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HAZARD AND RISK ASSESSMENT MANUAL

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1. CLASSIFICATION OF THE HAZARDOUS CHEMICALS

HAZARDOUS CHEMICAL DATA

Data are included in the body of the text on those chemicals used and shipped commercially and which meet one or more of the following criteria: A health hazard, a reactivity, or which present unusual storage or fire fighting problems or can become hazardous on being contaminated or mixed with other chemicals. There are many chemicals meeting these criteria that are not included because of lack of data on them. Thus, the reader should not assume that because a chemical is not included it does not possess any unusual hazards.

Several chemicals are listed in the body of the text whose only significant hazard is flammability. Further information on these and many other chemicals that are hazardous, primarily because of flammability, will be found in NFPA No. 325M, Fire-Hazard Properties of Flammable Liquids, Gases and Volatile Solids.

When given for a listed material, the information under this heading is intended to be a guide to assist in identifying the material in the form in which it is ordinarily encountered.

The Storage recommendations are intended to supplement but not replace those contained in pertinent standards. For example, storage of flammable liquids in containers or tanks should comply with the requirements of the

Flammable and Combustible Liquids Code (NFPA No.30).

Isolate and separate are terms used to describe recommended storage practices for certain hazardous chemicals. Isolated storage means storage away from incompatible materials in a different storage room or in a separate and detached building located at a safe distance. Separated storage refers to storage in the same fire area but separated by as much space as practible or by intervening storage from incompatible materials.

Fire Fighting Phases. This information indicates the best extinguishing media for fires involving the materials listed. The recommendations pertain to manual fire fighting.

Water is usually the best extinguishing or controlling agent due to its cooling effect and because it is usually available in large quantities. However, the selection of the extinguishing method should be made with caution as there are factors to be considered in any individual problem of extinguishemnet 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 type and size of fire anticipated must be carefully

considered and may call for special engineering judgement, 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 extinguishement were taken into consideration when preparing the statements in FIRE FIGHTING PHASES.

Flammable (Explosive) Limits and Range. In the case of gases or vapors which form flammable mixtures with air and oxygen, there is a minimum concentration in air or oxygen of vapor, below which propagation of flame does not occur on contact with a source of ignition. There is also a maximum proportion of vapor or gas in air above which propagation of flame does not occur. These boundary-line mixtures of vapor or gas with air, which, if ignited, will just propagate flame, are known as the " lower and upper flammable or explosive limits ", and are usually expressed in terms of percentage by volume of gas or vapor in air.

The range of flammable vapor or gas-air mixtures between the upper and lower flammable limits is known as the " flammable range ", also often referred to as the " explosive range ".

The flammable limits are not appreciably changed by normal variations in atmospheric pressure and temperature. Changes in humidity result in the upper limit being

changed to a small extent (due to oxygen displacement by water vapor) and the lower limit is only slightly changed. However, at high temperatures the upper limit is raised and the lower limit lowered, resulting in a greater flammable, or explosive range. Hence in processes involving high temperatures, the limits given for ordinary (ambient) temperatures no longer indicate the danger lines. The effect of high pressures on the limits is different for each gas or vapor, depending upon its nature.

In general, the upper limit is higher and the lower limit lower (i.e., the ranged is increased) for upward, than for downward or horizontal flame propagation. The limits for upward propagation are considered the most important from a safety standpoint, and therefore the flammable limits and ranges given will be for upward propagation unless otherwise noted.

Ignition Temperature ("auto" or "autogenous" ignition temperature). Ignition temperature of a substance, whether solid, liquid or gaseous, is the minimum temperature required to initiate or cause self-sustained combustion.

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

points, determined in a different type of testing apparatus are usually somewhat higher than the closed cup flash point figures for the same substances. Closed cup flash point figures are commonly used in determining the classification of liquids which flash in the ordinary temperature range, but for certain materials which have relatively high flash points, the open cup flash point testing is often preferred.

Life Hazards. Life hazards can result from inhalation, skin contact, skin absorption or oral ingestion. Recommendations on personnel protective equipment for individual chemicals are made on the basis of hazards that may exist under emergency conditions, such as spills or leaks, or under fire conditions. Types of breathing equipment and protective clothing are described in the following paragraphs.

Breathing Equipment for Toxic or Oxygen-Deficient Atmospheres. Respiratory protective devices are of two general types: (1) supplied or self-contained air or oxygen breathing apparatus, and (2) air-purifying respirators.

Self-contained breathing apparatus provides the wearer with respirable air from a source of supply independent of the atmosphere where the wearer is located. Air-purifying respirators remove contaminants from air

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 varying ignition temperatures are obtained.

Flash Point. Flash point of a liquid is the minimum temperature of the liquid at which it gives off vapor sufficient to form an ignitible mixture with the air near the surface of the liquid or 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 ignitible mixture. This term applies mostly to flammable liquids, although there are certain solids, such as camphor and naphtalene, that evaporate slowly or volatilize at ordinary, room temperature and therefore have flash points while still in the solid state.

The flash point figures represent closed cup tests except where the open cup flash point is designated by the initials "oc" following the figure. Open cup flash

surrounding the wearer.

Normally,self-contained breathing apparatus has a full face piece,which provides eye protection. Where self-contained breathing apparatus does not provide eye protection,thissshould be provided by goggles.

Full Protective Clothing. As used in this manual, full protective clothing means protection to prevent gases, vapors,liquids and solids from coming in contact with the skin. Full protective clothing includes the helmet,self-contained breathing apparatus,coat and pants customarily worn by fire fighters (turn-out or bunker coat and pants), rubber boots,gloves,bands around legs,arms and waist,and face mask,as well as covering for neck,ears and other parts of the head not protected by the helmet,breathing apparatus or face mask.

Special Protective Clothing. As used in this manual special protective clothing refers to clothing specially designed to protect against a specific hazard. Special protective clothing is recommended for those chemicals with a health hazard rating of 4.

Electrical Equipment. At present,there are chemicals for which there is no electrical equipment listed by any nationally recognized testing laboratory as suitable for use in Class I,Division I locations as defined

in the National Electrical Code (NFPA No. 70). When such a situation exists, precautions should be taken so that the location in question will meet the stipulations in paragraph 500-4(b) of the Code. Installation of electrical equipment suitable for Class I, Division 2 locations will satisfy the Code requirements.

Specific reference to the National Electrical Code requirements for special electrical equipment is made for those liquids having flash points below 100° F. It should be remembered that if a liquid with a flash point at or above 100° F is heated above its flash point, there may be instances of locations containing flammable atmospheres. Electrical installations in such locations should be in accordance with Article 501 of the National Electrical Code, and electrical equipment should be suitable for use in atmospheres containing flammable mixtures of the vapor.

Oxidizing Materials. Most oxidizing materials will decompose readily to yield oxygen when heated and may react readily with other chemicals. Because of their ability to furnish oxygen when heated, the hazard of oxidizing materials is greately increased at elevated temperatures. Violent reactions may occur when they are mixed with or contaminated by combustible materials, such as wood, paper, metal powders and sulfur. Under ordinary circumstances such mixtures are very sensitive to heat, friction and impact. Oxidizing materials include chlorates,

perchlorates,bromates,peroxides,nitric acids,nitrates and permanganates. Bromine,chlorine,fluorine and iodine react similarly to oxygen under some conditions and are therefore also classified as oxidizing materials.

Explosive substances in dilute form as components of manufactured articles of commerce are not included. Commercial and military explosives on which information is available in other publications are not included except for reference or comparison.

Hazard Identification System. The diagram identifies the "health","flammability" and"reactivity" (instability and water reactivity) of a chemical and indicates the order of severity of each hazard by use of one of five numerals gradings,from four (4),indicating the severe hazard or extreme danger,to zero (o),indicating no special hazard.

The following paragraphs summarize the meanings of the numbers in each hazard category and explain what a number should tell fire fighting personnel about protecting themselves and how to fight fires where the hazard exists.

HEALTH

4 A few whiffs of the gas or vapor could cause death; or the gas,vapor or liquid could be fatal on penetrating the fire fighters'normal full protective clothing which is designed for resistance to heat. For most chemicals having a Health 4 rating,the normall full protective clothing available to the average fire department will not provide ade-

quate protection against skin contact with these materials. Only special protective clothing designed to protect against the specific hazard should be worn.

3. Materials extremely hazardous to health, but areas may be entered with extreme care. Full protective clothing, including self-contained breathing apparatus, rubber gloves, boots and bands around legs, arms and waist should be provided. No skin surface should be exposed.

2. Materials hazardous to health, but areas may be entered freely with self-contained breathing apparatus.

1. Materials only slightly hazardous to health. It may be desirable to wear self-contained breathing apparatus.

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

FLAMMABILITY

4. Very flammable gases, very volatile flammable liquids, and materials that in the form of dusts or mists readily form explosive mixtures when dispersed in air. Shut off flow of gas or liquid and keep cooling water streams on exposed tanks or containers. Use water spray carefully in the vicinity of dusts so as not to create dust clouds.

3. Liquids which can be ignited under almost all normal temperature conditions. Water may be ineffective on these liquids because of their low flash points. Solids which form coarse dusts, solids in shredded or fibrous form that create flash fires, solids that burn rapidly, usually because they contain their own oxygen, and any material that ignites spontaneously at normal temperatures in air.

2. Liquids which must be moderately heated before ignition will occur and solids that readily give off flammable vapors. Water spray may be used to extinguish the fire because the material can be cooled to below its flash point.

1. Materials that must be preheated before ignition can occur. Water may cause frothing of liquids with this flammability rating number if it gets below the surface of the liquid and turns to steam. However, water spray gently applied to the surface will cause a frothing which will extinguish the fire. Most combustible solids have a flammability rating of 1.

0. Materials that will not burn.

REACTIVITY

4. Materials which in themselves are readily capable of detonation or of explosive decomposition or explosive reaction at normal temperatures and pressures. Includes materials which are sensitive to mechanical or localized ther-

mal shock. If a chemical with this hazard rating is in an advanced or massive fire, the area should be evacuated.

3. Materials which in themselves are capable of detonation or of explosive decomposition or of explosive reaction but which require a strong initiating source or which must be heated under confinement before initiation. Includes 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. Fire fighting should be done from an explosion-resistant location.

2. Materials which in themselves are normally unstable and readily undergo violent chemical change but do not detonate. Includes 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. Also includes those materials which may react violently with water or which may form potentially explosive mixtures with water. In advanced or massive fires, fire fighting should be done from a protected location.

REACTIVITY (Continued)

1. Materials which in themselves are normally stable but which may become unstable at elevated temperatures and pressures or which may react with water with some release

of energy but not violently. Caution must be used in approaching the fire and applying water.

o. Materials which are normally stable even under fire exposure conditions and which are not reactive with water. Normal fire fighting procedures may be used.

HAZARDOUS CHEMICAL DATA

Ref. no.	Designation	Description	Hazard identification			Personal protection	Storage	Remarks
			Health	Flammability	Reactivity			
1	2	3	4	5	6	7	8	9
1.	Acetaldehyde CH_3CHO	Colourless liquid at temperatures below 69°F, but rapidly volatilizes at this temperature	2	4	2	Wear self-contained breathing apparatus	Protect against physical damage Tanks provided with refrigeration and inert gas blanket	Electrical installation class I
2.	Acetic acid CH_3-COOH	A clear, colourless liquid with strong, pungent odor of vinegar	2	2	1	Wear self-contained breathing apparatus	Protect against physical damage Separate from oxidizing materials	-
3.	Acetic anhydride $(CH_3CO)_2O$	Colourless, liquid with very strong pungent acetic odor	2	2	1	Wear self-contained breathing apparatus	Protect against physical damage Store in cool, well-ventilated place	-
4.	Acetonitrile CH_3CN	Colourless liquid with an ethereal odor, burning sweetish taste	2	3	0	Wear self-contained breathing apparatus	Outside storage is preferable. Inside storage should be in standard flammable liquids storage	Electrical installation class I

1	2	3	4	5	6	7	8	9
5.	Acetyl chloride CH_3COCl	A colourless liquid with a pungent odor, It fumes in moist air.	3	3	2	Wear full protective clothing	Store in cool, dry well-ventilated free of sources of ignition	Electrical installations class I
6.	Acetylene $CH \equiv CH$	Colourless gas with slight garlic-like odor. Flammable limits 2.5% and 100%. Ignition temperature is low and varies to mixture composition, pressure and initial temperature	1	4	3	-	Store in cool, well-ventilated non-combustible place. Protect against lightning and static electricity. Store in cylinders upright	Electrical installation class I
7.	Acrolein $CH_2= CHCHO$	Colourless, volatile liquid with piercing disagreable odor.	3	3	2	Wear full protective clothing.	Do not store uninhibited acrolein under any circumstances. No alkaline materials or oxidizing materials permitted in storage room	Electrical installation Class I
8.	Acrolein dimer $(CH_2=CHCHO)_2$	Colourless liquid with an unpleasant acrolein like odor	1	2	1	Wear goggles	Separate from oxidizing materials	
9.	Acrylic acid $CH_2=CHCO.OH$	A colourless liquid with an acid odor, Flash point 130°F	3	2	2	Wear full protective clothing	Store in cool, well-ventilated, non-combustible place	

