ENGINEERING STANDARD

FOR

CLASSIFICATION OF FIRES AND FIRE HAZARD PROPERTIES

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PAGE No.

1. SCOPE

This Engineering Standard covers the general features and rules and minimum requirements for extinguishing fires in the related industries. Fire hazards, occupancy hazards, extinguishing methods, hazard identifications and classification etc. are also discussed.

2. REFERENCES

Throughout this Standard the following standards and codes are referred to. The editions of these standards and codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, form a part of this Standard. The applicability of changes in standards and codes that occur after the date of this Standard shall be mutually agreed upon by the Company and the Vendor/Consultant.

API (AMERICAN PETROLEUM INSTITUTE)

API RP 500A-1982 "Classification of Locations for Electrical Installations in Petroleum Refineries"

ASTM (AMERICAN SOCIETY FOR TESTING AND MATERIALS)

ASTM D 5-78	"Test for Penetration for Bituminous Materials"
ASTM E 681	"Determination of Flammable Limits"
ASTM D 86	"Standard Method of Test for Distillation of Petroleum Products"

IPS (IRANIAN PETROLEUM STANDARDS)

IPS-E-SF-200	"Sprinkler Systems"
IPS-E-SF-220	"Fire Water Distribution and Storage Facilities"
IPS-E-SF-380	"Fire Protection in Buildings"
IPS-E-EL-110	"Electrical Area Classification"

IP (INSTITUTE OF PETROLEUM)

IP part 15	"Electrical Area Classification"

3. DEFINITIONS AND TERMINOLOGY

3.1 Basic Method of Fire Fighting

Three factors shall be considered as follows:

Smothering

Reducing the feed of oxygen to the fire in order to prevent combustion.

Cooling

Keeping the surrounding areas of fire cooled by water to prevent spread of fire.

Starving

Cutting off the fuel supplying the fire.

3.2 Boiling Point

It is the temperature of a liquid at which the vapor pressure of the liquid equals the atmospheric pressure.

3.3 Classification of Construction

It is defined as classifying types of construction by surveying and allocating proper construction classification numbers to different types of structures.

3.4 Classification of Fires

Standardized system of classifying fires in terms of the nature of the fuel. The four classes of fires are A, B, C and D. For separate description of each class refer to Clause Numbers 5.1.1 to 5.1.4.

3.5 Classification of Hazard

It is selection of extinguishing agents for the specific class(es) of occupancy hazards to be protected and is classified as follows:

a) Light (Low) hazard.
b) Ordinary (Moderate) hazard.
c) Extra (High) hazard.

3.6 Classification of Occupancy Hazard

It is defined as classifying occupancies hazard in relation to their quantity and combustibility of contents by surveying and allocating proper occupancy hazard classification numbers to different occupancies.

3.7 Construction Classification Numbers

It is a series of numbers from 0.5 to 1.50 that are mathematical factors used in a formula to determine total water supply requirement of this Standard only.

3.8 Degrees of Health Hazards

Degrees of hazards are ranked according to the probable severity of hazard to personnel and are numbered from 4 to 0.

Number 4 has a severe hazard degree and Number 0 offers no hazard degree.

3.9 Degrees of Flammability Hazards

The degrees of hazards are ranked according to the susceptibility of materials to burning and are numbered from 4 to 0.

Number 4 has a severe hazard that materials will burn readily.

Number 0 indicates that materials will not burn.

3.10 Degrees of Reactivity Hazards

The degrees of hazards are ranked according to ease, rate and quantity of energy released, and are numbered from 4 to 0.

Number 4 is for materials which readily detonate or explode at normal temperature and pressure.

Number 0 is for materials which are normally stable and not reactive with water.

3.11 Electrical Area Classification, Extent

Areas are classified into three zones:

ZONE "O" is an area in which an explosive gas atmosphere is present continuously or is present for long period.

ZONE "1" is an area in which an explosive gas atmosphere is likely to occur in normal operation.

ZONE "2" is an area in which an explosive atmosphere is not likely to occur in normal operation and if it does occur it will exist for a short period only.

3.12 Fire

1) Process of combustion characterized by the emission of heat accompanied by smoke or flame or both.
2) Combustion spreading uncontrolled in time and space

3.13 Fire Hazard

Any situation process, material or condition that on the basis of applicable data, may cause a fire or explosion or provide a ready fuel supply to augment the spread or intensity of the fire or explosion and that poses a thread to life or property.

3.14 Fire Hazard Properties

Properties measured under laboratory conditions may be used as elements of fire risk assessment only when such assessment takes into account all of the factors which are pertinent to the evaluation of the fire hazard of a given situation.

3.15 Flammability Hazard

It is the degree of susceptibility of materials to burning. Many materials which will burn under one set of conditions will not burn under others. The form or condition of the material, as well as its inherent properties, effects the hazard.

3.16 Flammable (Explosive) Limits

All combustible gases and vapors are characterized by flammable limits between which the gas or vapor mixed with air is capable of sustaining the propagation of flame. Lower limit and upper limit are usually expressed as percentage of the material mixed with air by volume.

3.17 Flammable (Explosive) Range

The range of flammable vapor or gas air mixture between the upper and lower flammable limits is known as the " flammable range "or "explosive range".

3.18 Flash Point

Minimum temperature of liquid which it gives off sufficient vapor to form an ignitable mixture with the air near the surface of the liquid or within the vessel used.

3.19 Fire Point

The lowest temperature at which a liquid in an open container will give off sufficient vapors to burn when once ignited. It generally is slightly above the flash point.

3.20 Health Hazard

It is any property of material which either directly or indirectly can cause injury or incapacitation, either temporary or permanent from exposure by contact, inhalation or ingestion.

3.21 Ignition Temperature

Minimum temperature under prescribed test conditions at which the material will ignite and sustain combustion when mixed with air at normal pressure, without initiation of ignition by spark or flame.

3.22 Melting Point

It is the temperature at which a solid of a pure substance changes to a liquid.

3.23 Occupancy Hazard Classification Number

It is a series of numbers from 3 through 7 that are mathematical factors to be used in calculating total water supplies for fire fighting and fire protection.

