NFPA No.

69

# EXPLOSION PREVENTION SYSTEMS 1970

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## Official NFPA Definitions

Adopted Jan. 23, 1964: Revised Dec. 9, 1969. Where variances to these definitions are found, efforts to eliminate such conflicts are in process.

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## Standard on

# Explosion Prevention Systems

NFPA No. 69–1970

## 1970 Edition of No. 69

This standard was prepared by the National Fire Protection Association Committee on Explosion Protection Systems, and this edition was tentatively adopted at the 1969 Annual Meeting of the Association. The Tentative Standard, with amendments, was adopted as an official standard at the 1970 Annual Meeting.

## Origin and Development of No. 69

A new NFPA Committee was appointed in 1965 to develop standards for Explosion Protection Systems. These standards would include broad information on inerting to *prevent* explosions from occurring as well as venting to minimize damage when an explosion occurs within a container. The tentative draft on Explosion Prevention Systems was presented at the NFPA Annual Meeting in New York City, May 1969.

This Standard on Explosion Prevention Systems incorporates and considerably extends information and practices adopted in 1956, "Standards for Inerting for Fire and Explosion Prevention," (NFPA No. 69) and "Standards for Inert Gas for Fire and Explosion Prevention," former NFPA 12A, adopted in 1941, which was initiated jointly by the NFPA Committees on Dust Explosion Hazards and Manufacturing Hazards in 1930 and 1931, and adopted in 1931, with minor amendments in 1938 and 1941.

Much of NFPA No. 69 "Standards for Inerting for Fire & Explosion Prevention," adopted in 1956, has been made a part of Appendix A and Appendix B in this standard. Chapter II of this standard is meant to broaden the scope of NFPA No. 69 (1956). Hence, there is some repetition in these two sections.

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Scope: Responsible for explosion protection systems for all types of equipment (as opposed to buildings) except pressure venting devices designed to protect against overpressure of vessels containing flammable liquids, liquefied gases and compressed gases under fire exposure conditions, as now covered in existing NFPA standards.

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# Explosion Prevention Systems

NFPA No. 69–1970

## Foreword

The possibility of explosions resulting from deflagrations or detonations may be diminished or eliminated in certain processing, material handling, and storage facilities by eliminating sources of ignition and by one or a combination of special techniques defined herein.

There are many types of equipment and machinery which can be protected by these techniques. For each installation careful consideration should be given to such factors as the physical properties of the flammable materials; the size and shape of the equipment; the required amount, the reliability of supply and the purity of the additive medium; operational controls, instrumentation and maintenance requirements. General requirements are included herein. Details of each installation will necessarily vary according to the local conditions and the hazards involved. Authorities having jurisdiction and specialists in the particular field should be consulted as to the application of these standards.

In this Standard an effort has been made to distinguish carefully between the terms "explosion," deflagration," and "detonation."

## Introduction

**1. Purpose.** This Standard outlines the minimum requirements for the installation of systems for preventing explosions of enclosures where flammable gases, vapors, or suspended flammable mists or dusts may be confined. Basic information is included for the guidance of design engineers, authorities having jurisdiction and others concerned with such protection.

**2. Scope.**

**21.** This Standard is limited to the design, construction, operation, maintenance and testing of systems for:

(a) Reduction of oxidant concentration, and control of combustible concentration in flammable mixtures.

(b) Suppression of deflagrations (see definitions for distinction between "deflagration" and "explosion.")

**22.** This Standard does not include:

221. Systems which render explosives such as TNT, gunpowder, guncotton, etc., inactive to detonation or ignition.

222. Devices designed to protect against overpressure of vessels containing flammable liquids, liquefied gases, and compressed gases under fire conditions as now covered in existing NFPA Standards.

223. The preparation of tanks, piping, or other enclosures for hot work entry.

224. The general use of inert gases for fire extinguishment.

225. Rock dusting of coal mines, which is governed by the Federal Mine Safety Code. (See Par. B1100.)

**3. Definitions.** The dictionary and technical definitions of some terms used in this Standard are not necessarily descriptive of the usage for the Standard. Furthermore, common terms used by some industries may differ from those in other industries. Hence, the following specific definitions have been adopted:

**31.** BLANKETING is the technique of maintaining an atmosphere which is inert or enriched with a fuel above liquid in a container or vessel.

**32.** COMBUSTIBLE used synonymously with the term fuel, refers to a gas or mist or dust capable of being burned. Burning can be described as the chemical reaction of a combustible and gaseous oxidant (normally the oxygen of air) with resultant production of a flame.

When a combustible is intimately mixed with an oxidant and ignited, burning in the form of deflagration or detonation may result.

**33.** DEFLAGRATION is burning which takes place at a flame speed below the velocity of sound in the unburned medium.

**34.** DETONATION is a burning which takes place at a flame speed above the velocity of sound in the unburned medium.

**35.** EXPLOSION is a bursting of a building or container as a result of development of internal pressure beyond the confinement capability of the building or container.

**36.** FLAMMABLE RANGE refers to the range of concentration of gas or mist or dust, with oxidant (or the range of concentration of oxidant) over which flame propagation can occur. See Appendix B for a discussion of effects of temperature, pressure, etc., on flammable range.

**37.** INERT GAS is noncombustible, nonreactive, and incapable of supporting combustion with the contents of the system being protected.

**38.** INERTING is the process of rendering a combustible mixture noncombustible through the addition of an inert gas.

**39.** OXIDANT. An oxidant (or oxidizing agent) is any material or substance that can react with a combustible to produce burning or combustion, or a similar exothermic reaction. Oxygen in air is the most common oxidant.

**310.** PADDING (see Blanketing).

**311.** PURGE GAS is a gas suitable for rendering an atmosphere noncombustible. It may be inert or combustible and even air can also be used as a purge gas.

**312.** PURGING is the displacement of a gaseous oxidant or gaseous combustible by another gas to render the mixture noncombustible. The purge gas may or may not be an inert gas.

**313.** SUPPRESSION. Explosion suppression is a technique by which burning in a confined mixture is detected and arrested during incipient stages, preventing development of pressure which could result in an explosion.

**314.** VAPOR as specified in this Standard is a gas.

**315.** APPROVED refers to approval by the authority having jurisdiction.

**316.** The terms "psia" and "psig" as used in this Standard refer to pounds per square inch absolute and pounds per square inch gauge, respectively.