1	2	3	4	5	6	7	8	9
10.	Acrilcaitril $CH_2=CHCN$	A colcurless liquid with faintly pungent odor. Flammable limit 3% and 17%	4	3	2	Wear special protective clothing	Do not store uninhibited under any conditions Store drums on end with bungs up,no more than two high	
11.	Adiponitsile $NC(CH_2)_4CN$	Colourless liquid Flash point 200°F	4	2	0	Wear special protective clothing	Store in cool,dry,well-ventilated location, separate from other storage	
12.	Aldrin $C_{12}H_8Cl_6$	Brown to white crystalline solid	3	1	0	Wear special full protection clothing	Store in 1-and-5 gallon cans: 45 gallon drums	
13.	Alkylaluminums	20% or less by weight in hydrocarbon solution	3	3	3	Wear full protective clothing	Storage should be isolated.Separate from water,combustible materials or reactive materials	
14.	Allyl alcohol $CH_2=CHCH_2OH$	Colourless liquid with mustard like odor. Flammable limits 2.5% and 18%	3	3	0	Wearfull protective clothing	Separate from oxidizing materials Protect against physical damage	Electrical installations Class I
15.	Allyl bromide $CH_2=CHCH_2Br$	Colourless to light yellow liquid; Irritating,unpleasant odor	3	3	1	Wear full protective clothing	Store in cool,dry well-ventilated rooms	Electrical installations class I
16.	Allyl chloride $CH_2=CHCH_2Cl$	Colourless liquid with unpleasant pungent, odor	3	3	1	Wear full protective clothing	Store in cool,dry well-ventilated rooms	Electrical installations class I

1.	2	3	4	5	6	7	8	9
17.	Aluminium chloride $AlCl_3$	Orange tc yellcw thrcugh gray tc white pcwder. Melting point 381 ^{C}F	3	0	2	Wear full protective clothing	Stcre in cccl,dry area protected frcm rain and direct sunshine	-
18.	Amcnia NH_3	Cclcurless gas with extremely pungent cdcr	2	1	0	Wear full prctective clothing	Seperate frcm cther chamicals:oxidizing gases,chlcrine,brcmine,icdine,and acids	Electrical installations Class I
19.	Amcnium brcmide NH_4Br	Cclcurless,cdcrless, crystals cr a yellowish-white crystalline pcwder	2	0	0	Wear gcggles if eye prctection is nct prcvided	Stcre in dry lccetion separate frcm acids and alkalis	-
20.	Amcnium chlcride NH_4Cl	Cclcurless,cdcrless crystals cr cristalline masses	2	0	0	Wear gcggles if eye prctection is nct prcvided	Store in dry lccetion separate frcm acids and alkalis seperate frcm silver salts	-
21.	Amcnium flucride NH_4F	Cclcurless,deliquescent crystals	3	0	0	Wear full prctective clothing	Stcre in dry lccetion. Seperate frcm acid and alkalis	-
22.	Amcnium nitrate NH_4NO_3	White crystalline cr grenular sclid. Highly soluble in water	2	0	3	In fire ccndiitions,wear self-ccntained breathing apparatus	Store in well-ventilated buildings. Seperate frcm organic materials flammable liquids acids sulfur and charcoal	-
23.	Amcnium sulfate $(NH_4)_2SO_4$	Cclcurless crystals cr white granular pcwder	3	0	0	In fire ccndiitions wear full prctective clothing	Seperate frcm cxidizers such chlcrates and nitrates	-

1	2	3	4	5	6	7	8	9
24.	Aniline $C_6H_5NH_2$	Colcurless oily liquid with a characteristic cdcr	3	2	0	Wear full prctec- tive clothing	Store in cocl,dry well-ventilated loca- tion,away frcm any area where the fire hazard may he ecute	-
25.	Benzaldehyde C_6H_5CHO	Cclcurless tc yellcwish liquid,readily discer- nible almcnd-like cdor	2	2	0	Wear self-contain- ed breathing ap- paratus	Stcre in cccl,dry wall-ventilated lcca- tion	-
26.	Benzene C_6H_6	Colcurless liquid with arcmatic cdor. Flam- mable limits: 1.3% and 7.1%. Flash point:12°F	2	3	0	Wear self-con- tained breathing apparatus	Storage should ba in a standard flammable liquids storage,separate frcm oxidizing materials	Electri- cal in- stalla- tions Class I
27.	Benzctri- flucride $C_6H_5CF_3$	Water-white liquid with arcmatic cdcr Flas point 54°F	4	3	0	Wear fulll prctec- tive clothing	Protect against phy- sical damage. Sepa- rate from cxidizing materials	Ditto
28.	Benzichlc- ride $C_6H_5CH_2Cl$	Cclcurless tc yellcw liquid with arcmatic irritating cdor	2	2	1	Wear self-con- tained breathing apparatus	Glass bcttles,nickel drums up tc 55 gal- lons store in a ccol, dry,well-ventilated location	-
29.	Brcmin	Reddish-brcwn fuming liquid cr vapcur Bciling pcint 139°F	4	0	0	Wear special prc- tective clothing	Stcre in ccol,dry area cut of direct sunlight Separate frcm combustib le organic materials. Kaep abcve 20°F tc pre- vent freezing	-

1	2	3	4	5	6	7	8	9
30.	Bromine trifluoride BrF_3	Colourless liquid; fumes and smokes in air	4	0	3	Wear special protective clothing	Protect cylinders against physical damage. Isolate from other storage	-
31.	Butadiene-1,3 $CH_2=CHCH=CH_2$	A colourless mildly aromatic gas	2	4	2	Wear self-contained breathing apparatus	Outside storage is preferred. Inside storage should be in a cool well-ventilated, non-combustible location	Electrical installations Class I
32.	Butane $CH_3CH_2CH_2CH_3$	Gas	1	4	0	Wear special protective clothing	Outside storage is preferred	Ditto
33.	nButil acrylate $CH_2=CHCOOC_4H_9$	Colourless liquid	2	2	2	Wear self-contained breathing apparatus	Protect against physical damage. Outside storage is preferred. Separate from oxidizing materials	-
34.	nButylamine $C_4H_9NH_2$	Colourless volatile liquid with ammonia-like odor	2	3	0	Ditto	Separate from oxidizing materials and sources of heat. Outside storage is preferred.	Electrical installations Class I
35.	Butyraldehyde (normal and ISO) $CH_3(CH_2)_2CHO$ and $(CH_3)_2CHCHO$	Colourless liquids with a pungent odor	2	3	0	Ditto	Outside storage is preferred. Bulk storage tanks should be aluminium, stainless steel or glass-lined.	Ditto

1	2	3	4	5	6	7	8	9
36.	Butyric acid $CH_3(CH_2)_2COOH$	Colourless liquid with pungent putrid odor	2	2	0	Wear self-contained breathing apparatus	Store in cool,dry, well-ventilated location,separate from oxidizing materials	-
37.	Calcium cyanide $Ca(CN)_2$	White powder or crystals	3	0	0	Wear full protective clothing	Store in cool,dry place.Separate from other storage and protect from oxidizing materials	-
38.	Calcium hypochlorite $Ca(ClO)_2$	White powder granules or pellets with strong chlorine-like odor	2	0	2	Wear self-contained breathing apparatus	Drums. Store in cool, dry,well-ventilated place, away from combustible materials	-
39.	Carbon tetrachloride CCl_4	Colourless liquid; yields heavy vapors ethered odor	3	0	0	Ditto	Store in a cool,dry well-ventilated location	-
40.	Cellulose nitrate (not explosive grade) $C_{12}H_{17}(ONO_2)_3O_7$	A white fibrous pulp like material or amorphous powder wet with water,alcohol or some other solvent	2	3	3	In fire conditions wear self-contained breathing apparatus	Drums should be protected against damage and not exposed to heating,nor should material be allowed to dry out	National electrical code
41.	Chlorine Cl_2	Pungent,irritating greenish-yellow gas	3	0	0	Wear full protective clothing	Separate from combustible,organic or oxidizible materials, and especially isolate from acetylene,ammonia hydrogen	-

1	2	3	4	5	6	7	8	9
42.	Chlorobenzene C_6H_5Cl	Colourless liquid with aromatic odor	2	3	0	Wear self-contained breathing apparatus	Outside is preferable separate from oxidizing materials	Electrical installations Class I
43.	Chlorodiethyl aluminium $(C_2H_4)_2AlCl$	Colourless, pyrophoric liquid	3	3	3	Wear full protective clothing	Store in steel cylinders in isolated, well-ventilated place	-
44.	Chlorodiethyl silane $(C_2H_5)_2SiHCl$	Colourless liquid	3	3	0	Ditto	Outside storage is preferred. Inside, 55 gallon drums should be in a standard flammable liquid storage separate from oxidizing materials	Electrical installations Class I
45.	Chloroform $CHCl_3$	Heavy, water-white volatile sweet-tasting liquid with characteristic odor	2	0	0	Wear self-contained breathing apparatus	Store in cool, dry, well-ventilated location. Separate from strong alkalis	-
46.	Chloromethyl oxirane $(OCH_2CH)CH_2Cl$	Colourless mobile liquid; irritating chloroform like odor	3	3	2	Wear full protective clothing	Drum or tank cars. Separate from oxidizing materials and acids, bases	Electrical installations Class I
47.	Chlorosulfuric acid $ClSOOH$	Colourless to light yellow, fuming liquid	3	0	2	Ditto	Building may be constructed of wood, concrete or steel. Direct application of water should be from a protected location	-

1	2	3	4	5	6	7	8	9
46.	Cresol (O,m,p) $CH_3C_6H_4OH$	- Ortho-cresol, colourless liquid or crystals, melting point 87,6°F - Meta-cresol, colourless liquid, melting point 53,6°F - Para-cresol, colourless crystals, melting point 94,6°F	3	1	0	Wear self-contained breathing apparatus	Glass bottles, 10 and 55 gallons metal drums Store in a cool, dry, well-ventilated location. Separate from oxidizing materials	-
49.	Cumen $C_6H_5CH(CH_3)_2$	Colourless liquid Flammable limits: 0,9% and 6,5%	2	3	0	Ditto	Drums, tank cars, tank trucks. Separate from oxidizing materials	Electrical installations Class I
50.	Cyanogen NCCN	Colourless gas with pungent penetrating odor. Flammable limits 6,6% and 32%	4	4	2	Wear special protective clothing	High-pressure metal cylinders. Prevent shock. Keep cylinders away from any source of heat. Isolate from acids, water. Outside storage is preferred	Ditto
51.	Cyclohexylamine $C_6H_{11}NH_2$	Colourless to yellow liquid with ammonia like odor. Flammable limits not reported	2	3	0	Wear self-contained breathing apparatus	Outside storage is preferred. Separate from oxidizing materials	Ditto
52.	Diborane B_2H_6	Colourless gas repulsive, sweet odor. Flammable limits 0,8% and 88%	3	4	3	Ditto	Steel pressure cylinders. Storage should be in detached, well-ventilated place. Protect against electrical sparks, open flames or any other heat source	Ditto

1	2	3	4	5	6	7	8	9
53.	Dibutylamine $(C_4H_9)_2NH$	Colourless liquid with ammonia-like odor Flammable limits: lower 1.1% - upper not established	3	2	0	Wear full protective clothing	Steel drums and tank cars. Separate from oxidizing material and store in a cool, dry well ventilated location. Outside storage is preferred	-
54.	Dibutyl ether $C_4H_9OC_4H_9$	Colourless liquid, mild, ether like odor Flammable limits 1.5% and 7.6% Flash point 77°F	2	3	0	Ditto	Steel drums, tank cars. Separate from oxidizing materials. Protect against physical damage	Electrical installations Class I
55.	Dibutyl peroxide $(CH_3)_3COOC(CH_3)_3$	A colourless liquid flammable limits unrecorded. Boiling point 228°F	3	2	4	Wear self-contained breathing apparatus	Amber glass bottles, with vented caps. Outside storage is preferred. Isolate from easily oxidizable materials	Ditto
56.	Dichlorobenzene (ortho) C_6H_4Cl	Colourless liquid pleasant aromatic odor. Combustible liquid. Flammable limits 2.2% and 9.2%	2	2	0	Ditto	Store in a cool, dry well-ventilated location. Outside storage is preferred	-
57.	1,2-Dichloroethane ClC_2H_4Cl	Clear liquid with chloroform odor and sweet taste Flammable limits 6.2% and 16%	2	3	0	Ditto	Outside storage is preferred. Separate from oxidizing materials. Inside storage should be in a standard flammable liquids storage room	Electrical installations Class I