NFC Standards has allocated number 3 which is the lowest occupancy hazard number as the highest hazard grouping and number 7 which is the highest occupancy hazard number as the lowest hazard grouping.

For separate description of each number refer to Clause numbers 7.3 to 7.7.

3.24 Reactivity Hazard

Susceptibility of materials to release energy either by themselves or in combination with water.

3.25 Relative Vapor Density

It is the mass of a given volume of the material in its gaseous or vapor form compared with the mass of an equal volume of dry air at the same temperature and pressure.

3.26 Specific Gravity

It is the ratio of the weight of the substance to the weight of the same volume of water or air whichever is applicable.

3.27 Water Solubility

The extent to which a substance mixes with pure water to form a molecular homogeneous system at a given temperature.

4. UNITS

International System of Units (SI) in accordance with IPS-E-GN-100 shall be used.

5. CLASSIFICATION OF FIRES

5.1 Designation of Classes of Fires

The following designations shall be used for the purpose of classifying fires of different natures, in order to simplify spoken and written reference to them.

5.1.1 Class A

These are fires involving solid materials, usually of organic nature in which combustion normally takes place with the formation of glowing embers. Wood, cloth, paper, rubber, and many other combustible materials are some examples.

5.1.2 Class B

These are fires involving liquids or liquefiable solids which are flammable or combustible including gases or greases.

5.1.3 Class C

These are fires involving gases or materials in contact with energized power (when electrical equipment is de-energized the fire may continue to burn as a Class A,B or D fire).

5.1.4 Class D

These are fires involving combustible metals, such as Magnesium, Titanium, Zorconium. Sodium and Potassium.

6. CLASSIFICATION OF HAZARDS

This section denotes selection of extinguishing agents for the specific class (es) of occupancy hazards to be protected, and is classified as follows:

6.1 Light (Low) Hazard

Light hazard occupancies are locations where the total amount of Class A combustible materials, including furnishings, decorations and contents, are of minor quantity. This may include some buildings or rooms occupied as offices, classrooms, assembly halls, etc. This classification anticipates that the majority of contents items are either noncombustible or so arranged that a fire is not likely to spread rapidly. Small amounts of Class B flammables are included, provided that they are kept in closed containers and safely stored.

6.2 Ordinary (Moderate) Hazard

Ordinary hazard occupancies are locations where the total amount of Class A combustibles and Class B flammables are present in greater amounts than expected under Light (Low) Hazard Occupancies. These occupancies could consist of offices, classrooms, mercantile shops and allied storage, light manufacturing halls, research operations centers, auto showrooms, parking garages, workshops or support service areas of Light (Low) Hazard Occupancies, and warehouses containing Class I or Class II commodities, as defined in IPS-E-SF-380.

6.3 Extra (High) Hazard

Extra hazard occupancies are locations where the total amount of Class A combustibles and Class B flammables present, in storage, production, use, and/or finished product is over and above those expected and classed as ordinary (moderate) hazards. These occupancies could consist of woodworking, vehicle repair, aircraft and boat servicing, individual product display showrooms, product convention center displays, storage and manufacturing processes such as painting, dipping, coating, including flammable liquid handling refineries, petrochemical gas treating plants and stations. Also included is warehousing of or in process storage of other than Class I and Class II commodities.

7. CLASSIFICATION OF OCCUPANCY HAZARDS

This Section classifies occupancy hazards in relation to their quantity and combustibility of contents by surveying and allocating proper occupancy hazard classification numbers to different occupancies where adequate and reliable water supply systems do not exist.

7.1 General

7.1.1 Responsible authorities upon completing the survey specified below shall determine the Occupancy Hazard Classification Number as specified in 7.1.2 hereunder.

7.1.2 Responsible authorities shall perform an on site survey of all buildings, including type of construction, occupancies, and exposure, within the applicable jurisdiction to obtain the information needed to compute the total water supplies required. At the time of the on site survey, a record shall be prepared of available water supplies. This information is to be utilized for prefire planning purposes.

7.1.3 Residential areas may be surveyed as an area to determine square meters or cubic meters of each structure and distance to structural exposure hazards, but without a survey of contents.

7.1.4 These surveys may be combined with fire prevention or prefire planning inspections.

7.1.5 Occupancy Hazard Classification Numbers shall not be assigned to any structure not surveyed as specified in 7.1.2 above.

7.1.6 An Occupancy Hazard Classification Number shall not be assigned to any building when such building is protected by an automatic sprinkler system installed in accordance with applicable standard (see. IPS-E-SF-380).

7.1.7 Storage of products potentially hazardous from the standpoint of increased fire volume or of an explosive nature exists at many rural locations, and such products may be in sufficient quantities to increase the Occupancy Hazard Classification Number of the building.

7.2 Occupancy Hazard Classification Number

7.2.1 A series of numbers from 3 through 7 that are mathematical factors used in a formula to determine total water supply requirements of this standard only. The formulas are given in fire water distribution facilities under reference No. IPS-E-SF-220.

7.2.2 The occupancies listed in each section are only examples of types of occupancies for the particular classification, and these lists of examples shall not be interpreted as being exclusive. Similar occupancies shall be assigned the same Occupancy Hazard Classification Number.

7.2.3 Where more than one occupancy is present in a structure, the Occupancy Hazard Classification Number for the most hazardous occupancy shall be used for the entire structure.

7.3 Occupancy Hazard Classification Number 3

7.3.1 Occupancies in this classification are considered Severe Hazard Occupancies, where quantity and combustibility of contents are very high. Fire in these occupancies can be expected to develop very rapidly and have high rates of heat release.

7.3.2 When an exposing structure is of Occupancy Hazard Classification Number 3, it is considered an exposure hazard if within a distance of 15.2 m regardless of size.