**317.** VENTILATION is the process of supplying or removing air, by natural or mechanical means, to or from any space.

3171. General Ventilation is the removal of combustibles by moving air through the entire volume of a space. See Appendix A—Part I.

3172. Local Ventilation is the removal of combustibles from a small portion of a space and more particularly at the immediate vicinity of emission by withdrawing air from that small portion of the space. See Appendix A—Part I.

NOTE: The expressions "oxidant concentration reduction" and "combustible concentration reduction" are frequently used herein. Only in rare circumstances will it be practical to reduce the concentration of the oxidant or the combustible by selective removal. Instead, the usual method is to alter the composition of the mixture in the enclosure by adding a gas deficient in the component whose concentration it is sought to reduce. The concentration of all components of the original mixture not present in the diluent gas will be proportionately reduced. The process is essentially one of ventilation or dilution of the mixture as discussed in the Appendix.

# CHAPTER 1. GENERAL INFORMATION AND REQUIREMENTS

## 1100. General Information

**1110. Scope.** Chapter 1 contains general information and the design and installation requirements for features that are generally common to the explosion prevention systems described herein.

**1120. Types of Techniques.** There are three types of techniques recognized in this standard.

1121. Oxidant Concentration Reduction. The technique of maintaining the oxidant concentration below that where ignition can occur.

1122. Combustible Concentration Reduction. The technique of maintaining the combustible concentration below the flammable range.

1123. Suppression. The technique by which burning in a confined mixture is detected and arrested during incipient stages.

**1130. Use and Limitations.** Explosion prevention systems are useful within the limits of this Standard in reducing or eliminating fires and explosions in enclosures where flammable gases, vapors, dusts and certain combustible solids may be confined.

1131. These techniques are limited to enclosures where an atmosphere can be maintained which will not support combustion or where the atmosphere can be altered to prevent flame propagation. The techniques are not applicable to materials which provide their own oxygen such as nitrates, explosives, etc., to support combustion.

**1140.** The following may be protected by explosion prevention systems:

1141. Processing Equipment.

1142. Storage Equipment.

1143. Materials Handling Equipment.

1144. Laboratory and Pilot Plant Equipment.

1145. Rooms and Building. In such enclosures, consideration for the type of system must take into account the safety of personnel who may be exposed.

## 1200. Personnel Safety.

**1210. Hazards to Personnel.** The introduction of purging or inhibiting materials may create hazards to personnel such as oxygen deficiency and exposure to toxic products.

1211. Safety Requirements. In any proposed use of explosion protection systems where there is a possibility that personnel may be trapped in or enter into atmospheres made hazardous to health, suitable safeguards shall be provided to ensure prompt evacuation of and to prevent entry into such atmospheres and also to provide means for prompt rescue of any trapped personnel. Such safety features as personnel training, remote process operation, warning signs, discharge alarms and breathing apparatus shall be considered.

## 1300. Specifications, Plans and Approvals.

**1310. Purchasing Specifications.** Specifications for explosion prevention systems shall be prepared with care under the supervision of a competent engineer and with the advice of the authority having jurisdiction. To ensure a satisfactory system, the following items should be included in the specifications.

1311. The specifications should designate the authority having jurisdiction and indicate whether or not plans are required.

1312. The specifications should state that the installation shall conform to the Standard and meet the approval of the authority having jurisdiction.

1313. The specifications should include the specific tests that may be required to meet the approval of the authority having jurisdiction, and indicate how cost of testing is to be borne.

1314. These specifications should require the provision of equipment "listed" for the use intended.

**1320. Plans.** Where plans are required, they shall be prepared with care under the supervision of a competent engineer and with the advice of the authority having jurisdiction.

1321. These plans should be drawn to an indicated scale or be suitably dimensioned and should be made so they can be easily reproduced.

1322. These plans shall contain sufficient detail to enable the authority having jurisdiction to evaluate the hazard or hazards and to evaluate the effectiveness of the system. The detail on the hazards should include the materials, pertinent chemical and physical characteristics involved in the hazards, the location of the hazards, the enclosure or limits and isolation of the hazards, and the exposures to the hazard.

**1330. Approval of Plans.** Plans and calculations shall be submitted for approval before work starts.

1331. When field conditions necessitate any significant change from approved plans, the change shall be approved.

1332. When such significant changes from approved plans are made, corrected "as installed" plans shall be supplied to the owner and the authority having jurisdiction.

**1340. Approval of Installations.** As deemed necessary the completed system should be tested by qualified personnel to meet the approval of the authority having jurisdiction. These tests should be adequate to determine that the system has been properly installed and will function as intended. Only "listed" or "approved" equipment and devices should be used in the systems where applicable.

**1400. Basic Design Consideration.** In the design of an explosion prevention system, consideration shall be given to all aspects of the operation and maintenance of the system and the hazard being protected. Such aspects include personnel protection, physical characteristics of the enclosure, process operating conditions, controls and instrumentation, material properties, etc., and shall include any and all features necessary to assure effectiveness of the applied technique. The three techniques covered by this Standard require distinct considerations and each of these is detailed in the applicable chapter.

**1500. Reliability.** The operation of an explosion prevention system requires a high degree of reliability of equipment to assure achievement of the system performance. A system failure may result in extensive property damage, loss of production and injury to personnel. A thorough analysis of the system reliability shall be made along with incorporation of appropriate controls and instruments to assure the desired reliability.

## 1600. Inspection, Maintenance and Instructions.

**1610. Inspection and Test.** All systems shall be thoroughly inspected and tested for proper operation by a competent person.

1611. SPECIAL INSTRUMENTATION. Analyzers and other instruments may require inspections or tests more frequently than once a year. The tests should be made in accordance with the manufacturer's recommendations or as deemed necessary by operating conditions. Inspection, maintenance and operator training are necessary features of any explosion prevention technique. Reliability of instrumentation is only as good as the inspection and maintenance provided. Operator response and action to correct adverse process conditions indicated by instrumentation or otherwise is only as good as the frequency and thoroughness of training provided.

1612. Regular service contracts with the manufacturer or installing company are recommended.

1613. The goal of the inspection and testing shall be not only to ensure that the system is in full operating condition but shall indicate the probable continuance of that condition until the next inspection.

1614. The inspection report with recommendations shall be filed with the owner.

1615. Between the regular service contract inspection or tests, the system shall be inspected visually or otherwise by competent personnel, following an approved schedule and procedure.