1	2	3	4	5	6	7	8	9
58.	Dichlcrcmethane $ClCH_2Cl$	Clear liquid with mild chlcrcfcrm-like cdcr Flammable limits 12% and 19%	2	1	0	Wear self-ccntained breathing apparatus	Prctect against Electr physical damage cai in Stcre in a ccol,stelle- dry,well-venti- tions lated lccatien Class I awey frcm any area where the fire hazard may be acute	
59.	Diethylamine $(C_2H_5)_2NH$	Cclcurless alkaline liquid with an ammcnia like cdcr Flammable limits 1.8% and 10.1%. Flash pcint 0°F	2	3	0	Wear full prc- tective clcth- ing	Glass bcttles,drums tank cars. Ditte Outside or detach- ed stcrage is pre- ferred. Separate frcm cxidizing ma- terials	
60.	Diethylether $C_2H_5CC_2H_5$	Cclourless liquid with characteristic anesthe- tic cdcr. Flammable limits 1.9% and 36% Flash pcint 95°F	2	4	1	Wear self-ccn- tained breathing apparatus	Steel drums,glass Ditte bcttles,tank barges. Detached cutside stc- rage is preferred. Isolate frcm cther ccmbustible materials Separate frcm cxidiz- ing materials	
61.	Diizcprcpyl- amine $(CH_3)_2CH\ _2NH$	Colcurless liquid with an amine cdcr.Explcsive mixture with air.Flash point 30°F	3	3	0	Wear full pro- tective cloth- ing	Drums,tank cars. Ditte Prctect against physical damage. Cutside stcrage is preferred. Separate frcm cxidizing ma- terials	

1	2	3	4	5	6	7	8	9
62.	Diisopropyl ether $(CH_3)_2CHOCH(CH_3)_2$	Colourless volatile liquid with ethereal odor. Flammable limits 1.4% and 7.9% Flash point, minus 18°F	2	3	1	Wear self-contained breathing apparatus	Steel drums glass bottles and cans. Detached outside storage is preferred. Isolate from other combustible materials	Electrical installations Class I
63.	Dimethyl ether CH_3OCH_3	Colourless gas with an ethereal odor. Liquid below minus 11°F. Flammable limits 3.4% and 27%. Ignition temperature, 662°F	2	4	1	Ditto	Cylinders must be protected against physical damage Outside storage is preferred. Inside storage should be in cool, well-ventilated location	Ditto
64.	Dinitrobenzene $C_6H_4(NO_2)_2$	Colourless or yellow crystals, needles or plates. High explosive substance	3	1	4	For rescue purposes wear full protective clothing	Store only in a permanent magazine. This high explosive should be kept well away from nitrate explosives. Separate from oxidizing materials, combustibles, and sources of heat	-
65.	Dinitrotoluene $(NO_2)_2C_6H_3CH_3$	Yellow needle-crystals. can be detonated only by a very strong initiator or fire	3	1	1	Ditto	Metal barrels or drums. Wooden barrels with liners. Separate from oxidizers agents. Protect from damage to container	-
66.	Divinylbenzene $C_6H_4(CH=CH_2)_2$	Water-white liquid combustible liquid Flash point 169°F	2	2	2	Wear self-contained breathing apparatus	Drums tank cars. Store in cool, dry, well-ventilated location, away from any area where the fire hazard may be acute	-

1	2	3	4	5	6	7	8	9
67.	Ethene $CH_2=CH_2$	Colourless gas; sweet odor and taste. Flammable gas. Flammable limits 2.7% and 36% Ignition temperature 914°F	1	4	2	Wear self-contained breathing apparatus	Isolate from oxygen, chlorine, combustible organic and oxidizing materials. Store away from possible source of ignition outside storage is preferred.	Electrical installation Class I
66.	Ethylamine $C_2H_5NH_2$	Colourless liquid, boiling point 62°F having strong ammoniacal odor. Flammable limits 3.5% and 14%	3	4	0	Wear full protective clothing	Outside storage is preferred. Separate from oxidizing materials and source of heat	Ditto
69.	Ethylbenzene $C_6H_5C_2H_5$	Colourless liquid with an aromatic odor. Flammable limits 1.0% and 6.7% Flash point 59°F	2	3	0	Wear self-contained breathing apparatus	Outside storage is preferred. Isolate from acute fire hazard and oxidizing agents	Ditto
70.	Ethyl-chloride C_2H_5Cl	A Colourless, pungent liquid which boils at 54°F. Flammable limits 3.8% and 15.4% Flash point minus 58°F	2	4	0	Ditto	Outside storage is preferred. Inside storage should be in a standard flammable liquid storage room. Separate from oxidizing materials	Ditto

1	2	3	4	5	6	7	8	9
71.	Ethylene oxide CH_2OCH_2	Colourless gas at ordinary temperatures. Liquid below 51°F, has an ether-like odor. Flammable limits 3% and 100%. Flash point less than 0°F	2	4	3	Wear self-contained breathing apparatus	Steel cylinders, drums, insulated tank cars, tank barges. Should be kept cool, below 86°F. Should be stored outside, away from buildings and other materials. Do not permit chlorides, oxides, acids, organic bases, alkali metal hydroxides, metallic potassium or other combustible materials in storage room	Electrical installations Class I
72.	Ethyl-nitrite C_2H_5ONO	Colourless liquid. Flammable limits: 4.1% and 50%. Flash point minus 31°F	2	3	4	Ditto	Glass carboys and bottles. Outside storage is preferred. Separate from oxidizing materials. Protect from light. Protect with automatic sprinkler systems or total flooding carbon dioxide	Ditto
73.	Fluorine F_2	Pale-yellow gas with pungent odor Dangerous reactive gas. Toxic gas	4	0	3	Wear special protective clothing	Special steel cylinders. Isolate from other storage especially materials with which fluorine is known to react	-
74.	Formaldehyde HCHO	Colourless gas with a highly irritating odor. The commercial product is a colourless water solution containing 37% and 55% formaldehyde, stabilized against polymerization by 0.05% to 15% methyl alcohol	2	2	0	Wear self-contained breathing apparatus	Insulated tank cars; separate from oxidizing and alkaline materials. Minimum storage temperatures to prevent polymerization range from 83°F for 37% formaldehyde containing 0.05% methyl-alcohol to 29°F for formaldehyde containing 15% methylalcohol	Ditto

1	2	3	4	5	6	7	8	9
75.	Formic acid HCOOH	Colourless, fuming liquid, pungent, penetrating odor. Commercial product is a 90% water solution. Combustible liquid. Strong reducing agent	3	2	0	Wear full protective clothing	Stainless steel drums, or protected glass carboys. Store in cool, dry, well-ventilated place. Outside storage is preferred for stock supplies.	-
76.	Furfurol C_4H_3OCHO	Colourless to reddish-brown oily liquid with an almond odor. Flammable liquid	2	2	0	Wear self-contained breathing apparatus	Drums, tank cars; store in cool dry, well-ventilated location, away from any area where the fire hazard may be acute	-
77.	Hydrazine H_2NNH_2	Clear liquid with an ammonia like odor. Flammable liquid. Highly reactive reducing agent. Flammable limits 4.7% and 100%	3	3	2	Wear full protective clothing	Glass bottles and carboys in wooden boxes. Outside storage is preferred. Separate from oxidizing materials such as metal oxides peroxides and acids	-
78.	Hydriodic acid H.I.	Clear or pale yellow solution of hydrogen iodide in water, containing 57% hydrogen iodide	3	0	0	Ditto	Glass, earthenware bottles. Protect against physical damage	-
79.	Hydrogen H_2	Liquefied, is colourless, odorless liquid. Flammable limits 4% and 74% at atmospheric pressure	3	4	0	Wear special protective clothing designed to prevent liquefied hydrogen coming in contact with the body	Insulated containers, tank truck tank cars. Outdoor storage is preferred. Protect against physical damage	-

1	2	3	4	5	6	7	8	9
80.	Hydrogen chloride HCl	Colourless gas or a water solution which is a clear, colourless or slightly yellow fuming liquid with irritating pungent odor	3	0	0	Wear full protective clothing	Store in cool, well-ventilated place, separate from all oxidizing materials	-
81.	Hydrogen bromide HBr	Colourless gas or a water solution which is a clear colourless or slightly yellow fuming liquid	3	0	0	Ditto	Protect against physical damage. Store in cool, well-ventilated place, seperate from all oxidizing materials	-
82.	Hydrogen cyanide HCN	Clear, colourless liquid, boiling point 79°F, or gas with faint odor of bitter almonds. Extremly toxic	4	4	2	Wear special protective clothing	Steel cylinders or completely absorbed in inert material. Outside storage is preferred. Isolate from other storage and all possible sources of ignition	Electrical installations Class I
83.	Hydrogen fluoride HF	Clear, colourless fuming liquid (boiling point 67°F) aqueous solution or gas. Highly toxic and irritating to eyes, skin	4	0	0	Ditto	Lead carboys, wax or polyethylene bottles. Store in well-ventilated area, seperate from other storage	-
84.	Hydrogen peroxide H_2O_2	Colourless, clear, water like liquid. Extremely irritating to eyes, skin	2	0	1	Wear self-contained breathing apparatus	Protect against physical damage Store in cool, ventilated non-combustible area in vented containers, remote from combustible organic materials	-

1	2	3	4	5	6	7	8	9
85.	Hydrogen sulfide H_2S	Colourless gas, offensive strong odor similar to rotten eggs	3	4	0	Wear self-contained breathing apparatus	Outside storage is preferred. Inside storage should be in a cool, well-ventilated, non-combustible location	Electricals installations Class I
86.	Hydroxyl amine NH_2OH	White crystals or colourless liquid melting point is 93°F	1	3	3	Ditto	Protect against physical damage. Store in cool, non-combustible buildings and separate from oxidizing materials	-
87.	Isoprene $CH_2=C(CH_3)CH=CH_2$	Colourless, volatile liquid, Boiling point 93°F, Flash point minus 65°F	2	4	2	Ditto	Outside store is preferred. Inside storage should be in a standard flammable liquids storage room	Electricals installations Class I
88.	Isopropylamine $(CH_3)_2CHNH_2$	Colourless liquid below 90°F, ammoniacal odor	3	4	0	Wear full protective clothing	Protect against physical damage. Separate from other storage	-
89.	Linden $C_6H_6Cl_6$	White, crystalline or powdered solid, slightly volatile with a musty odor	2	1	0	Wear full protective clothing for liquid Wear self-contained breathing apparatus for powder	Store in a cool, dry, well-ventilated location, away from any area where the fire hazard may be acute	-
90.	Liquefied natural gas LNG	83-99% C_1, 1-13% C_2, 0.1-3% C_3, 0.2-1% C_4,	3	4	1	Wear special clothing designed to prevent LNG or the cold vapors for coming in contact with the body	Insulated tank trucks, tank cars, tank ships and barges	Electrical installations in Class I

1	2	3	4	5	6	7	8	9
91.	Lithium hydride LiH	Off-white, translucent powder	3	4	2	Wear full protective clothing	Metal barrels or drums. Store in isolated well-ventilated, cool, dry area	Electrical installations in Class I
92.	Maleic anhydride $(CH=CHCOOC)_2O$	Colourless crystalline needles or white lumps or pellets with an irritating odor	3	1	1	Ditto	Store in cool, dry, well ventilated location, away from any areas where the fire hazard may be acute	-
93.	Methacrylic acid $CH_2=C(CH_3)COOH$	A colourless liquid with an acid, repulsive odor	3	2	2	Ditto	Detached storage is preferred. Store in cool, well-ventilated rooms	Electrical installations in Class I
94.	Methyl acrylate $CH_2=CHCOOCH_3$	A colourless, volatile liquid with an acid odor. Flammable liquid	2	3	2	Wear self-contained breathing apparatus	Protect against physical damage. Outside storage is preferred. Avoid storage temperature in excess of 70°C. Separate from oxidizing materials	Ditto
95.	Methyl amines CH_3NH_2-mono $(CH_3)_2NH$-di $(CH_3)_3N$-tri	Gas at ordinary temperatures. Fish like odor in low concentration	3	4	0	Wear full protective clothing	Outside storage is preferred. Inside storage of gas should be in a cool, well-ventilated non-combustible locations	Ditto
96.	Methyl chloride CH_3Cl	Colourless gas with faintly sweet ethereal odor. Flammable limits 10.7% and 17.4%	2	4	0	Wear self-contained breathing apparatus	Protect against physical damage. Store in cool, well-ventilated areas of non-combustible construction, away from sources of ignition. Outside storage is preferred	Ditto