7.3.3 Occupancy Hazard Classification Number 3 example in oil, gas and petrochemical industries include:

- Aircraft Hangars
- Flour Mills

- Chemical Works and Plants
- Petrochemical works and Plants
- Explosive Storage
- Oil Terminals
- Grain Elevators and Warehouses
- Lumberyards
- Gas Compressors Stations
- Oil Refineries
- Gas Refineries
- Plastic Manufacturing and Storage
- Crude Oil Production Units
- Crude Oil Booster Stations
- Solvent Extracting
- Varnish and Paint Storage

7.4 Occupancy Hazard Classification Number 4

7.4.1 Occupancies in this classification are considered High Hazard Occupancies, where quantity and combustibility of contents are high. Fires in these occupancies can be expected to develop rapidly and have high rates of heat release.

7.4.2 When an exposing structure is of Occupancy Hazard Classification Number 4, it is considered an exposure hazard if within a distance of 15.2 m regardless of size.

7.4.3 Occupancy Hazard Classification Number 4 examples include:

- Building Materials
- Department Stores
- Exhibition Halls, Auditoriums, and Theaters
- Feed Stores, (without processing)
- Mercantiles
- Piers and Wharves
- Repair Garage
- Rubber Products Storage
- Warehouses, such as:
  - Paper
  - Furniture
  - Paint
  - Department Store
  - General Storage
- Wood Working Shops

7.5 Occupancy Hazard Classification Number 5

7.5.1 Occupancies in this classification are considered Moderate Hazard Occupancies, where quantity and combustibility of contents are moderate and stockpiles of combustibles do not exceed 3.7 m in height. Fires in these occupancies can be expected to develop quickly and have moderately high rates of heat release.

7.5.2 Occupancy Hazard Classification Number 5 examples include:

- Libraries (with large stock room areas)
- Machine Shops
- Metalworking Shops
- Pharmaceutical Stores
- Printing and Publishing Shops
- Restaurants
- Unoccupied Buildings

7.6 Occupancy Hazard Classification Number 6

7.6.1 Occupancies in this classification are considered Low Hazard Occupancies, where quantity and combustibility of contents are moderate and stockpiles of combustibles do not exceed 2.44 m in height. Fires in these occupancies can be expected to develop at a moderate rate and have moderate rates of heat release.

7.6.2 Occupancy Hazard Classification Number 6 examples include:

- Automobile Parking Garages
- Bakeries
- Barber or Beauty Shops
- Boiler Houses

7.7 Occupancy Hazard Classification Number 7

7.7.1 Occupancies in this classification are considered Light Hazard Occupancies, where quantity and combustibility of contents are low. Fires in these occupancies can be expected to develop at a relatively low rate and have relatively low rates of heat release.

7.7.2 Occupancy Hazard Classification Number 7 examples include:

- Apartments
- Colleges and Universities
- Dormitories
- Dwellings
- Fire Stations
- Hospitals
- Hotels & Guest Houses
- Libraries (Except large stock room areas)
- Offices (including data processing)
- Guard Houses
- Schools

8. CLASSIFICATION OF CONSTRUCTION

Classifying types of construction by surveying and allocating proper number to different types of structures and a series of numbers from 0.5 to 1.5 that are mathematical factors are used in a formula to determine total water supply requirement of this standard only.

According to NFC standards the "Slowest Burning" or lowest hazard type of construction, fire resistive, takes a construction classification number of 0.50. The "fastest burning" or highest hazard type construction, wood frame, takes a construction class number of 1.50.

8.1 General

8.1.1 Responsible authorities upon completing the survey specified in 8.1.2 below shall determine the Construction Classification Number from the sections of this standard.

8.1.2 For the purpose of this standard, each building surveyed shall be classified as to type of construction and shall be assigned, Construction Classification Number. However, no dwelling shall be assigned a Construction Classification Number higher than 1.0. All dwellings shall be assigned a Construction Classification No. 1 or lower when construction is non combustible or fire resistive.

8.1.3 Construction Classification Numbers shall not be assigned to any structure not surveyed as specified in 8.1.2 above.

8.1.4 Where more than one type of construction is present in a structure, the higher Construction Classification Number shall be used for the entire structure.

8.1.5 When a building is located within 15.2 m of the surveyed building and is 9.3 m^2 or greater in total area, the building is treated as an exposure with the water requirement calculated by the standard multiplied by 1.5.

8.2 Construction Classification Number

8.2.1 Fire Resistive Construction, Construction Classification Number 0.5

A building constructed of noncombustible materials (reinforced concrete, brick, stone, etc. and having any metal members properly "fireproofed") with major structural members designed to withstand collapse and prevent the spread of fire.

8.2.2 Noncombustible Construction, Construction Classification Number 0.75

A building having all structural members (including walls, floors, and roofs) of noncombustible materials and not qualifying as fire resistive construction.

8.2.3 Ordinary Construction, Construction Classification Number 1.0

Any structure having exterior walls or masonry or other noncombustible material, in which the other structural members are wholly or partly of wood or other combustible material.

8.2.4 Wood Frame Construction, Construction Classification Number 1.50

Any structure in which the structural members are wholly or partly of wood or other combustible material and the construction does not qualify as ordinary construction.

When a dwelling is classified as wood frame construction (that is, having structural members wholly or partly of wood or other combustible material) assign a Construction Classification Number of 1.0.

9. ELECTRICAL AREA CLASSIFICATION, EXTENT AND METHODS OF SAFEGUARDING OF ELECTRICAL INSTALLATION IN HAZARDOUS AREAS IN OIL, GAS AND PETROCHEMICAL INDUSTRIES

9.1 Full text of the above mentioned title is given in Iranian Petroleum Standard (IPS-E-EL-110 Parts I and II).

10. BASIC METHOD OF FIRE FIGHTING

10.1 Smothering

Reducing the concentration of Oxygen, the vapor phase of the fuel or both in the air to the point where combustion stops will smother fires. Carbon Dioxide is a good extinguishing agent but has disadvantage when used in a confined room or space. It will cause suffocation and endangers the life of those people living in the room.

Inhibiting the chemical reaction of fuel and Oxygen is caused by vaporizing Liquid, such as B.C.F.(or accepted replacement). These agents are specifically used for Class C fires.

10.2 Cooling

The quenching and cooling effects of water or of solutions containing large percentages of water are of first importance from cooling point of view in extinguishing fires involving Class A fires. Where total extinguishment is mandatory, a follow up with water or other Class A agent is essential.

