

Methane is highly flammable in air when the concentrations are within the limits given above. Methyl chloride does not produce as violent explosions as certain methane-air mixtures, yet explosions of this combustible in air may do considerable damage. Methylene chloride is entirely safe when mixed with air at ordinary temperatures and pressures, but it is flammable in air at elevated temperatures, and, when mixed with pure oxygen in the right proportions, forms highly explosive mixtures. Chloroform has no explosive properties, while carbon tetrachloride is entirely nonflammable with air or oxygen in any proportions, at ordinary temperatures and, in fact, is used to good advantage in the preparation of non-combustible, nonflammable dry-cleaning compounds. By the addition of the proper proportions of CCl_4 to combustible liquids, such as naphtha and petroleum distillates, the resulting mixtures are rendered incombustible and nonflammable. However, when these liquid mixtures evaporate, unless the vapor pressure of the combustible portion is as great as that of carbon tetrachloride, flammable liquid mixtures may remain. At least one serious explosion is known to have occurred from such a mixture. Conversely, should the combustible portion have a vapor pressure greater than that of carbon tetrachloride, the liquid residue would remain nonflammable, but flammable vapor-air mixtures could be formed from its evaporation.

Trichloroethylene and various Freon compounds may be used to advantage where liquids having nonflammable characteristics are required.

D. ELIMINATION OF IGNITION SOURCES

Combustible gases and vapors, mixed with air or pure oxygen in proportions to give flammable mixtures, may be employed safely provided all sources of ignition are eliminated. The atmosphere in the gasoline tanks of the millions of automobiles and trucks in use on our streets and highways contains either flammable mixtures or mixtures that become flammable when air is added, yet the number of accidents caused by these conditions is extremely small. This is largely because the tanks are kept closed, the mixtures inside the tanks are usually above the upper limit of flammability, and no sources of ignition are present in the tank or around the filler cap.

The safety engineer is primarily interested in the sources of ignition that may cause explosions. These sources may be classified as given below:

Ignition sources	Flames	Open lights Matches and cigarette lighters Fires in boilers and water heaters Burning material; incinerators
	Sparks	Static electricity Electrical shorts and arcs Lightning Sparks from tools
	Heated materials	Glowing metals; hot cinders Overheated bearings Electric light filaments Spontaneous combustion

Most of the sources of ignition given above can be controlled by establishing proper safety regulations and installing flameproof and vaporproof electrical equipment; others, by designing the plants so that boilers, water heaters, incinerators, and other equipment where there are open flames and incandescent materials are installed in other buildings at a safe distance from the place where the processes involving explosion hazards are carried out.

Static electricity has caused many serious fires and explosions and is one of the most difficult ignition hazards to control. There are few operations in which it may not be present. It is more serious in dry atmospheres where the relative humidity is below 50 per cent. Static electricity may be generated by friction, that is, by slipping belts, pulleys, and revolving machinery, and by passage of solids, liquids, or gases at high velocity through small openings. It also may be generated by impact, pressure, cleavage, and induction. It may be partly or totally eliminated by the proper grounding of all machinery, pipes, and other equipment where charges may accumulate. Whenever practical there is added safety in also maintaining the room humidity above 50 per cent.

E. SEGREGATION OF HAZARDOUS OPERATIONS

Operations that, through necessity rather than choice, require the use of large volumes of flammable gases or vapors should be segregated from other operations. This requires installation of hazardous processes in buildings at a safe distance, and, if heavy combustible vapors are involved, the elevation should be below that of other buildings, so that in case of a fire or explosion the liquids and vapors that may be released will not flow toward other adjacent buildings. Tables of safe distance for various operations involving the use of combustible liquids and vapors have not been developed adequately, as has been done in the manufacture and storage of explosives. Therefore, it becomes the duty of the safety engineer to use his own judgment as to what distance is safe for a given operation.

F. PROVISION OF ADEQUATE VENTILATION

The necessity for adequate ventilation where flammable gases and vapors are handled and used cannot be too strongly emphasized. This need for adequate ventilation applies not only to the spaces around the equipment in which the vapors may be present, but also to all conduits, trenches, and tunnels where pipes for conveying flammable gases and vapors and pipelines for conveying flammable liquids are installed. Such lines should be carried in the open air from one building to another, and in buildings they should be suspended above the floor level where they can be inspected readily for leaks.

The buildings should be of light material that will not offer too great resistance to applied pressure if an explosion occurs. The roofs should be provided with ventilators, and windows should be installed with tilting-type sashes that open when pressure is exerted from the inside. A reduction of pressure on the