1	2	3	4	5	6	7	8	9
97.	Methylcicle-pentane $C_5H_9CH_3$	Colcurless liquid Flash point, below 20°F flammable limits: 1.0% and 8.4%	2	3	0	Wear self-contained breathing apparatus	Glass bottles, cans, steel drums. Outside storage is preferred. Separate from oxidizing materials	Electrical installations Class
98.	Methyldi-chlorosi-lane CH_3HSCl_2	Colcurless liquid with an acid odor. Flammable limits 6.0% and 55%	3	3	2	Wear full protective clothing	Protect against physical damage. Outside storage is preferred. Separate from oxidizing materials	Ditto
99.	Methyl formate CH_3OCHO	Colcurless liquid Flammable limits 5% and 23%. Flash point minus 2°F	2	4	0	Wear self-contained breathing apparatus	Drums and tank cars. Store in cool, well-ventilated area, isolated from oxidizing materials. Keep containers closed	Ditto
100.	Methyl methacry-late $CH_2C(CH_3)COOCH_3$	Colcurless liquid Flammable limits 1.7% and 8.2%. Flash point 50°F	2	3	2	Ditto	Protect against physical damage. Outside storage is preferred. Separate from oxidizing materials	Ditto
101.	Motor fuel contain lead	Red, orange or blue liquids, with sweet musty odor Comprise a range of mixture lead compounds	3	3	3	Wear full protective clothing	Protect against physical damage. Store in a cool, isolated well-ventilated area. Keep away from fire, heat and strong oxidizing agents	Ditto
102.	Naphtha-lene $C_{10}H_8$	White, cristalline volatile solid or flakes having moth ball odor	2	2	0	Wear self-contained breathing apparatus	Protect against physical damage. Store in cool place, away from sources of heat and ignition. Separate from oxidizing materials	-

1	2	3	4	5	6	7	8	9
103.	Nitric acid HNO_3	Transparent, colourless to yellow or red fuming, suffocating, caustic and corcsive	3	0	0	Wear full protective clothing	Protect against physical damage. Separate from metallic powders, carbides, hydrogen sulfide, organic acid, and organic substances	-
104.	Nitroaniline $O_2NC_6H_4NH_2$	Yellow or orange needle crystals. Combustible. Flash point 390°F	3	1	3	Ditto	Protect against moisture and physical damage	-
105.	Nitrobenzene $C_6H_5NO_2$	Oily, pale to dark yellow or brown liquid, with a characteristic odor	3	2	0	Ditto	Protect against freezing and intense heat, and store away from any area where the fire hazard may be acute	-
106.	Nitromethane CH_3NO_2	Clear, colourless liquid, only slightly soluble in water Flammable liquid	1	3	3	In fire conditions wear self-contained breathing apparatus	Store in a suitably isolated outdoor storage facility. Because of the explosion potential presented, every possible means should be taken to protect the storage area	-
107.	Nitrophenol $O_2NC_6H_4OH$	Colourless slightly yellow crystalline solid. Combustible solid	3	1	0	Wear full protective clothing	Separate from combustible organic or other readly oxidizable materials	-
108.	Nitrotoluene $O_2NC_6H_4CH_3$	Pale yellow to yellow solid. Combustible solid	3	1	0	Ditto	Store in cool, dry, well-ventilated area, away from areas of high fire hazard	-
109.	Oxalic acid $HOOCCOOH:2H_2O$	Transparent, colourless crystals or white powder	2	1	0	In fire conditions wear self-contained breathing apparatus	Store in cool, dry, well-ventilated location, away from any area where the fire hazard may be acute	-

1	2	3	4	5	6	7	8	9
110.	Oxygen O_2-liquid	A blue liquid	3	0	0	Wear special protective clothing that will not ignite on contact with liquid oxygen	Isolated from combustible gas installations and combustible materials. Outside storage of liquid oxygen tanks is recommended	-
111.	Parathion $(C_2H_5O)PSOC_6H_4NO_2$	Deep-brown to yellow liquid, very toxic and can be fatal by skin contact	4	1	2	Wear special protective clothing	Store in areas where any spillage from containers will not endanger workers or contaminate other materials	-
112.	Perchloric acid $HClO_4$	Colourless, fuming oily, odorless liquid	3	0	3	Wear full protective clothing	Reagent bottle, kept in a heavy glass tray with larger capacity. Separated from combustible materials, or[illegible]nic materials	-
113.	Phenol C_6H_5OH	Colourless or white crystals, tending to be reddish if impurities are present	3	2	0	Ditto	Store in cool, dry, well-ventilated location. Outside storage is preferred.	-
114.	Phosgene $COCl_2$	Colourless gas with sharp pungent odor Poisons gas	4	0	0	Wear special protective clothing	Store outdoors or in a well-ventilated area of non-combustible construction	-
115.	Phosphoric acid H_3PO_4	Hygroscopic, transparent solid at room temperature	2	0	0	Wear self-contained breathing apparatus	Store in cool, dry, well-ventilated place, away from any area where the fire hazard may be acute	-

1	2	3	4	5	6	7	8	9
116.	Phthalic anhydride $C_6H_4(CO_2)O$	White, lustrous crystals or flakes. Flammable limits: 1.7% and 10.5%	2	1	0	Wear self-contained breathing apparatus	Store in bags in a cool, dry, well-ventilated location	-
117.	Potassium cyanide KCN	White lumps or crystals with faint odor of bitter almonds	3	0	0	Wear full protective clothing	Store in cool, dry place	-
118.	Propionaldehyde C_2H_5CHO	Colourless liquid with a suffocating fruity odor	2	3	1	Wear self-contained breathing apparatus	Drums, tank barges. Store in cool, well-ventilated place	Electrical installations Class I
119.	Propionic acid CH_3CH_2COOH	Colourless liquid with a slightly pungent, rancid odor	2	2	0	Ditto	Outside storage is preferred. Separate from oxidizing materials	-
120.	Propionic anhydride $(CH_3CH_2CO)_2O$	A colourless liquid with pungent odor Combustible liquid Boiling point 336°F	2	2	1	Ditto	Outside storage is preferred Store in cool, well-ventilated place, away from sources of heat, or contamination	-
121.	Propylene $CH_2=CH-CH_3$	A colourless gas liquid under pressure Flammable limits: 2% and 11.1%	1	4	1	Wear full protective clothing	Outside storage is preferred. Protect against source of ignition and heat	Electrical installations in Class I
122.	Propylene oxide CH_3CHOCH_2	Colourless liquid with etherlike odor Flammable limits: 2.8% and 37%	2	4	2	Wear self-contained breathing apparatus	Outside storage is preferred. Isolate from combustible materials and from oxidizing materials	Ditto
123.	Pyridine C_5H_5N	Colourless liquid Flammable limits: 1.8% and 12.4%	2	3	0	Ditto	Outside storage is preferred. Isolate from powerful oxidizing materials	Ditto

1	2	3	4	5	6	7	8	9
124.	Sodium Na	Silvery, soft, waxy metal. Extremely dangerous in contact with moisture or water	3	1	2	Wear full protective clothing	Keep away from water, avoid high temperatures Store under nitrogen or kerogene	-
125.	Sodium cyanide NaCN	White solid in form of granules, flakes or eggs	3	0	0	Wear full protective clothing. Remove contaminated clothing	Store in cool, dry place Separate from other storage and protect from acids and oxidizing materials	-
126.	Sodium fluoride NaF	Clear, lustrous crystals or white powder or balls	2	0	0	Wear self-contained breathing apparatus	Store in dry location. Do not store adjacent to acids or alkalis	-
127.	Styrene $C_6H_5CH=CH_2$	Colourless liquid with aromatic odor. Flammable limits: 1.1% and 6.1%. Flash point 90°F	2	3	2	Ditto	Outside storage is preferred. The monomer must be inhibited to prevent polymerisation	Electrical installations Class I
128.	Tetrachloroethylene $CCl_2=CCl_2$	Clear liquid with mild chloroform-like odor	2	0	0	Ditto	Store in cool, dry well-ventilated place	-
129.	Tetrahydrofuran C_4H_8O	Colourless liquid with ether-like odor	2	3	1	Ditto	Store in cool, dark and well ventilated area, away from sources of heat	Electrical installations in Class I
130.	Toluene $C_6H_5CH_3$	Colourless liquid with aromatic odor. Flammable limits: 1.4% and 6.7%	2	3	0	Ditto	Outside storage is preferred. Separate from oxidizing materials	Ditto

1	2	3	4	5	6	7	8	9
131.	Toluen-2,4-diisocyanate $CH_3C_6H_3(NCO)_2$	Water-white to pale-yellow liquid. Flammable limits: 0.9% and 9.5%	3	1	1	Wear full protective clothing	Store in a cool, dry, well-ventilated location, Separate from oxidizing materials	
132.	Tributylamine $(C_4H_9)_3N$	A colourless liquid with odor like ammonia combustible liquid	2	2	0	Wear self-contained breathing apparatus	Store in a cool, dry, well ventilated place. Separate from oxidizing materials	-
133.	Trichloroethylene $CHCl=CCl_2$	Clear liquid mild chloroform like odor	2	1	0	Ditto	Store in a cool, dry, well-ventilated place, away from area where the fire hazard may be acute	
134.	Trichlorosilane $HSiCl_3$	Colourless liquid below 89°F with an acid odor	3	4	2	Wear full protective clothing	Outside storage is preferred. Separate from oxidizing materials	Electrical installations in Class I
135.	Triethanol amine $(COCH_2CH_2)_3N$	Hygroscopic, alkaline liquid. Combustible. Soluble in water	2	1	1	Wear self-contained breathing apparatus	Store in a cool, dry, well-ventilated location. Avoid contact with copper or copper alloys	-
136.	Triethylamine $(C_2H_5)_3N$	Colourless liquid with an ammoniacal odor. Flammable limits: 1.2% and 8.0%	2	3	0	Ditto	Outside storage is preferred. Separate from oxidizing materials	Electrical installations in Class I

1	2	3	4	5	6	7	8	9
137.	Trinitro-benzene $C_6H_3(NO_2)_3$	Slightly yellowish crystals	2	4	4	For rescue operations, use complete protective clothing	This high explosive should be kept well away from initiator explosives; protect from physical damage	-
138.	Trinitro-toluene $(NO_2)_3C_6H_2CH_3$	Colourless light yellow solid in the form of crystals flakes, pallets	2	4	4	Ditto	This high explosive should be kept well away from initiator explosives Protect from physical damage	-
139.	Vinyl acetate $CH_2=CHOCOCH_3$	Colourless liquid Flammable limits 2.6% and 13.4%	2	3	2	Wear self-contained breathing apperatus	Outside storage is preferred. Should be kept seperated from oxidizing materials	Electrical installations in Class I
140.	Vinyl chloride $CH_2=CHCl$	Colourless gas at ordinary temperature Flammable limits: 3.6% and 33%	2	4	1	Ditto	Outside storage is preferred. Seperate from oxidizing materials	Ditto
141.	Zirconium Zr	Hard lustrous grayish scales or powder	1	4	1	Ditto	Protect against physical damage. Isolate from oxidizing materials	-
142.	Zirconium tetrachloride $ZrCl_4$	White lustrous crystals	3	0	1	Wear full protective clothing	Keep containers tightly sealed; outside storage is preferable	-

PROPERTIES OF COMMON FLAMMABLE CHEMICALS

	Hazard Identification					
	Health	Flamma-bility	Reac-tivity	Flash Pt. °F	Water Soluble	Fire Fighting Phases
1	2	3	4	5	6	7
Acetophenone	1	2	0	180(oc)	No	5
Acetone	1	3	0	0	Yes	2
Adipic Acid	1	1	0	385	No	7
Asphalt (typical)	0	1	0	400+(oc)	No	7
1-Bromopentane	1	3	0	90	No	4
Butane	1	4	0	Gas	No	1
1-Butane	1	3	0	84	Yes	2
2-Butanol	1	3	0	75	Yes	2
Butenes	1	4	0	Gas	No	1
Butyl Acetate	1	3	0	72	Slightly	2
Butyl Acetate (iso)	1	3	0	64	No	4
Butyl Benzoate (n)	1	1	0	225(oc)	No	7
Chloronexane	0	3	0	95	No	4
1-Chloropentane	1	3	0	55(oc)	No	4
Cod Liver Oil	0	1	0	412	No	7
Corn Oil	0	1	0	490	No	7
Cottonseed Oil	0	1	0	486	No	7
Cyclonexane	1	3	0	minus 4	No	4
Cyclonexanone	1	2	0	111	Slightly	3
Cyclonexyl Alconol	1	2	0	154	Slightly	3
Cyclopentane	1	3	0	less than 20	No	4
Cyclopropane	1	4	0	Gas	No	1
Decane (n)	0	2	0	115	No	5

(cont.)

1	2	3	4	5	6	7
Decanol	0	2	0	180	No	5
Dibutyl Phthalate	0	1	0	315	No	7
Diesel Fuel Oil No.1-D	0	2	0	100 min. or legal	No	5
Diesel Fuel Oil No.2-D	0	2	0	125 min. or legal	No	5
Diesel Fuel Oil No.4-D	0	2	0	130 min. or legal	No	5
Diethanolamine	1	1	0	305	Yes	6
Diethylene Glycol	1	1	0	225	Yes	6
Diethyl Phthalate(o)	0	1	0	325(oc)	No	7
Dioctyl Phthalate	0	1	0	425(oc)	No	7
Dipropylene Glycol	0	1	0	280	Yes	6
Ethyl Acetate	1	3	0	24	Slightly	2
Ethyl Alcohol	0	3	0	55	Yes	2
Ethyl Benzoate	1	1	0	greater than 204	No	7
2-Ethylbutanol	1	2	0	135(oc)	No	5
Ethylbutyl Acetate	1	2	0	130(oc)	No	5
Ethylbutyl Ketone	1	2	0	115(oc)	No	5
Ethylene Glycol	1	1	0	232	Yes	6
Ethel Methyl Ketone	1	3	0	21	Yes	2
Fuel Oil No.1 (Range Oil,Kerosine)	0	2	0	100 min. or legal	No	5
Fuel Oil No.2	0	2	0	100 min. or legal	No	5
Fuel Oil No.4	0	2	0	130 min. or legal	No	5
Fuel Oil No.5	0	2	0	130 min. or legal	No	5
Fuel Oil No.6	0	2	0	150 min. or legal	No	5
Gasoline	1	3	0	minus 45	No	4
Glycerine	1	1	0	320	Yes	6
Heptane (n)	1	3	0	25	No	4
Hexane (n)	1	3	0	minus 7	No	4
1-Hexanol	1	2	0	145	Slightly	3
Hydrogen	0	4	0	Gas	Slightly	1

(cont.)