10.3 Starving

Isolation of the sources supplying the fire, that is materials supporting combustion should be isolated by removing or transferring unburnt materials to a safe place.

11. PRINCIPLES OF FIRE PROTECTION

11.1 The principles of fire protection to be followed in a design will be a formulation of statement of requirements having regard to local site conditions such as the degree of potential fire hazard involved, back up available from the local fire service, and other site characteristic.

11.2 Although the requirements in this standards are based on established IPS standards, they must be considered in conjunction with governmental regulations and when these differ substantially from IPS standards, revision will be carried out accordingly.

11.3 The location of the site of fire station shall be sufficiently remote from installations to ensure that its operation is not impaired by incidents on them.

11.4 Equipment and its operating pressures within the works shall be compatible with that of outside fire brigades who may be called in the event of a major fire. This is of particular importance in relation to adapter, hoses and hose couplings.

11.5 Mutal aid arrangements will where possible, be formulated with other operating companies in the immediate area as part of an overall emergency plan.

Such aid should extend to mobile and portable fire equipment with or without manpower, integration of piped water supplies and fire pumping capability, foam stocks and use of specialized and selective items of safety equipment and mobile plant.

12. FIRE HAZARD PROPERTIES

The use of any single fire hazard property such as flash point, ignition temperature, etc., should not be used to describe or appraise the hazard or fire risk of a material, product, assembly or system under actual fire conditions. The subject fire hazard properties have been determined under controlled laboratory conditions and may properly be employed to measure or describe the response of materials, products, assemblies or systems under these conditions.

Properties measured under such conditions may be used as elements of a fire risk assessment only when such assessment takes into account all of the factors which are pertinent to the evaluation of the fire hazard of a given situation. Properties of the flammable materials are generally for materials in the pure form and may be different if there are impurities or where there are mixtures of materials.

12.1 Flash Point

Flash point of the liquid is the minimum temperature at which it gives off sufficient vapor to form an ignitible mixture with the air near the surface of the liquid within the vessel used. By "ignitible mixture" is meant a mixture within the flammable range (between upper and lower limits) that is capable of the propagation of flame* away from the source of ignition when ignited. Some evaporation takes place below the flash point but not in sufficient quantities to form an ignitable mixture. This term applies mostly to flammable and combustible liquids, although there are certain solids, such as camphor and naphthalene, that slowly evaporate or volatilize at ordinary room temperature, or liquids such as benzene that freeze at relatively high temperatures (5.5°C) and therefore have flash points while in the solid state.

The test apparatus used for the measurement of flash point is normally one of two types, of which there are several variants. These are called generally open cup and closed cup flash point testers. For most liquids the flash point determined by the closed cup method is slightly lower (in the region of 5% to 10% when measured in °C) than that determined by the open cup method. Flash points measured by the more sensitive closed cup method are, therefore, normally used and are given in Table 7 of BS. 5345 Part 1.

*** "By propagation of flame is meant the spread of flame from the source of ignition through a flammable mixture. A gas or vapor mixed with air in proportions below the lower limit of flammability may burn at the source of ignition; that is in the zone immediately surrounding the source of ignition, without propagating (spreading) away from the source of ignition. However, if the mixture is within the flammable range, the flame will spread through it when a source of ignition is supplied. The use of the term flame propagation is therefore convenient to distinguish between combustion which takes place only at the source of ignition and that which travels (propagates) through the mixture."**

12.2 Materials Having High Flash Points

Some materials have such high flash points that they do not form flammable mixtures with air at normal ambient temperature, even when exposed to the sun in tropical location. These should not be discounted as ignition hazards, however, because exposure to a suitably hot surface or use of the material at a temperature above its flash point may create a flammable mixture locally, which may be ignited by the same hot surface or an alternative ignition source. It is therefore necessary to consider the limitation of surface temperatures even when materials of high flash point are being processed. A liquid below its flash point can form a flammable mist if released under pressure as a jet.

Materials having high flash points may be used in processes involving high temperatures and possibly high pressures. The normal or accidental release to the atmosphere of compounds under such condition may present local explosion risks that would not normally be associated with high flash point materials. Materials having high flash points can form flammable mixtures with air (at subatmospheric pressure).

12.3 Liquid

For the purpose of this standard any material that has a fluidity greater than that of 300 penetration asphalt when tested in accordance with ASTM D 5-78. "Test for Penetration for Bituminous Materials". When not otherwise identified, the term liquid shall mean both flammable and combustible liquids.

12.3.1 Combustible liquid

A liquid having a flash point at or above 38°C.

Combustible Liquids shall be subdivided as follows:

Class IA liquids shall include those having flash points at or above 38°C and below 60°C.
Class II A liquids shall include those having flash points at or above 60°C and below 93°C.
Class III B liquids shall include those having flash point at or above 93°C.

12.3.2 Flammable liquid

A liquid having a flash point below 38°C and having a vapor pressure not exceeding 275/79 kPa. (absolute) (2.068 mm. Hg) at 38°C shall be known as a Class I liquid.

Class I liquids shall be subdivided as follows:

Class IA shall include those having flash points below 23°C and having a boiling point below 38°C.
Class IB shall include those having flash points below 23°C and having a boiling point at or above 38°C.
Class IC shall include those having flash points at or above 23°C and below 38°C.

12.4 Ignition Temperature

Ignition temperature of a substance, whether solid, liquid, or gaseous, is the minimum temperature required to initiate or cause self-sustained combustion independently of the heating or heated element.

Ignition temperatures observed under one set of conditions may be changed substantially by a change of conditions. For this reason, ignition temperatures should be looked upon only as approximations.

Some of the variables known to affect ignition temperatures are percentage composition of the vapor or gas-air mixture, shape and size of the space where the ignition occurs, rate and duration of heating, kind and temperature of the ignition source, catalytic or other effect of materials that may be present, and oxygen concentration. As there are many differences in ignition temperature test methods, such as size and shape of containers, method of heating and ignition source, it is not surprising that ignition temperatures are affected by the test method.