**1620. Maintenance.** These systems shall be maintained in full operating condition at all times. Impairment and restoration of this protection should be reported promptly to the authority having jurisdiction.

1621. Any troubles or impairments shall be corrected at once by competent personnel.

1622. Impairment to these systems may necessitate shutdown of a process being protected.

**1630. Instruction.** All persons who may be expected to inspect, test, maintain, or operate explosion prevention systems shall be thoroughly trained and kept thoroughly trained in the functions they are expected to perform.

## CHAPTER 2. OXIDANT CONCENTRATION REDUCTION

**2100. Description.** Explosion prevention can be provided in enclosed or nearly enclosed vessels, equipment, and rooms by maintaining the oxidant concentration low enough so that combustion or other exothermic oxidation reaction cannot be initiated under the most severe conditions of ignition. This chapter applies to oxidants in the gaseous phase.

### 2200. Application.

**2210.** Oxidant concentration reduction can be applied where mixtures of oxidant and combustible liquids, vapors, gases, mists, or solids or dust are confined within enclosures, and where in such enclosures, a limited oxidant concentration can be established and maintained. These techniques may be independent of, or supplementary to, other facilities for accident prevention and fire protection.

**2220.** The following enclosures may be protected by oxidant concentration:

2221. PROCESSING EQUIPMENT, such as enclosed reactors, mixers, pulverizers, mills, driers, ovens, filters, screens, cyclones, dust collectors, etc.

2222. STORAGE EQUIPMENT, such as atmospheric or low pressure tanks, pressure tanks, mobile facilities including tank cars, tank trucks, barges and cargo vessels, etc.

2223. MATERIALS HANDLING EQUIPMENT, such as pipe lines, pumps, hold-up or surge tanks, pneumatic and screw conveyors, and bucket elevators, etc.

2224. LABORATORY AND PILOT PLANT EQUIPMENT, such as hoods, glove boxes, test cells, etc.

2225. Entire rooms and buildings may be protected by oxidant reduction techniques. Since oxygen deficient atmospheres cannot sustain life and high fuel concentrations may be injurious to health, process equipment in these areas must be remotely operated or personnel must be provided with breathing apparatus before entry.

**2300. Limitations.** Oxidant concentration reduction is not applicable to unstable materials or processes or environments requiring an oxidant concentration above the minimum needed for combustion.

## 2400. Basic Design Considerations.

**2410. General.** In the design of an oxidant concentration reduction system, the following factors should be considered:

2411. Personnel protection.

2412. Hazards to be protected.

2413. Required reduction in concentration of oxidant. (See Appendix B.)

2414. Technique or combination of techniques to be used.

2415. Equipment gas supply source and installation method.

2416. Operation control equipment.

2417. Periodic maintenance, inspection and testing.

## 2500. System Types.

### 2510. Oxidant Deficient Purge Gas.

### 2520. Oxidant Absorption.

**2530. Oxidant Reduction by Catalytic Reaction with a Combustible.** This method reduces oxidant concentration by catalytically combining it with (a) fuel from the space to be inerted, (b) with separately supplied fuel, or (c) with both.

## 2600. Sources of Oxidant Deficient Purge Gas.

**2610. General.** When purging materials are used to reduce the oxidant concentration to provide fire and explosion prevention, the media shall be obtained from dependable sources capable of supplying continuously the amount required to maintain the desired degree of oxidant deficiency within the enclosure protected. There are a number of purge gas sources which are suitable within the prescribed limitations for this type of explosion prevention.

2611. COMMERCIALLY AVAILABLE GAS. Nitrogen, carbon dioxide, helium and argon for purging systems are available commercially as either liquids or gases. Caution shall be exercised in any specification of these gases to make certain that it meets the rigid requirements to provide the oxidant reduction desired. Analyses should be made of the gas composition before use.

2612. GAS GENERATORS. Package units are available for the production of an inert purge gas utilizing the combustion of a hydrocarbon to provide a gas having a low oxygen content. The instruments and controls necessary for providing the proper mixture of gas shall be incorporated in the unit in order to insure that the product is not contaminated in any manner. Extreme caution shall be taken with this type of unit in order to make certain that it does not represent a source of ignition through high temperature of the gas produced.

NOTE: With reference to flame failure controls suitable for inert gas generators refer to NFPA No. 85, Watertube Boiler-Furnaces, No. 85B, Gas Fired Multiple Burner Boiler–Furnaces.

2613. STACK OR FLUE GAS. The products of combustion from process furnaces or boiler furnaces have low oxygen concentration and may be suitable for purging operations. Purification systems may be required in order to avoid contamination of the protected enclosure or process.

2614. AIR SEPARATION. This method consists of the liquefaction of air and subsequent separation. The nitrogen produced may be used as a purge gas. Package units are available utilizing this technique.

2615. AMMONIA COMBUSTION. This method consists of the oxidation of ammonia with air to produce a high purity nitrogen suitable for use as a purge gas.

2616. STEAM. Steam used for purging should be supplied at a rate sufficient to maintain the vessel temperature at 160°F. or higher. Care must be taken to insure that condensation of steam by cooling does not so reduce the pressure within the vessel as to draw in atmospheric oxygen or to cause collapse of the vessel or fittings.

NOTE: Refer to U.S. Bureau of Mines Bulletin 627, Figs. 14, 34, 57, 76, 78, 79.

**2620. Location of Generator or Supply Facility.** The facilities for the generation, purification, and/or central storage of purge gas shall be in a safe location.

2621. Care shall be exercised to protect against loss of purge gas production or storage capacity from fire exposure or other abnormal plant operating conditions.

2622. Where the combustion method of producing a purge gas is used, the existence of the facility constitutes a hazard in itself; therefore its location and operation require careful scrutiny.

**2630. Reliability and Capacity.** A reliable and continuously available supply of purge gas shall be provided, having capacity to insure supply under peak demand conditions. Consideration should be given to the requirements for expansion of operations or plant facilities which require this form of protection.

Peak demand shall mean the maximum rate of application to all elements of this system. Consideration shall be given to initial purging requirements, leaks, influence of weather, such as temperature or barometric changes, maximum withdrawal rates from tanks, etc.

Where failure of the purge gas supply could create critical conditions an alternate supply should be considered, (e.g., by connecting cylinders or bulk transports to the system, to provide protection during the recharging period).

2631. Continuity of Supply. If gas is obtained only from storage tanks or gasholders, provisions shall be made to maintain the supply while recharging the tank or tanks.