1	2	3	4	5	6	7
Isopentyl Alcohol	1	2	0	109	Slightly	3
Isopropyl Alcohol	1	3	0	53	Yes	2
Lanolin	0	1	0	460	No	7
Lard Oil (commercial or animal)	0	1	0	395.	No	7
Linseed Oil (boiled)	0	1	0	403	No	7
Lubricating Oil (mineral)	0	1	0	300-450	No	7
Methanol	1	3	0	52	Yes	2
Methyl Acetate	1	3	0	14	Yes	2
2-Methyl-2-Butanol	1	2	0	103	Slightly	3
2-Methyl-2-Propanol	1	3	0	52	Yes	2
Methyl Salicylate	1	1	0	214	No	7
Mineral Oil	0	1	0	380(oc)	No	7
Octane	0	3	0	56	No	4
Octyl Alcohol (n)	1	2	0	178	No	5
Oleic Acid	0	1	0	372	No	7
Oleo Oil	0	1	0	450	No	7
Peanut Oil	0	1	0	540	No	7
Pentane	1	4	0	Less than minus 40	No	1
1-Pentanol (n)	1	3	0	91	Slightly	2
2-Pentanol	1	3	0	94	Slightly	2
Pentanol-3	1	2	0	104	Slightly	3
Pentyl Acetate (n)	1	3	0	77	Slightly	2
Pentyl Benzene	1	2	0	150(oc)	No	5
Pentyl Laurate	0	1	0	300(oc)	No	7
Pentylnaphthalene	0	1	0	255(oc)	No	7
Petroleum (crude)	1	3	0	20-90	No	4
Propane	1	4	0	Gas	No	1
Propyl Acetate	1	3	0	58	Yes	2
Propylene Glycol	0	1	0	210	Yes	6
Quenching Oil	0	1	0	365	No	1
Soy Bean Oil	0	1	0	540	No	7
Tallow Oil	0	1	0	492	No	7
Tetrahydronaphthalene	1	2	0	160	No	5

1	2	3	4	5	6	7
Transformer Oil	0	1	0	295(oc)	No	7
2,4,5-Trichloro-phenol in solvent	1	1	0	Solvent Flash Point	No	5
2,4,6-Trichloro-phenol in solvent	1	1	0	Solvent Flash Point	No	5
Trietnylene Glycol	1	1	0	350	Yes	6
Turpentine	1	3	0	95	No	4
Vegetable Oil (hydrogenated)	0	1	0	610(oc)	No	7

Fire Fighting Phases

The numbers at the left of the paragraphs below correspond to the numbers in the right-hand column of Table

1. FIRE FIGHTING PHASES: Stop flow of gas. Use water to keep fire-exposed containers cool and to protect men effecting the shutoff. If a leak or spill has not ignited, use water spray to disperse the gas or vapor and to protect men attempting to stop a leak.

2. FIRE FIGHTING PHASES: Use dry chemical "alcohol" foam, or carbon dioxide; water may be ineffective (see Explanatory), but water should be used to keep fire-exposed containers cool. If a leak or spill has not ignited, use water spray to disperse the vapors and to protect men attempting to stop a leak. Water spray may be used to flush spills away from exposures and to dilute spills to nonflammable mixtures.

3. FIRE FIGHTING PHASES: Use water spray, dry chemical, "alcohol" foam, or carbon dioxide. Use water to keep fire-exposed containers cool. If a leak or spill has not ignited, use water spray to disperse the vapors and to protect men attempting to stop a leak. Water spray may be used to flush spills away from exposures and to dilute spills to nonflammable mixtures.

4. FIRE FIGHTING PHASES: Use dry chemical, foam, or carbon dioxide. Water may be ineffective (see Explanatory), but water should be used to keep fire-exposed containers cool. If a leak or spill has not ignited, use water spray to disperse the vapors and to protect men attempting to stop a leak. Water spray may be used to flush spills away from exposures.

5. FIRE FIGHTING PHASES: Use water spray, dry chemical, foam, or carbon dioxide. Use water to keep fire-exposed containers cool. If a leak or spill has not ignited, use water spray to disperse the vapors and to provide protection for men attempting to stop a leak. Water spray may be used to flush spills away from exposures.

6. FIRE FIGHTING PHASES: Use water spray, dry chemical, "alcohol" foam, or carbon dioxide. Water or foam may cause frothing. Use water to keep fire-exposed containers cool. Water spray may be used to flush spills away from exposures and to dilute spills to noncombustible mixtures.

7. FIRE FIGHTING PHASES: Use water spray, dry chemical, foam, or carbon dioxide. Water or foam may cause frothing. Use water to keep fire-exposed containers cool. Water spray may be used to flush spills away from exposures.

CLASSIFICATION AND DEFINITIONS OF CLASSES OF DANGEROUS PRODUCTS

The definitions recommended are not definitions in the strict sense of the word. In practice, the aim is to provide general guidance as to which goods are dangerous and as the class in which, according to their characteristics, they should be included.

These definitions are so devised as to provide a common pattern according to which it should be possible to formulate the definitions included in the several national and international regulations.

In this way they promote uniformity in the classification of the various categories of dangerous goods The definitions recommeded, together with the list of dangerous products, should offer to those concerned the guidance they require.

Class 1 - Explosives

Class 1 comprises:

Explosive substances:

Substance which is not itself an explosive but which can form an explosive atmosphere of gas, vapour or dust is not included in class 1, except those which are too dangerous to transport or those where the predominant hazard is one appropriate to another class.

An explosive substance is a solid or liquid substance (or a mixture of substances) which is itself capable by chemical reactions of producing gas at such a temperature and pressure and such a speed as to cause damage to the surroundings.

A pyrotechnic substance is a substance or a mixture of substances designed to produce an effect by heat, light sound, gas or smoke or a combination of these as the result of non-detonative self-sustaining exothermic chemical reactions.

Class 1 is divided into five divisions:

1.1. Substances and articles which have a mass explosion hazard, which affect virtually the entire load practically instantaneously.

1.2. Substances which have a projection hazard but not a mass explosion hazard.

1.3. Substances which have fire hazard, either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard.

This division comprises substances which give considerably the radiant heat or which burn one after another, producing minor blast or protection effects or both.

1.4. Substances which present no significant hazard.

This division comprises substances which present only a small hazard in the event of ignition or initiation during transport.

1.5. Very insensitive substances

This division comprises explosive substances which are so insensitive that there is very little probability of initiation or (of) transition from burning to detonation under normal conditions of transport. As a minimum requirement they don't explode in the fire test.

Class 2 = Gases, compressed, liquefied or dissolved under pressure

The class comprises:

a) Permanent gases which cannot be liquefied at ambient temperatures.

b) Liquefied gases which can become liquid under pressure at ambient temperatures.

c) Dissolved gases which can be dissolved under pressure in a solvent, which may be absorbed in a porrous material.

d) Deeply refrigerated gases: liquid air, oxigen etc.

Class 3 = Inflammable liquids

The word inflammable has the same meaning as flammable: inflammable liquids are liquids, or mixtures of liquids, or liquids containing solids in solution or suspension, which give off an inflammable vapour at or below 65.6°C open test.

Class 4 - Inflammable solids

Substances liable to spontaneous combustion and substances which, on contact with water, emit inflammable gases.

Class 5 - Oxidizing substances, organic peroxides

These are substances which while themselves are not necessarily combustible, may, generally, by yielding oxygen, cause, or contribute to the combustion of other material.

Class 6 - Poisonous (toxic) and infectious substances

This class comprises: poisonous, which give off a poisonous gas or vapour and infectious substances containing disease producing microorganisms.

Class 7 - Radioactive substances

A radioactive subtance is defined as any substance of which the specific activity is greater than 0,002 microcuric per gramme.

Class 8 - Corrosives

These are substances which, by chemical action, will cause severe damage when in contact with living tissue or in the case of leakage, will cause material damage or will destroy, the height or the means of transport.

Class 9 - Miscellaneous dangerous substances

These are substances which during transport present a danger not mentioned by the other classes. This class is not essential for the purpose of carriage by rail or road.

Classification codes

The compatibility groups as shown in classification codes, should be adopted. The definitions are mutually exclusive except that a substance may qualify for compatibility group S, regardless of its inherent characteristics, if the packaging complies with the definition of that group.

Recommendations on packing for class 1

In principle, explosives should not be packed together with explosives of a different nature. However, when such mixed packing is allowed, it should be such that an accidental explosion of any part of the contents of the package would not be communicated to the rest of the contents.

Each package should be marked outside with name of its contents, as well as with the net weight of explosive and the gross weight of the package.

When the packaging includes a double envelope filled with water which may freeze during transport , a sufficient quantity of an anti-freeze agent should be added to the water to prevent freezing.

Where significant internal pressure is likely to develop in receptacles, such receptacles should be constructed so that detonation should not be possible because of the

internal pressure rise due to internal or external causes.

CLASSIFICATION CODES

Description of substance or article to be classified	Compatibility group	Classification code
1	2	3
Primary explosive substance	A	1.1 A
Article containing a primary explosive substance	B	1.1 B 1.2 B 1.4 B
Propellant explosive substance or other secondary deflagrating explosive substances or article containing such explosive substance	C	1.1 C 1.2 C 1.3 C 1.4 C
Secondary detonating explosive substance or black powder or article containing a secondary detonating explosive substance, in each case without means of initiation and without a propelling charge	D	1.1 D 1.2 D 1.4 D 1.5 D
Article containing a secondary detonating explosive substance, without means of initiation with a propelling charge	E	1.1 E 1.2 E
Article containing a secondary detonating explosive substance, with means of initiation with or without a propelling charge	F	1.1 F 1.2 F 1.3 F 1.4 F
Pyrotechnic substance, or article containing a pyrotechnic substance, or article containing both an explosive substance and an illuminating, incendiary, lachrymatory or smoke-producing substance (other than a water-activated article or one containing white phosphorus, phosphide or an inflammable liquid or gel)	G	1.1 G 1.2 G 1.3 G 1.4 G
Article containing both an explosive substance and white phosphorus	H	1.2 H 1.3 H
Article containing both an explosive substance and an inflammable liquid or gel	J	1.3 J
Article containing both an explosive substance and a toxic chemical agent	K	1.2 K 1.3 K

1	2	3
Explosive substance or article containing an explosive substance and presenting a special risk needing isolation of each type	L	1.1 L 1.2 L 1.3 L
Substance or article so packed or designed that any hazardous effects arising from accidental functioning are confined within the package unless the package has been degraded by fire, in which case all blast or projection effects are limited to the extent that they do not significantly hinder or prohibit fire fighting or other emergency response efforts in the immediate vicinity of the package	S	1.4 S

Method E_1 Inner: not necessary
Outer: bags, paper, textile, plastics

Method E_2 Inner: receptacles, metal, paper, plastics
Outer: barrels, boxes

Method E_3 Inner: bags, plastics, rubber, textile
Outer: barrels, drums, steel removable

Method E_6 Inner: bags, plastics, textile rubber
Outer : barrels, boxes, drums

Method E_7 Inner: bags, textile, rubber
Outer: boxes, drums

Method E_{11} Inner: bags, paper, waxed, plastics, textile
Outer: barrels, boxes, drums

Method E_{13} Inner: bags, plastics, sheets
Outer: barrels, boxes

Method E_{14} Inner: bags, rubber, textile
Outer: barrels, drums

Method E_{15} Inner: not necessary
Outer: drums, aluminium, steel, reinforced chime

Method E_{16}	Inner: as specified by the competent national authority
	Outer: as specified by the competent national authority
Method E_{17}	Inner: cans, metal, glass plastics
	Outer: boxes, natural wood
Method E_{18}	Inner: bags, paper, plastics, sheets
	Outer: barrels, boxes, drums
Method E_{21}	Inner: boxes, fibreboard
	Outer: cans, metal, paper, plastics
Method E_{24}	Inner: bags, rubber, textile, plastics
	Outer: boxes, fibreboard