Ignition temperature of a substance, whether solid, liquid or gaseous is the minimum temperature required to initiate or cause self-sustained combustion in the absence of any source of ignition.

Ignition temperatures observed under one set of conditions may be changed substantially by a change of conditions. For this reason, ignition temperatures should be variables known to affect ignition temperatures are percentage composition of the vapor or gas-air mixture, shape and size of the space in which the ignition occurs, rate and duration of heating and type and reactivity of other materials present in the space in which the ignition occurs. As there are many differences in ignition temperature test methods, such as size and shape of ignition chambers, composition of ignition chambers, method of heating, rate of heating, residence time and method of flame detection, it is not surprising that reported ignition temperatures are affected by the test methods employed.

12.5 Flammable (Explosive) Limits

All combustible gases and vapors are characterized by flammable limits between which the gas or vapor mixed with air is capable of sustaining the propagation of flame.

The limits are called the lower flammable limit (LFL) (lower explosive limit LEL) and the upper flammable limit (UFL) (upper explosive limit UEL) and are usually expressed as percentages of the material mixed with air by volume.

Where flammability is presented for materials with flash points above 40°C, the determinations have been made at an elevated temperature sufficient to give the quoted concentration.

In popular terms, a mixture below the lower flammable limit is too "lean" to burn or explode and a mixture above the upper flammable limit is too "rich" to burn or explode.

Research has shown that the limits of flammability is not a fundamental combustion parameter, but is dependent upon many variables which include, in part, the surface to volume ratio of reaction chamber, the flow direction, and velocity. In some experiments it appears that with laminar flow, the upper limit increases with increasing velocity, reaches a maximum value independent of the tube diameter and then decreases with turbulent flow. On the contrary, the lower limit has been unaffected by flow rate.

ASTM E 681 is an existing standard method for determination of flammability limits. Gases and vapors may form flammable mixtures in atmospheres other than air or oxygen, as for example hydrogen in chlorine.

12.6 Flammable (Explosive) Range

The range of flammable vapor or gas air mixture between the upper and lower flammable limits is known as the flammability range, "also often referred to as the "explosive range". For example, the lower limit of flammability of butane at ordinary ambient temperatures is approximately 1.6 percent vapor in air by volume, while the upper limit of flammability is about 8.4 percent. All concentrations by volume of butane vapor in air falling between 1.6 percent and 8.4 percent are in the flammable or explosive range.

No attempt is made to differentiate between the terms "flammable" and "explosive" as applied to the lower and upper limits of flammability.

Gas/air mixtures outside this range are non flammable under normal atmospheric condition. Concentration above the UFL in free atmospheric conditions cannot be controlled and further dilution with air will produce mixtures within the flammable range.

12.7 Specific Gravity

The specific gravity of a substance is the ratio of the weight of the substance to the weight of the same volume of another substances.*

Specific gravity, as commonly used and as used in the Table 3 refers to the ratio of the weight of a substance to the weight of an equal volume of water.

The figures given in the Table 3 for specific gravity are rounded off to the nearest tenth. For materials having a specific gravity from 0.95 to 1.0 the information is given as 1.0. For those materials with a specific gravity of 1.0 to 1.05 the information is given as 1.0+.

In a few cases, such as the fuel oils, where percentage composition of the substance varies, specific gravity information is given as greater than 1 (>1) or less than 1 (<1).

*** "Temperature affects the volume of liquids, and temperature and pressure affect the volume of gases. It is therefore necessary to make corrections for effects of temperature and pressure when making accurate specific gravity determinations"**

12.8 Relative Vapor Density

The relative vapor density of a material is the mass of a given volume of the material in its gaseous or vapor form compared with the mass of an equal volume of dry air at the same temperature and pressure. It is often calculated as the ratio of the relative molecular mass of the material to the average relative molecular mass of air (the value of the latter being approximately 29).

12.9 Boiling Point

The boiling point of a liquid is the temperature of a liquid at which the vapor pressure of the liquid equals the atmospheric pressure. Therefore, the lower the boiling point the more volatile and generally the more hazardous is the flammable liquid.

Where an accurate boiling point is unavailable for the material in question, or for mixtures which do not have a constant boiling point, for purposes of this classification the 10 percent point of a distillation performed in accordance with ASTM D86 (Standard Method of Test for Distillation of Petroleum Products) may be used as the boiling point of the liquid.

12.10 Melting Point

It is the temperature at which a solid of a pure substance changes to a liquid.

12.11 Boil Over

An event in the burning of certain oils in an open top tank when, after a long period of quiescent burning, there is a sudden increase in fire intensity associated with expulsion of burning oil from the tank. Boil over occurs when the residues from surface burning become more dense than the unburned oil and sink below the surface to form a hot layer, which progresses downward much faster than the regression of the liquid surface. When this hot layer, called a "heat wave" reaches water or water in oil emulsion in the bottom of the tank, the water is first superheated, and subsequently boils almost explosively, overflowing the tank. Oils subject to boil over consist of components having a wide range of boiling points, including both light ends and viscous residues. These characteristics are present in most crude oils, and can be produced in synthetic mixtures.

Note:

A boil over is an entirely different phenomenon from a slop over, or froth over. Slop over involves a minor frothing which occurs when water is sprayed onto the hot surface of a burning oil. Froth over is not associated with a fire but results when water is present or enters a tank containing hot viscous oil. Upon mixing, the sudden conversion of water to steam causes a portion of the tank contents to overflow.

12.12 Water Solubility

Information of the degree to which a flammable liquid is soluble in water is useful in determining effective extinguishing agents and methods. Alchol resistant type foam, for example, is usually recommended for water soluble flammable liquids. Also, water soluble flammable liquids may be extinguished by dilution although this method is not commonly used because of the amount of water required to make most liquids nonflammable, and there may be danger of frothing in this method if the burning liquid is heated to over 100°C.

13. EXTINGUISHING METHODS

The extinguishing methods that are recommended for flammable liquid fires are in most instances suitable for use on different fires. Carbon dioxide, dry chemical, foam and vaporizing liquid type extinguishing agents have all been found suitable for use on flammable liquid fires of moderate size, such as fires in dip tanks or small flammable liquid spills.

