacuation is the urgent immediate egress or escape of people away from an area that contains an imminent threat, an ongoing threat or a hazard to lives or property.

Examples range from the small-scale evacuation of a building due to a storm or fire to the large-scale evacuation of a city because of a flood, bombardment or approaching weather system, especially a Tropical Cyclone. In situations involving hazardous materials or possible contamination, evacuees may be decontaminated prior to being transported out of the contaminated area.

Evacuation Sequence

The sequence of an evacuation can be divided into the following phases:

1. detection
2. decision
3. alarm
4. reaction
5. movement to an area of refuge or an assembly station
6. transportation

The time for the first four phases is usually called pre-movement time.
The most common equipment in buildings to facilitate emergency evacuations are fire alarms, exit signs, and emergency lights. Some structures need special emergency exits or fire escapes to ensure the availability of alternative escape paths.

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Additional information

- https://www.old.iitr.ac.in/safety/Indian%20Standards/1641%20FIRE%20SAFETY%20OF%20BUILDINGS.pdf
- https://www.old.iitr.ac.in/safety/Indian%20Standards/1643%20FIRE%20SAFETY%20OF%20BUILDINGS-EXPOSURE%20HAZARDS.pdf
- https://www.old.iitr.ac.in/safety/Indian%20Standards/1644%20FIRE%20SAFETY%20OF%20BUILDINGS-EXIT%20REQUIREMNETS%20&%20PERSONAL%20HAZARDS.pdf
- https://www.old.iitr.ac.in/safety/Indian%20Standards/1646%20FIRE%20SAFETY%20OF%20BUILDINGS-ELECTRICAL%20INSTALATION.pdf
- https://www.old.iitr.ac.in/safety/Indian%20Standards/1905%20FIRE%20SAFETY%20OF%20BUILDINGS-FF%20EQUI.%20&%20INSTALLATION%20OF%20FIRE%20PROOF%20DOORS.pdf

GAS CYLINDER SAFETY

Certain specific properties of compressed gases make them highly useful in various research activities. These gases, however, can be dangerous if not handled in an appropriate manner. Many of the odorless and colorless gases are highly toxic and flammable and this calls for utmost care while handling them.

TYPES OF GASES

- **Flammable gas**

Flammable gas burns or explodes if it is mixed with air, oxygen or other oxidant, in the presence of a source of ignition.

- **Inert gas**

Inert gas is resistant to chemical action under normal temperature and pressure conditions.

- **Oxidizing gas**

Oxidizing gas supports combustion.

- **Pyrophoric gas**

Pyrophoric gas spontaneously ignites upon exposure to air.

- **Corrosive gas**

Corrosive gas can burn and destroy body tissues on contact. Corrosive gases can also attack and corrode metals.

- **Poisonous (Toxic) gas**

Poisonous (Toxic) gas is harmful to humans when it exceeds the maximum allowable concentration in air.

HAZARDS IN GAS CYLINDER USAGE

- Oxygen deficient atmosphere resulting in asphyxiation.
- Formation of flammable gas air mixtures in case of leakage of flammable gas.
- Oxygen enriched atmosphere in case of leakage of oxygen gas.
- Injury caused by fall of gas cylinders during handling.
- Exposure to high concentrations of toxic or corrosive gases in case of leakage.
- Gas cylinders can explode when exposed to high temperatures, e.g., in case of fire.
- If the valve breaks, the sudden release of compressed gas can turn it into a lethal projectile.
- Gas cylinders should be capped when they are not connected to the system.

Oxygen deficiency:

Leakage of any gas (except oxygen) inside a confined/enclosed space can cause displacement of oxygen resulting in an oxygen deficient atmosphere. Entry into a workspace with oxygen level below 19.5% is unsafe and not permitted.

Oxygen levels and effects:

Above 21%	Oxygen enriched atmosphere
20.95%	Normal atmospheric level
19.5%	Minimum required level
19.5 -12%	Increased breathing rates, accelerated heartbeat, and impaired thinking.
0-12%	Faulty judgment, intermittent respiration, and exhaustion
6-10%	Nausea and unconsciousness
Less than 6%	Cessation of breathing followed by cardiac arrest

Oxygen enrichment:

- An atmosphere having more than 21% of oxygen is considered as an oxygen enriched atmosphere and is not safe for entry/working.
- A leakage of oxygen gas in an enclosed space can result in an oxygen enriched atmosphere.
- An excess of oxygen in the air can be a fire hazard, as oxygen is a supporter of combustion and it causes materials to burn violently.