LIST OF DANGEROUS CHEMICALS

Substance or article		Hazards		Packing
Number	Designation	Class division	Subsidiary risks	Packing method
1	2	3	4	5
1.	Ammonium picrate, dry or containing by weight, less than 10 per cent water	1.1 D	+	E 2
2.	Cyclotrimethylene-trinitramine (cyclonite, hexogene, or R.D.X.) containing, by weight, at least 15 per cent water or at least 10 per cent phlegmatiser	1.1 D	+ 6.1	E 6
3.	Diazodinitrophenol, containing, by weight, at least 40 per cent water or mixture of alcohol and water	1.1 A	+	E 3
4.	Diethyleneglycol dinitrate containing, by weight, at least 25 per cent non-volatile water-insoluble phlegmatiser	1.1 D	+	E 7
5.	Dinitrophenol, dry or containing by weight, less than 15 per cent water	1.1 D	+ 6.1	E 2
6.	Dinitrophenates (alkali metals) dry or containing by weight, less than 15 per cent water	1.3 C	+ 6.1	E 2
7.	Dinitroresorcinol, dry or containing by weight, less than 15 per cent water	1.1 D	+	E 2
8.	Hexanitrodiphenylamine (dipicrylamine or hexyl)	1.1 D	+	E 11
9.	Guanyl nitrosamino-guanylidene hydrazine, containing by weight, at least 30 per cent water	1.1 A	+	E 3
10.	Guanyl nitrosamino-guanyltetrazene (tetrazene), containing, by weight, at least 30 per cent water or mixture of alcohol and water	1.1 A	+	E 3
11.	Lead azide, containing by weight, at least 20 per cent water or mixture of alcohol and water	1.1 A	+	E 3

1	2	3	4	5
12.	Lead styphnate (lead trinitroresorcinate), containing by weight, at least 20 per cent water or mixture of alcohol and water	1.1 A	+	E 3
13.	Mannitol hexanitrate (nitromannite) containing by weight, at least 40 per cent water or mixture of alcohol and water	1.1 D	+	E 14
14.	Mercury fulminate, containing by weight, at least 20 per cent water or mixture of alcohol and water	1.1 A	+	E 3
15.	Nitroglycerine, desensitized with at least 40 per cent, by weight, non-volatile water insoluble phlegmatiser	1.1 D	+ 6.1	E 7
16.	Nitroglycerine, spirit of, containing more than 1 per cent but not more than 10 per cent nitroglycerin in solution in alcohol	1.1 D	+	E 17
17.	Nitrostarch, dry or containing by weight, less than 20 per cent water	1.1 D	+	E 19
18.	Nitro urea	1.1 D	+	E 2
19.	Penterythrite tetranitrate (pentaerythritol tetranitrate or peth) containing by weight, at least 25 per cent water or at least 15 per cent phlegmatiser	1.1 D	+	E 6
20.	Pentolite, dry or containing by weight, less than 15 per cent water	1.1 D	+	E 13
21.	Trinitroaniline (picramide)	1.1 D	+	E 2
22.	Trinitrophenol (picric acid), dry or containing, by weight, less than 30 per cent water	1.1 D	+	E 2
23.	Trinitrochlorobenzene (picryl chloride)	1.1 D	+	E 2
24.	Potassium salts of nitro aromatic derivatives, explosive	1.3 C	+	E 21
25.	Sodium salts of nitro aromatic derivatives, explosive	1.3 C	+	E 21
26.	Tetranitroaniline	1.1 D	+	E 2
27.	Trinitrophenylmethyl-nitramine (tetryl)	1.1 D	+	E 11

1	2	3	4	5
28.	Trinitrotoluene (TNT), dry or containing by weight, less than 30 per cent water	1.1	D	+	E	2
29.	Trinitroanisole	1.1	D	+	E	2
30.	Trinitrobenzene, dry or containing, by weight, less than 35 per cent water	1.1	D	+	E	2
31.	Trinitrobenzoic acid, dry or containing by weight, less than 30 per cent water	1.1	D	+	E	11
32.	Trinitrometacresol	1.1	D	+	E	2
33.	Trinitronaphthalene	1.1	D	+	E	2
34.	Trinitrophenetole	1.1	D	+	E	2
35.	Trinitroresorcinol (styphnic acid), dry or containing by weight, less than 20 per cent water or mixture of alcohol and water	1.1	D	+	E	2
36.	Urea nitrate, dry or containing by weight, less than 20 per cent water	1.1	D	+	E	2
37.	Ammonium nitrate containing more than 0.2 per cent of combustible substances, including any organic substance calculated as carbon, to the exclusion of any other added substance	1.1	D	+	E	1
38.	Ammonium nitrate fertilizer which is more liable to explode than ammonium nitrate containing 0.2 per cent of combustible substances, including any organic substance calculated as carbon to the exclusion of any other added substance	1.1	D	+	E	1
39.	Barium azide, dry or containing by weight, less than 50 per cent water or alcohol	1.1	A	+ 6.1	E	3
40.	Cyclotetramethylene-tetranitramine (H.M.X. or octogene) containing by weight at least 15 per cent water or at least 10 per cent phlegmatiser	1.1	D	+	E	6
41.	Sodium dinitroorthocresolate, dry or containing by weight, less than 15 per cent water	1.3	C	+	E	2
42.	Sodium picramate, dry or containing, by weight, less than 20 per cent water	1.3	C	+	E	2

1	2	3	4	5
43.	Zirconium picramate, dry or containing by weight, less than 20 per cent water	1.3 C	+	E 2
44.	Nitroguanidine (picrite), dry or containing, by weight, less than 20 per cent water	1.1 D	+	E 18
45.	Nitrocellulose with less than 25 per cent water (or alcohol) by weight	1.1 D	+	E 16
46.	Nitrocellulose with less than 18 per cent plasticizing substance, by weight	1.1 D	+	E 16
47.	Nitrocellulose with not less than 25 per cent alcohol by weight	1.3 C	+	E 15
48.	Nitrocellulose with not less than 18 per cent plasticizing substance by weight	1.3 C	+	E 15
49.	5-Nitrobenzotriazol	1.1 D	+	E 2
50.	Trinitrobenzenesulphonic acid	1.1 D	+	E 2
51.	Trinitrofluorenone	1.1 D	+	E 2
52.	Trinitrotoluene (TNT) mixed with trinitrobenzene or hexanitrostilbene	1.1 D	+	E 2
53.	Trinitrotoluene (TNT) mixed with trinitrobenzene and hexanitrostilbene	1.1 D	+	E 2
54.	Tritonal (TNT mixed with aluminium)	1.1 D	+	E 2
55.	Cyclotrimethylene-trinitramine (cyclonite or hexogene or RDX) mixed with cyclotetramethylenetetranitramine (HMX) or octogene), containing by weight at least 15 per cent water or at least 10 per cent phlegmatiser	1.1 D	+	E 6
56.	Hexanitrostilbene	1.1 D	+	E 11
57.	Hexotonal, cast (hexogen mixed with trinitrotoluene and aluminium)	1.1 D	+	E 13
58.	Trinitroresorcinol (styphnic acid) containing by weight not less than 20 per cent water (or mixture of alcohol and water)	1.1 D	+	E 24

2. PLOT PLAN DESIGN

PLOT PLAN DESIGN

The profile components of a complex and their connection. The main sections of a complex or chemical works are:

a. Production

b. Utilities and common services

c. Mechanical-energetic and instruments maintenance

d. Urban public maintenance works

e. Raw materials, end products and auxiliary materials storage

f. Loading-unloading platforms

g. Waste water treatment

Sections "b" thru "g" are meant to serve the main production section, their activity being subordinated to ensuring the industrial production of the complex.

Multiple connections are achieved between the auxiliary sections and the production section in fields specific to each section separately, their activity being subordinated to the rythmical supply of raw materials, sale of chemical products, mechanical maintenance of equipment, supply of spare parts, periodical, planned inspections and emergency inspection, start-up and restart-up of process plants, liquid effluent and waste water treatment so that their discharge should meet the requirements of the norms in force. The smooth operation of this complex mechanism requires a good planning of the auxiliary sections activities, highly qualified labour, tools and devices having the accuracy class suitable to necessary operations.

The construction of the auxiliary sections shall keep the pace with the development of the production section, by main development stages, taking care to locate them as far as possible in the consumption or servicing center of productive plants.

a. Within the production section, multiple connections are established between the process plants making up this section in view of processing certain subproducts and semifinished products.

The attached illustration shows the connection between the process plants making-up a modern refinery and an adjacent petrochemical complex. From this analysis it results:

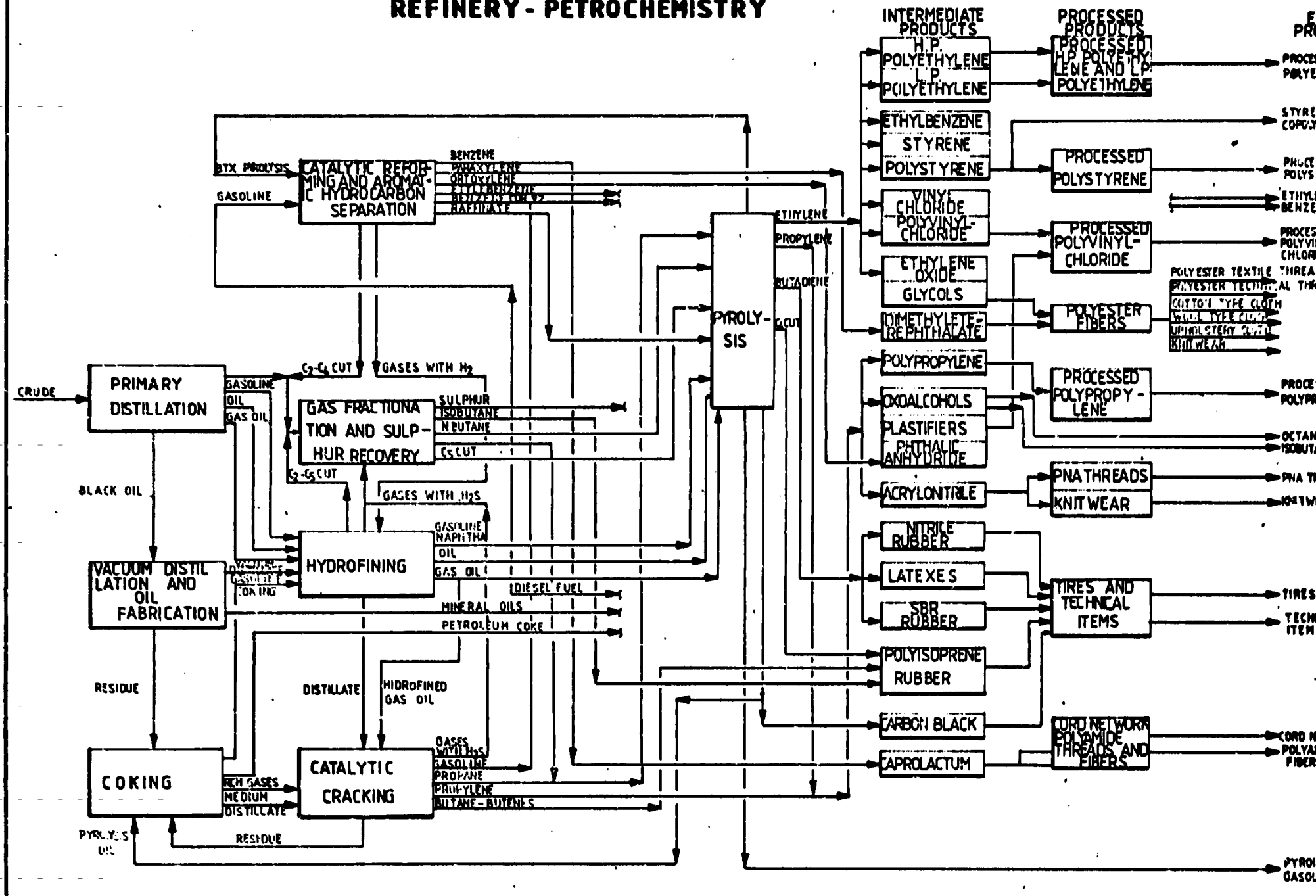
- the significant share of the refinery products meant to petrochemical processing (propane, propylene, butane-butene, isobutane, gasoline, oil, raffinate, gas oil, benzene, xylenes, sulphur, a.s.o.);

- recycle of some petrochemical products to refinery such as (benzene-toluene-xylene cut, pyrolysis gasoline, pyrolysis oil);

- the multiple connections existing between refinery productions on one hand and the petrochemical productions on the other hand.

b. The utilities section covers all the units securing the production of so-called "secondary utilities", i.e. recycled water, demineralized water, instrument air, nitrogen, oxygen, process air, refrigeration, condensate collection stations sized up so as to secure the necessary quantity

FLOW DIAGRAM OF AN INTEGRATED COMPLEX
REFINERY - PETROCHEMISTRY



of utilities at the battery limit of each process unit.

The location of the utilities section in the vicinity or even in the consumption center of the process units contributes to the reduction of investment values for the connection pipes, piperacks and power saving for pumping.

e.g. The other auxiliary sections shall be sized up according to the specific activities they are meant for by the detailed drawings.