The following comments pertain to other extinguishing methods that have been found suitable for control or extinguishment of certain types of flammable liquid fires.

Water spray (fog) is particularly effective on fires in flammable liquids and volatile solids having flash points above 38°C but with liquids having flash points above 100°C, frothing may occur.

Automatic sprinklers are similar to water spray in extinguishing effectiveness. Their principal value, however, is in absorbing heat and keeping surroundings cool until a flammable liquid fire burns out or is extinguished by other means. Overflow drains on open tanks prevent sprinkler discharge from causing burning liquid to overflow and spread the fire. Sprinklers have a good record of fire control in garages, paint and oil rooms, and in storage areas where flammable liquids are largely in closed containers and water from sprinklers keeps the containers cool.

13.1 Selecting an Extinguishing Method

The selection of the extinguishing method should be made with caution as there are factors to be considered in any individual problem of extinguishment which may affect the choice of extinguishing agent and the method of application. Flowing fires, such as might be caused by a leaking overhead pipe, with the liquid on the ground also burning, are always difficult to extinguish. The amount and rate and method of application of the extinguishing material in relation to the size and type of fire anticipated must be carefully considered and may call for special engineering judgment, particularly in large-scale applications. The use of standard approved equipment is also of major importance.

The chemical and physical properties of a flammable substance will also affect the choice of an extinguishing method. Ordinary type foam, for example, would not be suitable on a fire involving a water-soluble flammable liquid. These special properties affecting extinguishment were taken into consideration when preparing the statements in the Extinguishing Method column of Table 325 M of NFPA. The following paragraphs describe the properties of the flammable liquid, volatile solid or gas that are responsible for the statements in this column.

13.2 Numerically Designated Extinguishing Methods

1) Water may be ineffective fighting fires with low flash points. This precautionary wording is used for materials having a flash point below 38°C. Obviously, the lower the flash point the less effective water will be. However, water can be used on low flash point liquids when applied in the form of a spray to absorb much of the heat and to keep exposed material from being damaged by the fire.

Much of the effectiveness of using water spray, particularly from hose lines, will depend on the method of application. With proper nozzles, even gasoline spill fires of some types have been extinguished when coordinated hose lines were used to sweep the flames off the surface of the liquid. Water also has been used to extinguish fires in water-soluble flammable liquids by cooling, diluting and mixing the flammable liquid with water. In the distilling industry, spray streams from hose lines have been used effectively to achieve control and extinguishment.

The inclusion of phrase "water may be ineffective" is to indicate that although water can be used to cool and protect exposed material, water may not extinguish the fire unless used under favorable conditions by experienced fire fighters trained in fighting all types of flammable liquid fires.

2) Water or foam may cause frothing when applied on flammable liquids having flash points above 100°C or the boiling point of water. This remark is included only as a precaution and does not indicate that water or foam should not or could not be used in fighting fires in such liquids. The frothing may be quite violent and could endanger the life of the fire fighter particularly when solid streams are directed into the hot burning liquid. On the other hand, water spray carefully applied has frequently been used with success in extinguishing such fires by causing the frothing to occur only on the surface, and this foaming action blankets and extinguishes the fire. To be considered in this regard are not only those liquids with a flash point above 100°C but also any viscous liquids. For example, certain asphalts have a small amount of low flash point solvent added for fluidity purposes but because of the viscosity the frothing action may occur.

3) Water may be used to blanket fire and accomplish extinguishment when the flammable liquid has a specific gravity of 1.1 or heavier, and is not water soluble. Here again, however, the method of applying water is significant since the water must be applied gently to the surface of the liquid.

4) Water may be ineffective except as a blanket is included in the Extinguishing Method column as a warning that since the liquid has a flash point below 38°C water may be ineffective except when applied gently to the surface to blanket and extinguish the fire. This statement applies only to those liquids that are not soluble in water and are heavier than water.

5) Alcohol foam is recommended for all water soluble or polar flammable liquids except for those that are only "very slightly" soluble. Certain judgment factors are again introduced since, for some liquids, ordinary foam might be used successfully to extinguish fires for liquids only "slightly" soluble in water, particularly if regular foam was applied at increased rates over that normally recommended. Conversely, some flammable liquids, such as certain higher molecular weight alcohols and amines, will destroy "alcohol" foam even when applied at very high rates. Foam should not be used on water reactive flammable liquids. Recently developed "alcohol" foams have been listed by independent testing laboratories for use on both polar and non-polar flammable liquids.

In the Iranian Oil industries, protein foam (regular) is generally used on the most flammable liquids, paints, etc.

Fluoroprotein Foam a protein foam incorporating specially selected fluorinated surfactants is also used to increase foam fluidity and fire knockdown. This type of foam can be used in both premix and concentrated application only.

6) Stop flow of gas rather than extinguish the fire is usually the best procedure to follow when escaping gas is burning. It may be dangerous to extinguish the flame and allow the gas to continue to flow, as an explosive mixture may be formed with air which, if ignited, may cause far greater damage than if the original fire had been allowed to burn. Extinguishing the flame by carbon dioxide or dry chemical may be desirable where necessary to permit immediate access to valves to shut off the supply. In many cases, however, it is preferable to allow the flame to continue, keeping the surroundings cool with water spray to prevent ignition of other combustible materials.

14. SUGGESTED HAZARD IDENTIFICATION

The increasing use of a wide variety of chemicals, many of which introduce problems other than flammability, led to the need for a simple hazard identification system. The purpose of such a system would be to safeguard the lives of those individuals who may be concerned with fires occurring in an industrial plant or storage location.

This Standard provides simple, readily recognizable and easily understood markings which will give at a glance a general idea of the inherent hazards of any material and the order of severity of these hazards as they relate to fire prevention, exposure and control. Its objectives are to provide an appropriate alerting signal and on the spot information to safeguard the lives of both public and fire fighting personnel during fire emergencies. It will also assist in planning for effective fire fighting operations and may be used by plant design engineers and plant protection and safety personnel.