Flammable vapour air mixtures:

- A leakage of a flammable gas would form a flammable vapour air mixture.
- If the vapour air mixture is within the flammable range, it can explode in the presence of an ignition source.

Flammability limits:

- Vapour air mixtures will only ignite within a well-specified range of composition.
- The lower flammable limit (LFL) is the leanest mixture that can ignite, i.e., the mixture with the smallest fraction of combustible gas.
- The upper flammable limit (UFL) is the richest fraction of combustible gas mixture that can ignite.

Toxicity:

Toxicity is the ability of a substance to produce an unwanted physiological effect when the substance has reached a sufficient concentration at a certain site in the body.

Toxicity-Threshold Limit Value(TLV):
The concentration of an airborne substance to which an average person can be repeatedly exposed without adverse effects.

PURCHASING/ RECEIVING GAS CYLINDERS

- Purchase smallest quantities wherever and whenever possible.
- When receiving gas cylinders:
  Ensure that they are properly labeled.
  Do not accept cylinders without label of the content.

- Visually inspect for damage.
- Ensure that the gas cylinders are received with valve caps.

STORAGE OF GAS CYLINDERS

- Gas cylinders must be stored in a separate storage area outside the building.
- The storage area must be protected from weather.
- Flammable gas cylinders must be separated from oxygen cylinders by a distance of 6m or by a wall of 30 minutes fire resistance.
- Empty cylinders must be marked /tagged and stored separately.

STORAGE OF GAS CYLINDERS INSIDE LABS

- Only gas cylinders for immediate use must be stored inside the laboratory.
- Materials must not be stored in front or on top of gas cylinders.
- All cylinders in the laboratories must be clearly labeled.
- Gas cylinders must not be stored near exits and passages.
- Gas cylinders must be stored away from heat sources.
- Place the valve cap on the cylinder whenever the regulator is removed.
- Cylinders must always be kept chained or supported in a manner to prevent fall.

TRANSPORTATION OF GAS CYLINDERS INSIDE LABS

Before moving gas cylinder

- Valve must be closed.
- Regulator must be removed.
- Cylinder must be capped.
- Secure the cylinder in a cylinder cart (with chain).

SAFE USE OF GAS CYLINDERS

- Refer the Material Safety Data Sheet (MSDS) for the gas before usage, to know about the hazards and precautions to be taken.

- Do not tamper with the cylinder valves.
- Always use the correct regulator for the cylinder.
- Inspect the regulator for damage before use.
- Never use damaged regulators, piping, etc.
- After the regulator is attached, the cylinder valve must be opened just enough to indicate pressure on the regulator gauge and all connections must be checked with a compatible solution for leaks.
- Do not stand in front of the regulator gauge or the valve outlet side, while opening the valve.
- Use safety glasses while working with gas cylinders.
- Before a regulator is removed from a cylinder, the cylinder valve must be closed and the regulator relieved of gas pressure.
- Ensure proper ventilation in the area where gas cylinders are stored.
- Spindle key must always be placed at an easily accessible location, for closing the valve in case of emergency.
- A cylinder must never be emptied to a pressure lower than 25 psi as the residual contents may become contaminated if the valve is left open.
- Close cylinder valve whenever:
  work is finished
  cylinder is empty
- Store toxic/pyrophoric gases in gas cabinets.
- Gas detectors must be installed for detecting gas leaks.
- The cylinder valve and other fittings used with gas cylinders must be compatible with the type of gas used. Incompatible materials can cause gas leak.
- Greasy and oily materials must never be used on oxygen cylinders or fittings as it can cause explosion.
- Regulators for oxygen service must never be used with flammable gases. Cross contamination of internal parts may result in rapid oxidation and fire.
- If a gas leak occurs from the cylinder inside the gas cabinet it must not be removed from the cabinet.

EMERGENCY MEASURES

- No attempt must be made to repair a leak from the base of the valve.
- Personal protective equipment must be used while dealing with toxic/corrosive gas leaks.