The profile components of a complex takes well established areas within the plot plan of a chemical works.

Hereinunder are given some guidelines concerning the structure of a plot plan whose main characteristics are process functionality and safety.

2.4.1. Industrial Area

The area meant to the construction of units made up of several industrial enterprises, interconnected for co-operation in the process of production or supply of utilities common services, access roads and transportation represents an industrial area. The industrial areas can be on current production, partially occupied or free lands meant for future industrial constructions.

Industrial areas can be classified according to several criteria as follows:

a) According to the importance of the industrial area:

- of national interest
- of urban interest

b) According to the specific of the units in the industrial area:

- industrial production
- liquid and solid substances storages
- mixed: production and storages

c) According to the nature of the processes applied in the productive units:

- refinery
- refinery and petrochemistry
- petrochemistry
- chemistry
- machine building
- metallurgy
- energetics

d) According to the hazard of the industrial units in the area:

- explosion hazard
- fire hazard
- high pollution

The location of industrial areas in the vicinity of urban or rural places is established by systematization plans of the concerned places, taking into account the following criteria:

- proximity of existing access roads, railways and rivers or connection possibilities;
- availability of nonproductive or low productive land;

- observance of architectural demands for urban development

- uphill of a place, judging by prevailing wind direction;

- transportation means for operation personnel of chemical plants.

The systematization surveys regarding the land meant for the industrial areas make an analysis of all aspects concerning: nature of land, supply of primary utilities, transportations, environmental protection and fuel supply.

2.4.2. Plot Plan of a Chemical Complex

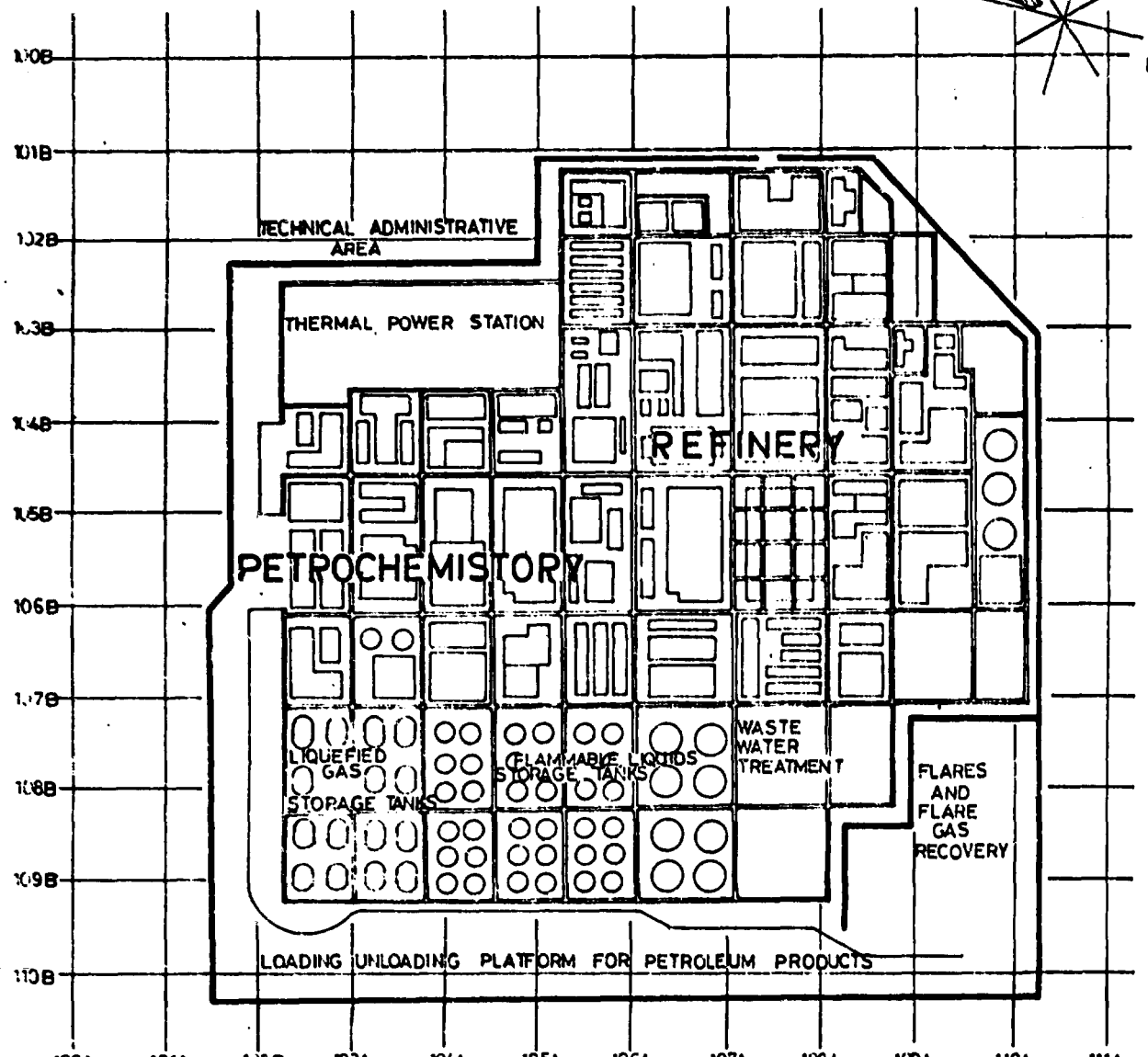
The plot plan of a chemical complex means the reprezentation in orthogonal projection of all industrial constructions, main equipment roads, railways, piperacks, sewers and social-administrative buildings at scale 1:5000 or 1:2000. Parts of the plot plan can also be scaled to 1:500. The attached illustration shows a plot plan of a hypothetical petrochemical complex.

One can see the arrangement of profile components in certain areas of the plot plan, as follows: auxiliary units, productive plants, utilities and common services, storage tanks farm, loading-unloading platforms, waste water treatment, flares and off gases recovery.

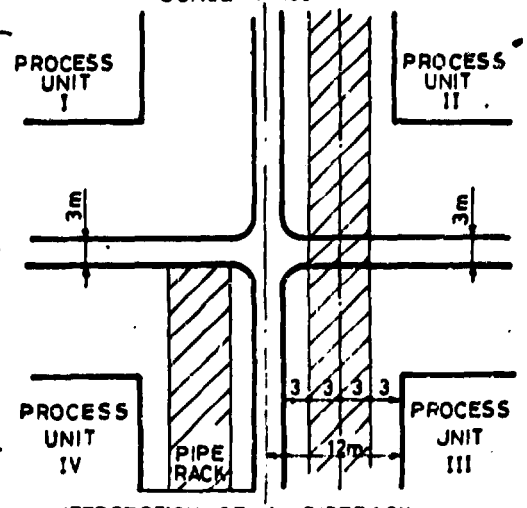
The arrangement of profile components is done according to the following, more important criteria: auxiliary units cover all the administrative and overhauling offices located at a distance of minimum 100 m from the productive plants, outside the hazardeous area.

PLOT PLAN OF AN INTEGRATED COMPLEX RAFINERY PETROCHEMISTORY

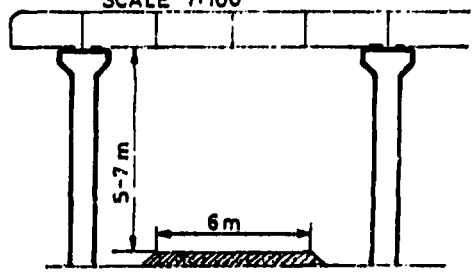
SCALE 1 : 5000



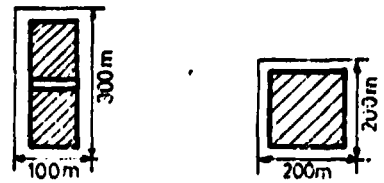
ROAD CROSSING DETAIL
SCALE 1 : 100



INTERSECTION OF A PIPERACK AND A ROAD
SCALE 1:100



DIMENSIONS OF PROCESS PLATFORMS
SCALE 1 : 500



PROCESS PLATFORM

PROCESS PLATFORM

The productive plants are located in the flow of raw materials, intermediate and end products, in process buildings not bigger than 150 x 300 m.

Provisions shall be made between the process buildings for traffic and pedestrian access roads to permit circulation of solid materials, firemen, repairs and maintenance aggregates and operation personnel.

Utilities and common works are located as far as possible in the gravity center of process consumers and are built according to the development stages of the productive plants of the Complex.

Storage tanks farms and loading and unloading platforms are located by their destination, for flammable liquids, liquefied gases, corrosive chemical substances at distances specified by fire fighting regulations.

Waste water treatment facilities are located outside the production areas to the direction of natural land inclination.

The plot plan should divide the areas and facilities into independent risk areas that would contain, as nearly as possible, one general type of equipment such as tanks, spheres, bullets, pipe racks, process units, utilities building, waste water treatment, flares and various types of buildings.

The following classification is known for flammable liquid:

Class A : Flammable liquid is a liquid having a flash point below 100°F (37,8°C) and a vapor pressure not exceeding 40 psi (absolute) at 100°F.

Class IA - have flash points below 73°F and a boiling point below 100°F

Class IB - have flash points below 73°F and a boiling point at or above 100°F

Class IC - have flash points at or above 73°F and a boiling point below 100°F

Class B : Combustible liquid has a flash point at or above 100°F. Combustible liquids are as follows:

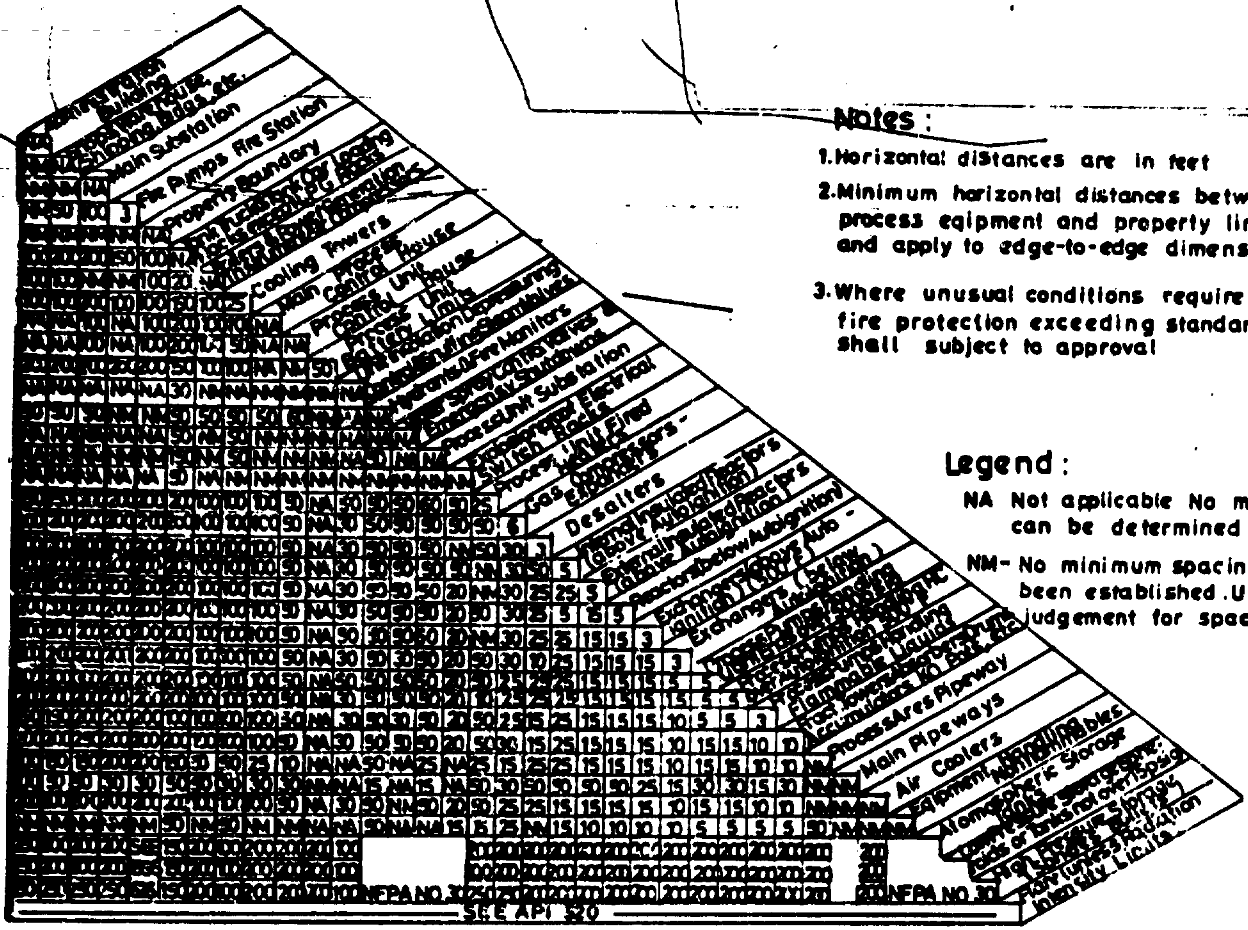
Class II - liquids have flash points at or above 100°F and below 140°F

Class IIIA - liquids have flash points at or above 140°F and below 200°F

Class IIIB - liquids have flash points at or above 200°F

Class C : Unstable (reactive) liquids are those which in the pure state or as commercially produced or transported will vigorously polymerize, decompose, condense, or will become self active under conditions of shock, pressure or temperature.