2632. Gas Generators. If gas generators are used without storage tanks or gasholders, their combined capacity shall be such that loss of a single unit will not reduce the supply below the peak demand requirements.

2633. Flue Gas. When purge gas is obtained from boiler or furnace flue gases provision shall be made for alternate sources to supply critical needs.

2634. Standby Utilities. The utilities provided for the purge gas generating equipment should be reliable, and where practical standby electrical power and fuel should be available to insure continued operation of the generating equipment.

### 2640. Gas Conditioning Equipment.

2641. Purge gas used for protection of any process or equipment shall be conditioned to insure freedom from contamination harmful to the gas distribution system or to the product or material being protected.

2642. When flue gases are used for purging, suitable means such as filters or spray washers should be used to remove dust, soot, cinders, etc.

2643. Purge gases obtained from a combustion process shall be at a temperature compatible with the process before being introduced into a vessel so as to not be a source of ignition or excessive condensation.

2644. When an exhaust or flue gas is used as the purging medium, a suitable means shall be provided to prevent flame from entering the process or compartment being protected.

## 2700. Distribution.

### 2710. Piping System.

2711. DISTRIBUTION SYSTEM. Distribution systems shall be designed and installed in accordance with good engineering practices and with due consideration given to future plant expansion.

2712. STRAINERS, SCREENS, & FILTERS. Strainers, screens or filters should be provided as necessary to prevent rust and scale from entering critical parts of the system, such as traps, pressure regulators, etc.

2713. MOISTURE TRAPS. Moisture traps shall be provided when necessary and lines shall drain toward the traps. Adequate blow-down connections shall be provided. Moisture traps releasing flammable, reactive, or toxic gases shall be vented to a safe location. Moisture traps shall be protected from freezing.

2714. PRESSURE SENSING DEVICES. Pressure sensing devices with indicators or recorders shall be provided where necessary throughout the system.

2715. EXCESS FLOW CONTROLS. Where two or more subdivisions in the system are protected, means shall be provided to automatically prevent excessive flow of purge gas due to failure or malfunction in one part of distribution system from reducing the supply to other protected subdivisions below a predetermined amount.

2716. BLOCK VALVES. A manual shutoff valve shall be provided in each major division of the main distribution system.

2717. CHECK VALVE AND ANTIBACKFLOW DEVICES. A check valve or other suitable device shall be provided at each connection between a purge gas point of use and the main distribution system to prevent contamination of the distribution system through drop of purge gas pressure or by excessive pressure in the purged unit. An additional check valve or other suitable device shall be provided on the discharge side of the purge gas supply tank. A single check valve shall not be considered a positive backflow connection.

2718. CROSS-CONNECTIONS. Cross connections between the purge gas distribution system and any other system, such as compressed air, shall be prohibited unless positive measures are taken to prevent backflow from one system to the other

2719. SYSTEM TESTING. The distribution system shall be cleaned and functionally tested before being placed in service. The method of testing should not create a hazard for the subsequent use of the system.

### 2720. Application of Purge Gas at Points of Usage.

2721. Purge gas shall be so introduced and exhausted as to insure effective distribution in order to accomplish desired oxidant concentration reduction throughout the enclosure. Multiple inlets and outlets may be necessary.

2722. In *manually* operated purging systems restrictive orifices should be installed to limit the flow based upon peak demand of the purge gas at point of use. In *instrument controlled* systems where rust and scale are problems, restrictive orifices should also be installed to prevent excessive drain of the system if controls stick in the wide open position.

2723. CONNECTION TO PROTECTED UNITS. Rigid piping or flexible connections designed for maximum purge gas pressure may be used to connect the purge gas supply system to the unit being protected.

2724. If flexible, nonmetallic connections are used, positive means shall be provided for continuous electrical bonding, in accordance with NFPA No. 77.

## 2800. Instrumentation.

**2810.** Suitable instrumentation should be used to monitor the quantity and quality of the purge gas supply. Instrumentation should be provided to determine the effectiveness of inerting the protected equipment.

**2820. Limitations.** It should be recognized that reliability of the instrumentation is only as good as the inspection and maintenance provided. Also, operator response and action to correct adverse process conditions indicated by instrumentation is only as good as the frequency and thoroughness of training provided.

### 2830. Gas Supply Instruments.

2831. COMBUSTIBLE ANALYZER. Where the purge gas is produced by one of the methods in Sections 2530, 2612, 2613, or 2615 involving the use of combustibles, a suitable combustible analyzer shall be installed with audible and visual alarms to signal a predetermined high level of combustible concentration.

2832. OXIDANT ANALYZER. Where purge gas is produced by one of the methods described in Sections 2612 to 2615, inclusive, appropriate instrumentation shall be provided to measure the concentration of oxidant.

2833. OTHER INSTRUMENTS. Temperature, pressure, flow measuring devices and other appropriate instruments should be provided. Where the conditions being measured are especially critical, these measurements should be continuously recorded, provide alarms, and be interlocked to initiate whatever automatic corrective measures may be feasible.

### 2840. Analysis of Purge Gas.

2841. PURGE GAS ANALYSIS. A means to monitor quality of purge gas shall be provided on the distribution system ahead of the points of use.

2842. OXIDANT CONCENTRATION ANALYSIS. A means shall be provided to determine that there has been an effective oxidant concentration reduction in the space to be protected.

2843. AUTOMATIC SYSTEMS. Where there is hazard to personnel, property, and continued production, the instrumentation shall be fixed, connected to continuous recorders, provide alarm functions at predetermined conditions and interlocked for automatic safe shutdown or other corrective measures, when dangerous conditions are approached.

2844. SAMPLING. Samples shall be taken from as many points on the distribution system, within or downstream of the protected equipment as is necessary to assure that the desired oxidant concentration reduction is achieved throughout the entire process.

### 2850. Analyzers.

2851. ANALYZER INSTALLATIONS. Permanently installed analyzers are the most versatile. They can be arranged to sample from a number of points, to alarm at various points, and can be equipped with relays to control other equipment.

2852. PORTABLE ANALYZERS. Portable analyzers are mainly used for intermittent analysis such as spot checking protected equipment where oxidant reduction has to be carried out at infrequent intervals.

2853. CALIBRATION OF ANALYZERS. Analyzers shall be calibrated for the specific gases they are to monitor. Where analyzers are used for specific applications, gas samples shall be withdrawn at scheduled intervals for laboratory analysis or analyzers shall be calibrated frequently against samples of known composition.