- The building must be evacuated immediately if a gas (flammable/pyrophoric/toxic/corrosive) leak becomes uncontrollable.
- Emergency measures must be undertaken only by trained personnel.
- The gas supplier must be intimated immediately.
- Self Contained Breathing Apparatus(SCBA) must be used while dealing with toxic/corrosive gas leaks or if an oxygen deficient atmosphere exists.
- Contact Emergency team in case of any support required.

Cryogen Safety

Manage Cryogen Safely-

A cryogenic liquid is defined as a liquid with a normal boiling point below -240°F (-150°C, 123°K). The most commonly used industrial gases that are transported, handled, and stored in the liquid state at cryogenic temperatures are argon, helium, hydrogen, nitrogen, and oxygen. There are a number of general precautions and safe practices that must be observed because of the extremely low temperatures and high rates of conversion into gas of all the cryogenic liquids. There are also specific precautions that must be followed where a particular liquid may react with contaminants or may present other hazards associated with that particular product such as asphyxiation or flammability. As always, end users should have and be thoroughly familiar with the Material Safety Data Sheet (MSDS) for their specific product. All operators must be familiar with the instructions provided with the equipment to be used with the cryogenic liquid. The vapors and gases released from cryogenic liquids also remain very cold. They often condense the moisture in air, creating a highly visible fog. In poorly insulated containers, some cryogenic liquids actually condense the surrounding air, forming a liquid air mixture

Properties of cryogenic fluids:

- Extreme low temperatures.
- Large ratio of expansion in volume from liquid to gas.
- Most cryogenic liquids are odourless and colourless when vapourised to gas.
- Boiling points of cryogens
  Helium - 269.9 0C
  Hydrogen - 252.7 0C
  Neon - 245.9 0C
  Nitrogen - 195.8 0C
  Oxygen - 183.0 0C
- Liquid to gas expansion ratios of cryogens Helium 1 to 757
  Hydrogen 1 to 851
  Neon 1 to 1438
  Nitrogen 1 to 696
  Oxygen 1 to 860

Storage

- Cryogenic fluids are stored in well insulated containers to minimize loss due to boil off.
- The most commonly used container for handling cryogenic fluids is the Dewar flask.
- Dewar flasks are non-pressurized, vacuum jacketed vessels.

Handling-

Always handle cryogenic liquids carefully. Their extremely low temperatures can produce cryogenic burns of the skin and freeze underlying tissue. When spilled on a surface, they tend to spread as far as the quantity of liquid spilled and the physical confines of the area permit. They can cool large areas. The vapors coming from these liquids are also extremely cold and can produce burns. Exposure to these cold gases, which is too brief to affect the skin of the face or hands, may affect delicate tissues, such as the eyes. Stand clear of boiling and splashing liquid and the cold vapors that are released. Boiling and splashing always occur when filling a warm container or when inserting objects into the liquid. Always perform these operations slowly to minimize the splashing and boiling. Never allow any unprotected part of your body to touch uninsulated pipes or vessels containing cryogenic liquids. The extremely cold material may stick fast to skin and tear the flesh when you attempt to withdraw it. Even nonmetallic materials are dangerous to touch at these low temperatures. Use tongs to immerse and remove objects from cryogenic liquids. In addition to the hazards of frostbite or flesh sticking to cold materials, objects that are soft and pliable at room temperature, such as rubber or plastics, are easily broken because they turn brittle at low temperatures and may break when stressed.

Personal Protective Equipment (PPE):

One must be thoroughly familiar with the properties and safety considerations before handling a cryogenic liquid and its associated equipment. The eyes are the most sensitive body part to the extreme cold of the liquid and vapors of cryogenic liquids. The recommended personal protective equipment for handling cryogens includes a full face shield over safety glasses, loose-fitting thermal insulated or leather gloves, long sleeve shirts, and trousers without cuffs. In addition, safety shoes are recommended for people involved in the handling of containers. Depending on the application, special clothing suitable for that application may be advisable. A special note on insulated gloves: Gloves should be loose-fitting so they are able to be quickly removed if cryogenic liquid is spilled on them. Insulated gloves are not made to permit the hands to be put into a cryogenic liquid. They will only provide short-term protection from accidental contact with the liquid. In emergency situations, self-contained breathing apparatus (SCBA) may be required.