This system identifies the hazards of a material in terms of three categories; namely, "Health," "Flammability," and "Reactivity" and indicates the order of severity in each of these categories by five divisions ranging from "four (4)" indicating a severe hazard to "zero (0)" indicating no special hazard.

While this system is basically simple in application, the hazard evaluation which is required for the precise use of the signals in a specific location must be made by experienced, technically competent persons. Their judgment must be based on factors encompassing a knowledge of the inherent hazards of different materials, including the extent of change in behavior to be anticipated under conditions of fire exposure and control.

14.1 Health Hazards

A health hazard is any property of a material which either directly or indirectly can cause injury or incapacitation, either temporary or permanent, from exposure by contact, inhalation or ingestion.

14.1.1 General

14.1.1.1 This section deals with the capacity of a material to cause personal injury from contact with or absorption into the body.

Only hazards arising out of an inherent property of the material, or a property of the products of combustion of the material, will be considered. Injury resulting from the heat of a fire or force of an explosion is not included.

14.1.1.2 In general, health hazard in fire fighting or other emergency conditions is that of a single exposure which may vary from a few seconds up to an hour. The physical exertion demanded in fire fighting or other emergency conditions may be expected to intensify the effects of any exposure.

14.1.1.3 There are two sources of health hazards. One arises out of the inherent properties of the material. The other arises out of the toxic products of combustion or decomposition of the material. The hazard degree shall be assigned on the basis of the greater hazard that could exist under fire or other emergency condition. The common hazards from the burning of ordinary combustible materials are not included.

14.1.1.4 The degree of hazard shall indicate to fire fighting personnel one of the following: that they can work safely only with specialized protective equipment; that they can work safely with suitable respiratory protective equipment; or that they can work safely in the area with ordinary clothing.

14.1.2 Degrees of hazards

Degrees of hazards are ranked according to the probable severity of hazard to personnel as follows:

DEGREE OF HAZARD No. 4

Materials which on very short exposure could cause death or major residual injury even though prompt medical treatment were given, including those which are too dangerous to be approached without specialized protective equipment. This degree should include:

a) Materials which can penetrate ordinary rubber protective clothing. Such as Hydrogen Chloride (HCL)

b) Materials which under normal conditions or under fire conditions give off gases which are extremely hazardous (i.e. toxic or corrosive) through inhalation or through contact with or absorption through the skin (e.g. Carbon Tetra Chloride (CTC) which gives off "phosgene" which is highly toxic when exposed to heat.)

DEGREE OF HAZARD No. 3

Materials which on short exposure could cause serious temporary or residual injury even though prompt medical treatment were given, including those requiring protection from all bodily contact. This degree should include:

a) Materials giving off highly toxic combustion products. Such as Hydrogen Cyanide (HCN)
b) Materials corrosive to living tissue or toxic by skin absorption. Such as Mercury Salts and Acetic Anhydride.

DEGREE OF HAZARD No. 2

Materials which on intense or continued exposure could cause temporary incapacitation or possible residual injury unless prompt medical treatment is given, including those requiring use of respiratory protective equipment with independent air supply. This degree should include:

a) Materials giving off toxic combustion products. Such as Ammonium Perchlorate NH_4ClO_4.

b) Materials giving off highly irritating combustion products. Such as Acrolein CH_2:CHCHO.

c) Materials which either under normal conditions or under fire conditions give off toxic vapors lacking waning properties. Such as Acetonitrile CH_3CN.

DEGREE OF HAZARD No. 1

Materials which on exposure would cause irritation but only minor residual injury even if no treatment is given, including those which require use of an approved canister type gas mask. This degree should include:

a) Materials which under fire conditions would give off irritating combustion products. Such as Acetic Anhydride $(CH_3CO)_2O$

b) Materials which on the skin could cause irritation without destruction of tissue. Such as Calcium Hypochlorite (Bleaching powder) $Ca(ClO)_2$.

DEGREE OF HAZARD No. 0

Materials which on exposure under fire conditions would offer no hazard beyond that of ordinary combustible material.

14.2 Flammability Hazards

14.2.1 General

This section deals with the degree of susceptibility of materials to burning. Many materials which will burn under one set of conditions will not burn under others. The form or condition of the materials, as well as their inherent properties, affects the hazard.

14.2.2 Degrees of Hazard

The degrees of hazard are ranked according to the susceptibility of materials to burning as follows:

DEGREE OF HAZARD No. 4

Materials which will rapidly or completely vaporize at atmospheric pressure and normal ambient temperature or which are readily dispersed in air, and which will burn readily. This degree should include:

a) Gases.

b) Cryogenic materials.

c) Any liquid or gaseous material which is a liquid while under pressure, and having a flash point below 23°C and having a boiling point below 38°C (Class IA flammable liquids).

d) Materials which on account of their physical form or environmental conditions can form explosive mixtures with air and which are readily dispersed in air, such as dusts of combustible solids and mists of flammable or combustible liquid droplets.

DEGREE OF HAZARD No. 3

Liquids and solids that can be ignited under almost all ambient temperature conditions. Materials in this degree produce hazards atmospheres with air under almost all ambient temperatures or, though unaffected by ambient temperatures, are readily ignited under almost all conditions. This degree should include:

a) Liquids having a flash point below 23°C and having a boiling point at or above 38°C and those liquids having a flash point at or above 23°C and below 38°C (Class IB and class IC flammable liquids).

b) Solid materials in the form of coarse dusts which may burn rapidly but which generally do not form explosive atmospheres with air.

c) Solid materials in a fibrous or shredded form which may burn rapidly and create flash fire hazards such as cotton, sisal and hemp.

d) Materials which burn with extreme rapidity, usually be reason of self-contained oxygen (e.g., dry nitrocellulose and many organic peroxides).

e) Materials which ignite spontaneously when exposed to air.

DEGREE OF HAZARD No. 2

Materials that must be moderately heated or exposed to relatively high ambient temperatures before ignition can occur. Materials in this degree would not under normal conditions form hazardous atmospheres with air, but under high ambient temperatures or under moderate heating may release vapor in sufficient quantities to produce hazardous atmospheres with air. This degree should include:

a) Liquids having a flash point above 38°C, but not exceeding 93°C.
b) Solids and semisolids which readily give off flammable vapors.