# CHAPTER 3. COMBUSTIBLE CONCENTRATION REDUCTION

**3100. Description.** Explosion prevention can be provided in enclosed or nearly enclosed vessels, equipment and rooms by maintaining the combustible concentration below the flammable range so that a self-sustaining combustion or other exothermic oxidation reaction cannot be initiated under the most severe conditions of temperature or pressure which may be encountered by the system.

## 3200. Application.

**3210.** Combustible concentration reduction can be applied where combustible-oxidant mixtures are confined within enclosures and where, in such enclosures, a controlled concentration of combustibles can be established and maintained. These techniques may be independent of, or supplementary to, other facilities for accident prevention and fire protection.

**3300. Limitations.** Combustible concentration reduction is not applicable to processes or environments requiring a combustible concentration within the flammable range, nor to unstable materials which contain their own oxygen for combustion, such as explosives, cellulose nitrate, etc.

## 3400. Basic Design Considerations.

**3410. General.** In the design of a combustible concentration reduction system the following factors should be considered:

3411. PERSONNEL PROTECTION.

3412. HAZARDS TO BE PROTECTED.

3413. REQUIRED COMBUSTIBLE CONCENTRATION REDUCTION. Various properties of the combustible need to be ascertained such as flammable range, flash point, ignition temperature, boiling point, as well as process or product since these will influence the type of protection that can be applied.

Good general practice is to reduce the combustible concentration to 25% of the lower flammable limit. However, it is recognized that it is not possible to avoid higher concentrations at the immediate vicinity of the source of combustible.

A concentration of combustibles up to 60% of the lower flammable limit may be approved when automatic instrumentation with safety interlocks is provided.

NOTE: See NFPA 325M for Flammability Limits.

3414. Technique or combination of techniques to be used.

3415. Variations in processes and materials. Because of the variations in the processes and combustibles used, the proper design of equipment, selection of material and type of installation may involve a separate engineering problem for each installation to assure a high degree of dependability and reliability.

3416. OPERATION CONTROL EQUIPMENT. Controls should be adequate to maintain proper operation of equipment and to signal and protect against unsafe conditions.

3417. OPERATIONAL REQUIREMENTS. Consideration shall be given to periodic maintenance, inspection and testing.

## 3500. Systems Types.

**3510. Vapor Pressure Reduction.** It may be practical to reduce the vapor pressure of a combustible by cooling to prevent formation of an ignitible mixture, i.e., to cool the mixture below its flashpoint. A suitable safety factor should be used. If cooling below 32°F. is required, prior removal of moisture may be necessary to avoid accumulation of ice.

**3520. Dust Collectors and Mist Eliminators.** Concentrations of combustibles may be reduced by means of collectors, precipitators, filters, adsorbers, etc.

**3530. Liquid Sprays.** Concentrations of combustibles may be reduced by absorption or entrainment in a liquid spray.

**3540. Catalytic Oxidation.** The combustible concentration can be reduced by recirculating the atmosphere containing it through a catalytic oxidation unit in which the combustible and oxidant undergo catalytic reaction in concentrations below the flammable range. If there is a possibility that the combustible concentration may extend into the flammable range, flame arresting means should be provided. These should be periodically inspected and cleaned.

**3550. Displacement.** Although air and water are the common displacement media, others may be used for combustible concentration reduction.

**3600. System Capacity.** The necessary capacities of the systems for maintaining safe concentrations of combustibles under normal and abnormal conditions depend on:

**3610. Permissible Concentration of**

3611. Combustible.

3612. Diluent, if used.

**3620. Factor of Safety Required.**

**3630. Normal and Abnormal Operating Conditions.**

**3640. Size and Shape of Facilities to be Protected.**

**3650. Atmospheric Conditions.**

**3660. Technique Employed.**

**3670. Effectiveness of Reduction, and Efficiency of Reaching Equilibrium.**

**3680. Flow Pattern of the Displacement Medium**—entrance and withdrawal locations.

### 3700. Instrumentation.

**3710. General.** Suitable instrumentation should be used to indicate the effectiveness of the combustible concentration reduction.

**3720. Operation Control Equipment.**

3721. Means to control and monitor the effectiveness of combustible concentration reduction should be provided.

3722. AUTOMATIC SYSTEMS. Where the equipment being protected presents severe exposure to personnel, or where property is of high value, or is critical to continued operations, the instrumentation shall be fixed, connected to continuous recorders, provide alarm functions at predetermined conditions and be interlocked for automatic safe shutdown or other corrective measures when dangerous conditions are approached.

3723. SAMPLING. Samples should be taken from as many points within or downstream of the protected equipment as is necessary to assure that the desired combustible concentration reduction is achieved throughout the entire protected enclosure or equipment.

**3730. Analyzers.**

3731. FIXED ANALYZERS can be arranged to sample from a number of points, to alarm at various points, and can be equipped with relays to control other equipment.

3732. PORTABLE ANALYZERS are mainly used for intermittent analysis such as spot checking protected equipment where combustible concentration reduction has to be carried out at infrequent intervals.

3733. Where analyzers are used for specific applications, samples shall be withdrawn at frequent intervals for laboratory analysis or analyzers shall be calibrated frequently against samples of known composition.

### 3740. Other Instruments.

3741. Temperature, pressure, flow and other appropriate measurements should be provided as necessary. Where the conditions being monitored are especially critical, these measurements should be continuously recorded, provide alarms, and be interlocked to initiate such automatic, corrective measures as may be required.

3742. Calibration and Maintenance of Instruments. Instruments and interlocks shall be checked for proper operation at suitable intervals.

The instrument system shall be maintained in full operating conditions at all times.

Any troubles or impairments shall be corrected at once by qualified personnel.

## 3800. Operation Requirements.

**3810. General.** During design and installation, proper consideration shall be given to factors affecting operation, periodic maintenance and inspection. The signaling or control system of the process interlocked with the ventilating, cooling, or other protective equipment shall be periodically checked. Depending on the processing operation and the inadvisability of shut-downs, auxiliary equipment shall be available to take over should blowers, vacuum pumps, compressors, or other protective equipment fail.

3811. If air is used for reduction of combustible concentrations, outlets shall be located where the exhausted air cannot enter the fresh air intakes under any circumstances. Air intakes shall be located where no flammable vapors or gas can enter even in the event of spillage or leakage from equipment containing flammable materials. Filters, driers, or precipitators in the air inlet shall be located so that they are readily accessible for cleaning or maintenance.