Special Inert Gas Precautions:

The potential for asphyxiation must be recognized when handling inert cryogenic liquids. Because of the high expansion ratios of cryogenic liquids, air can quickly be displaced. Oxygen monitors are recommended whenever cryogenic liquids are handled in enclosed areas. People should not be permitted in atmospheres containing less than 19.5% oxygen without supplied air. Liquid helium has the potential to solidify air, which can block pressure-relief devices and other container openings. This can result in pressure buildup that may rupture the container.

Special Oxygen Precautions:

There can be no open flames in any areas where liquid oxygen is stored or handled. Do not permit liquid oxygen or oxygen-enriched air to come in contact with organic materials or flammable or combustible substances of any kind. Some of the organic materials that can react violently with oxygen when ignited by a spark or even a mechanical shock are oil, grease, asphalt, kerosene, cloth, tar, and dirt that may contain oil or grease. If liquid oxygen spills on asphalt or other surfaces contaminated with combustibles, do not walk on or roll equipment over the spill area. Keep sources of ignition away for 30 minutes after all frost or fog has disappeared. Any clothing that has been splashed or soaked with liquid oxygen or exposed to high oxygen concentrations should preferably be removed immediately and aired for at least an hour. Personnel should stay in a well-ventilated area and avoid any source of ignition until their clothing is completely free of any excess oxygen. Clothing saturated with oxygen is readily ignitable and will burn vigorously.

Special Hydrogen Precautions:

No ignition of any kind in any area where liquid hydrogen is stored or handled. All major pieces equipment should be properly grounded. All electrical equipment and wiring should be in accordance with National Fire Protection Association Pamphlet 50B and/or National Electrical Code, Article 500. Boil-off gas from closed liquid hydrogen containers used or stored inside buildings must be vented to a safe location. Liquid hydrogen should not be poured from one container to another, or transferred in an atmosphere of air. If this is done, the oxygen in the air will condense in the liquid hydrogen, presenting a possible explosion hazard. Liquid hydrogen also has the potential of solidifying air which can block safety relief devices and other openings, which may lead to rupture of the container. Dewars and other containers made of glass are not recommended for liquid hydrogen service. Breakage makes the possibility of explosion too hazardous to risk. Every effort must be made to avoid spills, regardless of the rate of ventilation, because it is impossible to avoid creating a flammable vapor cloud.

About Venting From Cryogenic Liquid Containers:

All cryogenic containers vent to atmosphere to prevent hazardous pressure buildup inside the container. Typically, there are two levels relatively low pressure vent valves plus a frangible disk that will blow out and vent the entire container if the internal pressure goes beyond a certain point. In order to prevent total evacuation of the container DO NOT VALVE OFF the low pressure poppet valves. While they can be noisy, they are also necessary. Continuous venting is not normal, this could mean that there is dirt in the vent valve or that it is otherwise damaged. If this occurs, CALL THE VENDOR and ask them to pick up and exchange the container ASAP. While frost around the top of a venting container is just indicative that the cold, venting vapors are condensing the moisture in the air, frost at the bottom or on the sides of the cylinder indicate that the container is fault y and damaged. Again, CALL THE VENDOR and ask them to pick up and exchange the container ASAP. If the container is dented or otherwise physically damaged, it should not be accepted from the vendor.

First aid:

People suffering from lack of oxygen should be moved to fresh air. If the victim is not breathing, administer artificial respiration. If breathing is difficult, administer oxygen. Obtain immediate medical attention. Self-contained breathing apparatus (SCBA) may be required to prevent asphyxiation of rescue personnel. For skin contact with cryogenic liquid nitrogen, remove any clothing that may restrict circulation to the frozen area. Do not rub frozen parts, as tissue damage may result. As soon as practical, place the affected area in a warm water bath that has a temperature not in excess of 105°F (40°C). Never use dry heat. Call a physician as soon as possible. Frozen tissue is painless and appears waxy with a possible yellow color. It will become swollen, painful, and prone to infection when thawed. If the frozen part of the body has been thawed, cover the area with a dry sterile dressing with a large bulky protective covering, pending medical care. In the case of massive exposure, remove clothing while showering the victim with warm water. Call a physician immediately. If the eyes are exposed to the extreme cold of the liquid nitrogen or its vapors, immediately warm the frostbite area with warm water not exceeding 105°F (40°C) and seek immediate medical attention.