DEGREE OF HAZARD No. 1

Materials that must be preheated before ignition can occur. Materials in this degree require considerable preheating, under all ambient temperature conditions, before ignition and combustion can occur. This degree should include:

a) Materials which will burn in air when exposed to a temperature of 815°C for a period of 5 minutes or less. (Oily Woolen Material) Phenol (Carbolic Acid) 1319°F C715.

b) Liquids, solids and semisolids having a flash point above 93°C. This degree includes most ordinary combustible materials. (Fuel Oil No. 2).

DEGREE OF HAZARD No. 0

Materials that will not burn. This degree should include any material which will not burn in air when exposed to a temperature of 815°C for a period of 5 minutes.

14.3 Reactivity (Instability) Hazards

a) Reactive materials are those which can enter into a chemical reaction with other stable or unstable materials.

For purposes of this standard, the other material to be considered is water and only if its reaction releases energy. Reactions with common materials, other than water, may release energy violently. Such reactions shall be considered in individual cases, but are beyond the scope of this identification system.

b) Unstable materials are those which in the pure state or as commercially produced will vigorously polymerize, decompose or condense or become selfreactive and undergo other violent chemical changes.

c) Stable materials are those that normally have the capacity to resist changes in their chemical composition, despite exposure to air, water and heat as encountered in fire emergencies.

14.3.1 General

14.3.1.1 This section deals with the degree of susceptibility of materials to release energy. Some materials are capable of rapid release of energy by themselves, as by self-reaction or polymerization, or can undergo violent eruptive or explosive reaction other materials.

14.3.1.2 The violence of reaction or decomposition of materials may be increased by heat or pressure, by mixture with certain other materials to form fuel-oxidizer combinations, or by contact with incompatible substances, sensitizing contaminants or catalysts.

14.3.1.3 Because of the wide variations of accidental combinations possible in fire or other emergencies, these extraneous hazard factors (except for the effect of water) cannot be applied in a general numerical scaling of hazards. Such extraneous factors must be considered individually in order to establish appropriate safety factors such as separation or segregation. Such individual consideration is particularly important where significant amounts of materials are to be stored or handled, such as aluminum powder, magnesium powder.

14.3.1.4 The degree of hazard shall indicate to fire fighting and emergency personnel that the area should be evacuated, that the fire may be fought from a protected location, that caution must be used in approaching the fire and applying extinguishing agents, or that the fire may be fought using normal procedures, such as Chlorine, Ammonia or H_2S gas or liquified LPG.

14.3.2 Degrees of hazards

The degrees of hazards are ranked according to ease, rate and quantity of energy release as follows:

DEGREE OF HAZARD No. 4

Materials which in themselves are readily capable of detonation or of explosive decomposition or explosive reaction at normal temperatures and pressures. This degree should include materials which are sensitive to mechanical or localized thermal shock at normal temperatures and pressures, such as Black Powder or Gelegnite.

DEGREE OF HAZARD No. 3

Materials which in themselves are capable of detonation or of explosive decomposition or explosive reaction but which require a strong initiating source or which must be heated under confinement before initiation. This degree should include materials which are sensitive to thermal or mechanical shock at elevated temperatures and pressures or which react explosively with water without requiring heat or confinement.

DEGREE OF HAZARD No. 2

Materials which in themselves are normally unstable and readily undergo violent chemical change but do not detonate. This degree should include materials which can undergo chemical change with rapid release of energy at normal temperatures and pressures or which can undergo violent chemical change at elevated temperatures and pressures. It should also include those materials which may react violently with water or which may form potentially explosive mixtures with water.

DEGREE OF HAZARD No. 1

Materials which in themselves are normally stable, but which can become unstable at elevated temperatures and pressures or which may react with water with some release of energy but not violently.

DEGREE OF HAZARD No. 0

Materials which in themselves are normally stable, even under fire exposure conditions, and which are not reactive with water.

14.4 Special Hazards

This section deals with other properties of the material which may cause special problems or require special fire fighting techniques.

14.4.1 Symbols

14.4.1.1 Materials which demonstrate unusual reactivity with water shall be identified with the letter W with a horizontal line through the center.

14.4.1.2 Materials which possess oxidizing properties shall be identified by the letters OX.

14.4.1.3 Materials possessing radioactivity hazards shall be identified by the standard radioactivity symbol. (see. BS 1635)

Shape and proportions of symbol

The basic symbol for signifying ionizing radiation or radioactive materials shall be designed and proportioned as illustrated in Fig. 1.

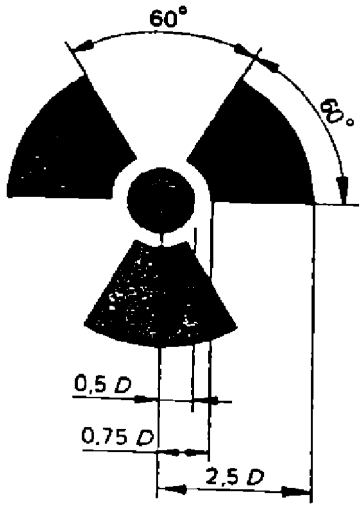

Fig. 1

15. OXYGEN MIXTURES

The values in Table 325 M of NFPA are based upon experiments in normal air, except where otherwise indicated. In oxygen the values may be different and an increase in hazard is probable. Mixtures of two or more flammable materials may have properties different from their components. In the case of mixtures it is common practice to base precautions on the properties of the more hazardous component.

16. MISTS AND FROTHS

In finely divided form such as a mist or spray, liquids can be ignited at temperatures below their flash points. As in the case of vapors a minimum concentration of droplets must be present to support combustion. Froths also may be ignited below flash point temperatures.

17. FIRE HAZARD PROPERTIES OF FLAMMABLE LIQUIDS, GASES AND VOLATILE SOLIDS

For hazardous chemical data, flammability, reactivity and extinguishing methods reference should be made to 86 pages of table 325 M in NFPA Volume 10.