3812. If it is possible for the combustible concentration to extend into the flammable range, flame arresting means should be provided. These should be periodically inspected and cleaned.

**3820.** Delegation of responsibility for reduction of combustible concentration shall be defined. Safe operation requires that the areas of hazard be fully recognized by all personnel involved in the process operations.

# CHAPTER 4. EXPLOSION SUPPRESSION SYSTEMS

**4100. General.** Explosion suppression is a technique by which burning in a confined mixture is detected and arrested during incipient stages, preventing development of pressure which could result in an explosion.

**4200. Use and Limitations.** Explosion Suppression Systems can be used where combustible gases, mists, or dusts may be present within enclosures and where the suppressant can be effectively distributed.

**4210. The Following may be Protected by Suppression Systems:**

4211. PROCESSING EQUIPMENT, such as enclosed reactors, mixers, blenders, pulverizers, mills, driers, ovens, filters, screens, dust collectors, etc.

4212. STORAGE EQUIPMENT, such as atmospheric or low pressure tanks, pressure tanks, mobile facilities, etc.

4213. MATERIAL HANDLING EQUIPMENT, such as pneumatic and screen conveyors, bucket elevators, etc.

4214. LABORATORY AND PILOT PLANT EQUIPMENT—hoods, glove boxes, test cells and equipment indicated in paragraphs 4211, 4212, 4213.

**4220.** There are limitations in the use of explosion suppression systems which must be recognized. Such limitations involve the nature, size and geometry of the equipment to be protected and the physical and chemical properties of the reactants. Applications of suppression systems require careful study because of the technical complexity of the hazards.

**4300. Personnel Safety.**

**4310. Hazards to Personnel.**

4311. Halogenated hydrocarbons are commonly used as suppressants in these systems. Toxic products may, therefore, be present after discharge of a system.

4312. The high speed operation of a suppression system is normally achieved through the use of electroexplosive devices. Improper handling of these devices during installation and maintenance may create a hazard to personnel in the surrounding area.

### 4320. Safety Requirements.

4321. In any proposed use of a suppression system where there is a possibility that personnel will be in locations receiving a suppressant discharge, suitable safeguards shall be provided to insure prompt evacuation. Such safety features as personnel training, warning signs, discharge alarms, and breathing apparatus shall be used.

A positive interlock shall be provided to disconnect electrical power when maintenance is being performed on the system. A positive interlock shall be provided to rearm the system before operations can be resumed.

4322. Electrical continuity checks of the system shall be performed only with a blasting galvanometer or device having a maximum current output of 15 milliamperes and a power source of one volt or less.

### 4400. Specifications.

**4410.** Specifications for explosion suppression systems shall be drawn up under the supervision of an engineer competent in the field. The specification shall state that the installation shall conform to this Standard and shall only use listed or approved equipment or devices.

### 4500. Basic Design Considerations.

**4510. General.** In the design of a suppression system, the basic factors should be determined and considered:

4511. Personnel Safety.

4512. Deflagration characteristics.

4513. Hazard to be protected.

4514. Suppressing technique.

4515. Installation and operation procedures.

**4520. Determination of Deflagration Characteristics.** Since the design of a suppression system is based upon the (a) rate of pressure rise, (b) rate of burning, etc., of a deflagration during its incipient stages, such information is necessary for proper design. Extensive testing has been accomplished on a wide range of materials, but as new materials and processes are developed, tests should be performed by a recognized laboratory.

**4530. Determination of Hazard to be Protected.** A thorough hazard analysis shall be performed to establish the type and degree of explosion hazard inherent in the process. Such factors as the type and ratio of combustible and oxidant, total volume to be protected, critical operating conditions, etc., should be reviewed as well as possible malfunction situations that may affect the extent of the hazard. It is vital that this analysis be as extensive and complete as possible to assure that maximum protection is provided by the suppression system.

**4540. Determination of Suppressing Techniques.** The suppression system shall be capable of sensing the predominant characteristic of the incipient deflagration. Careful consideration is necessary on processes with a wide variation in pressure and temperature conditions to assure that the detection mode is predominant over the entire range. In addition, the selection of the suppressant shall be made with consideration of the possible chemical reaction between it and the materials that may be encountered. A proof test of the compatibility of the suppressant may be necessary.

**4550. Determination of Installation and Operating Procedures.** After the type of equipment that will comprise a system has been established, the proper location of detectors and suppressors shall be determined. The necessity for detection speed and high speed dispersion of the suppressant requires a careful study for proper installation of the suppression equipment. Accurate information on the physical dimensions of the equipment or enclosure along with operating conditions should be available for review.

## 4600. Operating Devices.

**4610. Detection.** The detection of an incipient deflagration can be accomplished by sensing either the pressure increase or radiant energy from the combustion. After the detector setting is exceeded, an electrical signal actuates the suppression devices.

4611. Detectors may be used which respond to a rate of pressure rise from the incipient deflagration. Such units are applicable where wide pressure fluctuations are normally encountered in the process. Caution shall be exercised using this sensing mode to assure that sufficiently rapid detection is achieved over the entire flammable range.

4612. Static pressure detectors may be used where a constant pressure level is normal. A fast response is essential for rapid detection along with maximum overpressure sensitivity.

4613. Radiation sensors may be used as detection devices for suppression systems under special circumstances. The complexity and extreme sensitivity of such devices require a complete engineering analysis to assure proper operation and only persons competent in this field should assume responsibility for specifying this type of device.

4614. Temperature sensors are normally too slow for use in a suppression system. Under unusual circumstances, however, this method of detection may be applicable, but actual tests should be performed to confirm the effectiveness.

**4620. Suppression.** The suppression or extinguishing equipment disperses the suppressant into the enclosure to be protected within the period of time available before destructive pressures are reached.

4621. A suppressor may be a frangible container which is ruptured by an electroexplosive device to disperse the suppressant. The entire shell of the unit should be retained on the base during and after actuation.

4622. High rate discharge extinguishers are designed to contain a quantity of the suppressant under pressure, which expels the material through an opening created by the action of an electroexplosive device. The valve mechanism shall be retained by the unit during and after discharge. The container shall be manufactured in accordance with the applicable Department of Transportation regulation.

4623. The dispersal of the suppressant can under unusual circumstances be accomplished through piping and spray nozzles. Dispersal times and patterns shall be firmly established by test before final design is completed.