Minimum spacing for refinery and petrochemical plants



Notes:

1. Horizontal distances are in feet
2. Minimum horizontal distances between buildings, process eqipment and property lines are shown and apply to edge-to-edge dimensions.
3. Where unusual conditions require closer spacing, fire protection exceeding standard requirements shall subject to approval

Legend:

NA Not applicable No measurable distance can be determined

NM- No minimum spacing requirements has been established. Use engineering judgement for spacing

3. HAZARD IDENTIFICATION, ANALYSIS AND CONTROL

HAZARD IDENTIFICATION, ANALYSIS AND CONTROL

The industrial risk is defined under the form of certain production losses, probably annually, or human casualities as a result of unforeseen technical incidents. If we were to put it into a relation we could write:

$R = F \times S$ where R - risk or annual losses which might occur (t/yr)

F - frequency or number of unforeseen events which might occur in an year

S - severity or average loss per event t/event

The possibilities of applying the relation depend on several factors, among which: identification of risk, determination of accidents frequency and average severity per event, have the highest share.

Undeniably the risk identification remains the most difficult problem due to the high multitude and diversity of events (from gasket breaking to equipment failure) which may lead to technical accidents. A very useful means may be the statistics of the events in similar plants which may represent a basis for identification of foreseeable risk.

In view of risk identification and determination of the severity and frequency of technical events it is necessary to proceed to a classification of the technical accidents, as follows:

1. Common accidents which do not result in plant

shut-down but can end in injuring the personnel, disabling employees temporarily (low intensity fire, acid or basic burns, electrocution, falling, etc.)

2. Fires of large proportions, explosions of process equipment release of noxious which may lead to plant deterioration and shut-down over a long period of time and human losses.

3. Long time pollution of the environmental medium by contamination of groundwater table due to the infiltration of some chemical residues not subjected to biodegradation, discharge to atmosphere of toxic gases, etc.

4. Human accidents which may be caused by misuse or abuse of some materials and chemicals, such as: pesticides, polyurethanes, pharmaceuticals.

Based on statistics made by special organizations the frequency of dangerous accidents in crude processing industry and petrochemistry is estimated as follows:

Table

Type of event	Annual frequency
Fire at storage tank with oil or petrochemical liquid products	3.3×10^{-4}
Explosion or fire at liquefied gas tank	3.0×10^{-6}
Explosion or fire at a process plant	1.4×10^{-4}
Damage of equipment with nonflammable substances	2.0×10^{-5}

Damage frequency of the specific equipment in the chemical industry, according to the published data, is

given hereunder:

- valve breaking	1.0×10^{-8}/h
- flange breaking	1.0×10^{-8}/h
- compensator breaking	1.0×10^{-8}/h
- pump or compressor damage	1.0×10^{-8}/h
- valve blocking in "off" or "on" position	1.0×10^{-5}/h
- damage of an electronic control system	1.0×10^{-6}/h
- storage tank failure	1.0×10^{-6}/yr
- pipe breaking	1.8×10^{-9}/m.yr

The following steps can be taken during plant design and operation in order to reduce the risk:

a. Passive steps taken during the time of project elaboration for the process plant, i.e.

- grouping of the hazardous equipment in well-defined areas at the time of plot plan execution, so that the effects of fire propagation be minimized

- use of gas detectors in areas presenting the danger of hydrocarbon vapours release

- advanced process automation, furnishing of interlocking systems for flows with fire or explosion hazard

- selection of construction materials for equipment and pipes to withstand the operating temperatures and pressures of the process plants

- design of foundations, reinforced concrete and steel structures assured against earthquakes or strong winds.

b. Active steps taken during the occurrence of the technical accident in view of limiting its destructive effects, among which:

- training of operation personnel by simulation of accidents in order to test the personnel capability of prompt action

- maintenance of audible and optic alarm system, of noxious and flammable gas detectors which shall energize the proper signals in case of danger

- precaution inspection of safety valve operation

- periodic inspection of fire fighting means which are part of plant endowment.

The passive and active steps specific to each process are established at the same time with the elaboration of design documentation and operation instructions of the process plant.

Hazard analysis estimated the frequencies and consequence of accidents caused by loss of containment events. It considered the possible failures of engineered systems and petrochemical personnel to cope with, or mitigate, the effects of these accidents.

To simplify the analysis, each process unit was divided into process sections. It was estimated the risk associated with process sections in many petrochemical areas and then compared these estimates to an acceptance criterion

with these areas, indicate where improvement is needed and where efforts to reduce risk may be most cost-effective.

The motivation for estimating the risk of a particular activity is often to judge whether a level of risk is acceptable. One example of a criterion for acceptable risk comparison is the "constant risk criterion".

A level of constant risk exists when the product of the frequency and consequence for each category of accidents is the same for all categories of accidents regardless of the level of consequence of the accidents. The constant risk criterion is a completely objective or rational criterion for risk comparison when the decision-maker has infinite resources with which to offset losses from accidents.

Often, however, the level of concern that a company has for some types of accidents is greater than that for other types of accidents. For example, a company may be willing to spend resources to reduce the products of expected frequencies and consequence for accidents that could totally destroy a plant (low-frequency, high consequence accidents), while they may not be willing to spend more to prevent nuisance-type accidents (high-frequency, low-consequence accidents) even if the absolute risk associated with the two types of accidents is the same.

In other words, the company expresses more concern for very high-consequence accidents and is willing to spend more than a fair share (from an absolute risk standpoint) of money to reduce the absolute risk of high-consequence accidents below the absolute risk associated with nuisance-type accidents.

The risks associated with loss of containment events in the selected areas included two general types of impacts: safety impacts and economic impacts.

There are many types of safety impacts that can affect refinery personnel and/or the general public outside the refinery.

Economic impacts must be taken into consideration since they are often the result of fires and explosions.

The possible economic consequence of a fire or explosion include business interruption, equipment damage, and inventory losses.

Based on the economic risk analysis we developed some specific recommendations for the individual process units. The following are some examples of general conclusions and recommendations:

Compressors

Accidents involving process sections containing compressors are the dominant economic risk contributors.

We recommended that the refinery maintain a regular surveillance, inspection, and testing program for these large, important compressors. Vibration detection and pattern recognition technology is available to detect incipient disruptive compressor failures that can lead to loss of containment accidents. A program using this technology will help reduce the expected frequency of compressor failures, thus reducing the economic risk for the refinery.

Enclosed area

A release of light hydrocarbon within an enclosed area creates the potential for explosions. Several process sections consisting of compressors within buildings have high risk importances because there is no assurance that hydrocarbon leaks will be detected and corrected before an explosion occurs.

Therefore, we recommended that the refinery provide the following:

1. continuous, positive ventilation in compressor buildings
2. control room alarms and compressor shutdowns (and isolation) on high explosive levels in these buildings

Reliable, positive ventilation will prevent explosive concentrations from developing for all but the most severe loss of con-

tainment events. The control room alarms will quickly alert operators to a potentially explosive condition so they can perform an orderly shut-down of the affected system. The automatic compressor shutdowns will reduce the chance of ignition of any explosive mixtures and limit the size of the release (in some cases).

Heaters

Process heaters are the second most important component type contributing almost one-fifth of the absolute risk and one-fourth of the concern risk.

We recommended that the refinery institute a reliability improvement program for process heaters. They already had a standard for the design and construction of new process heaters. The design features in this standard, in our judgment, reduce the expected frequency of heater fires and explosions during startup and normal operation to a very low (acceptable) level. However, determining which process heaters should be retrofitted and which design improvements should be made (since the retrofitting cost can be large) requires a more detailed quantitative analysis.

Heat exchangers

We recommended a surveillance program for important heat exchangers. Process section failures involving heat exchangers are the third most important type of failure. The most likely cause of heat exchanger failures is a leak or rupture of the head flange (gasket). Recent events at the refinery have shown that the design of some heat exchangers

is inadequate for their present service conditions. Reviewing the service versus design conditions for heat exchangers should be a first step in this program.

Implementing a surveillance program will help ensure that important heat exchangers are operated within design limits. The program would monitor the performance of head gasket seals for critical areas, thus reducing the risk associated with heat exchangers in the refinery.

Gas cooler

Since the tube arrangement of the fin-fan cooler makes performing adequate on-stream inspection of the tubes almost impossible, we recommended replacement of the tubes of the recycle gas cooler with tubes manufactured of corrosion-resistant material to reduce the expected frequency of accidents caused by failures of this cooler. The refinery should conduct a survey to determine if there are any other uninspectable (on stream) fin-fan coolers in service conditions that might warrant replacement as well.

Pumps

The most common type of pump loss of containment event is a seal leak or rupture. Monitoring the performance of pump seals (especially for hot pumps) will allow for detection of incipient failures and the reduction of the expected frequency of leaks. Periodic use of vibration detection equipment will allow the refinery to detect incipient internal pump failures-such as bearing failures or impeller rubbing - that could cause pump ruptures.

If a pump rupture occurs in a pump located in a high-equipment-density area, such as in a pump alley, it is very difficult to gain access to the area to fight the ensuing fire. Many of the high-risk accident sequences involving pumps are sequences in which refinery personnel have virtually no chance to mitigate the effects of the release (to isolate the component) before a substantial amount of damage occurs. Therefore, we recommended that the refinery install fixed fire deluge systems in important pump alleys (e.g., the Crude Unit).

A crucial element in successfully coping with loss of containment accidents is the ability to quickly and correctly detect and diagnose the failure that has occurred. Many important (high-risk) accident sequences involve relatively long detection times because the refinery depends heavily on local detection of releases by operating and maintenance personnel or passerby.

The importance of long detection times will be magnified when proposed staff reductions are implemented at the refinery. This necessarily will decrease the chance of successfully coping with accidents. Therefore, we recommend that the refinery provide remote-controlled video or infrared monitoring of critical areas in the refinery. The visual signal from these cameras can be fed to each operating area control room , to the area supervisor's office building, or to the refinery shift superintendent's office. These scanning cameras will help reduce detection time for some (but not all) accidents, thus reducing refinery risk.

The petrochemical units should implement an incident-reporting system that includes, at a minimum, the following information:

1. the apparent cause of the incident
2. the operator and system responses
3. the timing of detection and response actions
4. the actual equipment damage and business interruption costs
5. the repair/shut-down time
6. any personnel injuries
7. operating staff actions to prevent similar incidents

In addition, inspection and engineering staff should use these reports as input to an ongoing experience review process. This review should examine the implications of the incident from a wider perspective than is possible for the operating staff. Specifically, this second level review should address these topics:

1. the true root-cause of the incident
2. the potential for similar incidents elsewhere in the refinery
3. other possible outcomes of the incident based on different operating conditions or operator responses

A system like the one described could be implemented at all units. Ultimately, the strength (or weakness) of any incident-reporting system lies with the people charged with the reporting responsibility. These personnel should be trained on how to adequately report significant events.

REFERENCES

1. National fire protection - association - National fire codes, 1980 vol.3.11 and 13

2. Usines de traitement de petrole brut de ses dérivés et residus - Commission interministérielle des dépots d'hydrocarbures - France, Paris le 19.XI.1975

3. Ivănuş Gheorghe - Process Economics International, volume 4, no.3, 1983

4. L.F.Williams - Process Economics International, volume 4, no.3, 1983

5. J. Singh - Gas explosions in compartimented vessels: pressure piling, Chem.Eng.Res.Des. Vol.62, November 1984

6. C.H. Vervalin - Hydrocarbon Processing, December 1983

7. J.S.Arendt and Co. - A risk-based analysis of a petroleum refinery. Paper presented at the 1984 Winter National Meeting of the American Institute of Chemical Engineers, March 12-14, 1984 Atlanta, Georgia

8. H.Ozog and A. Little - Hazard identification analysis chemical engineering - Feb.-May 1985

9. R.Nelson - Hydrocarbon Processing, Aug.1977

10. M. Chandhani - Hydrocarbon Processing, Nov.1981

11. S. Fitt - The chemical engineering nr.368, 1981

12. J. Singh - The calculation of explosion parameters in non-spherical vessels,1983

13. S. Atalah - Chemical Engineering, Sept.1980

14. S. Crain - Hydrocarbon Processing, Jan.1980

15. J. Fussel and D. Wagner - Fault tree analysis as a part of mechanical system design. National bureau of standards special publication, NBS-SP-487, NTIS, 1977

16. Gh.Ivănuş + colab. -Piroliza hidrocarburilor , Editura Tehnică, Bucureşti, 1980

17. N. Irving - Dangerous properties of industrial materials, 1967

18. G. Hommel - Handbuch der gefährlichen güter, 1980