**4630. Electroexplosive Devices.** The extreme speed of operation of a suppression system normally requires the use of electroexplosive devices for dispersing the suppressant. High reliability is also achieved through the use of these devices.

4631. Explosive devices are sensitive to high temperature conditions and care shall be taken in selecting their mounting locations to assure that the maximum temperature rating of the detonator is not exceeded.

4632. Electroexplosive devices used in series shall all be of the same manufacturer and demonstrated to be suitable for series firing.

4633. Shipment and storage shall be in accordance with applicable state and federal regulations.

4634. Since the firing time of all electroexplosive devices varies with firing current, a reliable source of energy shall be used.

**4640. Power Unit.** A power unit shall be incorporated in each system to provide the functions outlined in the following paragraphs:

4641. The unit shall provide the required current for firing the electroexplosive devices.

4642. The unit shall be designed and installed in accordance with the National Electrical Code.

4643. A supervisory signal shall be provided by the unit for detecting an open electrical circuit or other faults in the system. A visual alarm shall be provided.

4644. Emergency standby power shall be provided for use when a main power failure occurs.

4645. Audible and visual alarms shall be provided through auxiliary contacts when the system operates.

**4650. Suppressant.** The material which is distributed throughout the enclosure may vary in accordance with the combustible, oxidant, and the environmental condition. The following paragraphs describe the predominant types:

4651. HALOGENATED HYDROCARBONS. These materials, stored in the liquid state, will inhibit combustion by entering into a chemical reaction process. Materials such as bromochloromethane, bromotrifluoromethane, etc., may be applicable for use with the majority of combustibles. Demonstration of suitability of these materials shall be made when elevated temperatures or pressures are expected or when the oxidant is a material other than air.

4652. WATER. Suppression systems using water are effective against ordinary combustible materials. The quantity required is normally greater than that of a chemical inhibiting agent and test data must be available to substantiate the effective concentrations. A suitable freezing point depressant shall be used when ambient temperatures will be less than 32°F.

## 4700. Installation Requirements.

**4710. Mounting.** The equipment shall be mounted in the location and manner specified by the system designer.

4711. Detectors shall be mounted to prevent malfunction from vibration or other environmental conditions.

4712. The suppressors shall be mounted to prevent damage or failure due to vibration or other environmental conditions.

4713. Suitable protective means shall be provided on or in front of the detectors and suppressors to prevent accumulation of material which would prevent their proper function.

4714. Adequate measures shall be taken to ensure, by sealing and other methods, that terminal points and mechanical parts are protected from moisture ingress.

4715. Care should be taken in selecting mounting locations so that temperature ratings of components will not be exceeded.

### 4720. Electrical.

4721. All wiring to the suppression equipment shall be grounded and shielded from all other wiring.

4722. If a multiple installation is to be made, all wiring for each system shall be run in separate conduit. Shielded cable may be used in lieu of separate conduit.

4723. All conduit shall be sealed to prevent moisture from accumulating in the equipment.

## 4800. Inspection and Maintenance.

**4810. Inspection and Tests.** All suppression systems shall be thoroughly inspected and tested every three months by a qualified technician. Regular service contracts with the manufacturer are recommended.

4811. Inspection and testing shall insure that the system is in full operating condition and shall indicate the probable continuance of that condition until the next inspection.

4812. Suitable tests shall be made when any inspection indicates their advisability.

4813. The technician's report with recommendations shall be filed with the user.

4814. Between regular service contract inspections, the system shall be inspected visually or otherwise by qualified personnel, following an approved schedule.

4815. At least annually, all suppressant containers shall be checked for leakage.

**4820. Maintenance.** These systems shall be maintained in full operating conditions at all times.

4821. Any troubles or impairment shall be corrected at once by qualified personnel.

**4830.** In the event of system operation all components shall be inspected, replacement parts shall be installed under proper supervision, and the system tested by a qualified technician before being restored to full operating condition.

# APPENDIX A. INERT GAS SYSTEMS

## PART I—GENERAL REQUIREMENTS

**A1000. Requirements for Purging Methods.**

**A1010. The Limitations of Purging Methods Must Be Recognized.** These include:

A1011. The reliability of the source and adequacy of supply of purge gas, including peak demand considerations.

A1012. Freedom of purge gases from moisture or other constituents which might contaminate the material protected. Contamination by absorption in long time storage may occur. Some purge gases may be excessively soluble at application pressure or may be reactive with certain materials in the process.

A1013. Dependability of instrumentation and venting devices and adequacy of maintenance of these items.

A1014. The vapors from enclosures being purged should be vented to a safe point outside of enclosures and away from ignition sources. Although a vapor or gas may be purged within the enclosure, combining of such mixtures with atmospheric air may produce a flammable atmosphere.

A1015. Under some conditions, purging gases when introduced into equipment such as tanks could cause agitation with static generation.

**A1020. Suitability of Gases from Various Sources.** It must be recognized that purging gases generated by any of the several acceptable methods outlined in these standards may not necessarily be suitable for all applications. In general, the physical and chemical properties of the flammable materials involved will govern the type and purity of purge gas selected for use. Chlorinated or fluorinated hydrocarbons are sometimes used. Even though costly, the maximum permissible oxygen in a safe mixture may be considerably higher than is permissible when using carbon dioxide or nitrogen. Attention is called to the fact that some halogenated hydrocarbons, *carbon dioxide,* and in some cases at elevated temperatures nitrogen, can react violently with certain dusts or may be ineffective in providing protection against explosions of certain combustible metal dusts, such as aluminum, magnesium, titanium, zirconium, thorium and uranium. Argon, helium and other rare gases are used for inerting in some special applications.

**A1030. Availability of Purge Gases.** Sources of large quantities of purge gas include carbon dioxide, nitrogen, and mixtures of nitrogen and carbon dioxide produced by combustion including internal combustion engine exhaust; off gases from oxidation reactions and other purge gas producers; and natural gas. Air separation can be used as a source of nitrogen.

**A1040. Personnel Safety.** In general, personnel should not enter enclosures where there is a deficiency of oxygen. When deemed necessary to enter they must be protected by oxygen or air-supplied respiratory equipment before entering an enclosure in which an inert atmosphere or oxygen deficient atmosphere exists. Canister type gas masks shall not be worn for respiratory protection against inert gases because they do not supply oxygen. Toxic hazards of certain inerting gases must be recognized. Inadvertent release of inert gas into occupied areas also requires consideration.

**A1100. Methods of Purge Gas Application.**

## A1110. General.

A1111. Selection of an appropriate method of purge gas application will depend on:

(a) The objective (e.g., oxidant or combustible concentration reduction, exclusion of oxidant).

(b) Size, shape and function of enclosure, possibility of leakage.

(c) Frequency of use (e.g., occasional, as when shutting down equipment vs. continuous, as with operating facilities).

(d) Availability, and reliability of purging gases.

(e) Degree of supervision necessary and available.

(f) Cost, relative to degree of protection achieved for personnel and investment.

A1112. (a) Where complete exclusion of oxidant is required, the purge gas must be oxidant free, and the rate of supply must be in excess of the leakage rate plus the peak volume requirement, as specified in A1130.

(b) Where conditions require oxidant reduction to prevent existence of a flammable mixture, rather than complete oxidant elimination, purge gas containing some oxidant may be used. The oxidant content of the purge gas must be considered in calculating purge gas requirements. Alternatively, conditions may be such that the desired degree of oxidant concentration reduction is normally greatly exceeded, in which case an occasional small influx of air can be tolerated, and the supply rate can be adjusted accordingly.

A1113. The principles described herein apply equally to purging for oxidant concentration reduction, and purging for combustible concentration reduction, employing either an inert gas, a combustible gas, or air (see Ventilation—Par. A1140).

A1114. Size of equipment will ordinarily dictate the rate of supply of purge gas, but shape and function may make one method of application much more effective than another.

A1115. Frequency of use can have a bearing on both the choice of purging medium and method of application.

## A1120. Methods of Application.

A1121. Any of several methods may be used to insure the formation and maintenance of a noncombustible atmosphere in an enclosure to be protected. These include "batch" methods applicable to "one time" or occasional use, as in purging equipment during shut down, and "continuous" methods intended to insure safe conditions during normal operations.

A1122. BATCH PURGING METHODS include syphon, vacuum, pressure and venting to atmosphere.

A1123. CONTINUOUS PURGING METHODS include fixed rate application and variable rate or demand application.

A1124. SYPHON PURGING. Equipment may be purged by filling with liquid (product or water) and introducing purge gas into the vapor space as the liquid is drained from the enclosure.

The volume of purge gas required will be equal to the volume of the vessel, and the rate of application can be made to correspond to the rate of draining. See NFPA No. 410-C

A1125. VACUUM PURGING. Equipment which normally operates at reduced pressure, or in which it is practical to develop reduced pressure, may be purged during shut down by breaking the vacuum with purge gas.

If the initial pressure is not low enough to insure the desired low oxidant concentration it may be necessary to re-evacuate and repeat the process.

The amount of purge gas required will be determined by the number of applications required to develop the desired oxidant concentration.

Where two or more containers or tanks are joined by a manifold and must be purged as a group, the vapor content of each container or tank should be checked to determine that complete purging has been accomplished.

A1126. PRESSURE PURGING. Enclosures may be purged by increasing the pressure within the enclosure by introducing purge gas under pressure, and, after the gas has diffused, venting the enclosure to the atmosphere.

More than one pressure cycle may be necessary to reduce the oxidant content to the desired percentage. Where two or more containers or tanks are joined by a manifold and must be purged as a group, the vapor content of each container or tank should be checked to determine that desired purging has been accomplished. Where a container filled with flammable material is to be emptied and then purged, purge gas may be applied to the vapor space at a pressure consistent with equipment design limitations, thus accomplishing both the emptying of the vessel and the purging of the vapor space in the same process.

A1127. SWEEP-THRU PURGING. This process involves introducing a purge gas into the equipment at one opening, and letting the enclosure content escape to the atmosphere at another, thus sweeping out residual vapor. The quantity of purge gas required will depend on the physical arrangement. A pipe line can be effectively purged with only a little more than one volume of purge gas if the gas can be introduced at one end and the mixture released at the other. However, vessels will require quantities of purge gas much in excess of their volume.

If the system is complex, involving side branches through which circulation cannot be established, the method may be impractical, and pressure or vacuum purging might be indicated.

The relationship between the number of volumes of purge gas circulated and the reduction in concentration of the critical component in original tank contents, *assuming complete mixing,* is shown on the attached graph, Figure 1.

It will be noted:

(a) The total quantity required may be less than that for a series of steps of pressure purging.

(b) From 4 to 5 volumes of purging medium will suffice to almost completely displace the original mixture, *assuming complete mixing.*

A1128. FIXED RATE APPLICATION. This method involves the continuous introduction of purge gas into the enclosure at a constant rate, which must be sufficient to supply the *peak* requirement in order that complete protection may be provided, and a corresponding release of purge gas and whatever gas, mist or dust has been picked up in the equipment.

(a) Advantages are simplicity, lack of dependence on devices such as pressure regulators, and possible reduced maintenance.

(b) Disadvantages are:

(1) Where the space contains a volatile liquid, a continuous loss of product due to constant "sweeping" of the vapor space by the purge gas.

(2) Increased total quantity of purge gas, because it is supplied whether needed or not.

(3) Possible disposal problems (toxic and other effects) for the mixture continuously released.

(c) Flow Control. Figure 2 shows a method of flow control which can be used with fixed rate application.

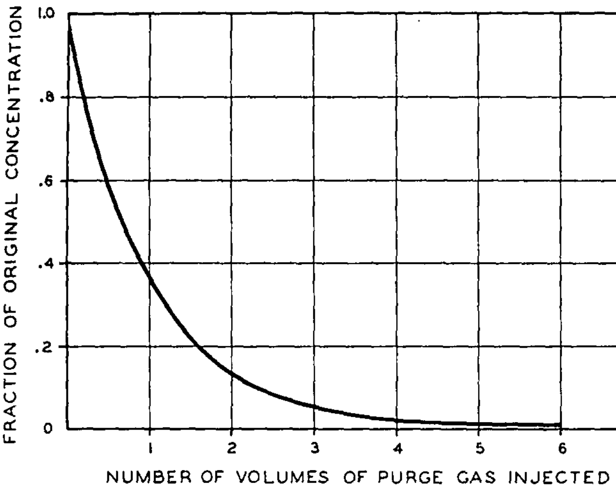

**Fig. 1. Dilution ratio—purging at atmospheric pressure.**
***(Complete Mixing assumed)***

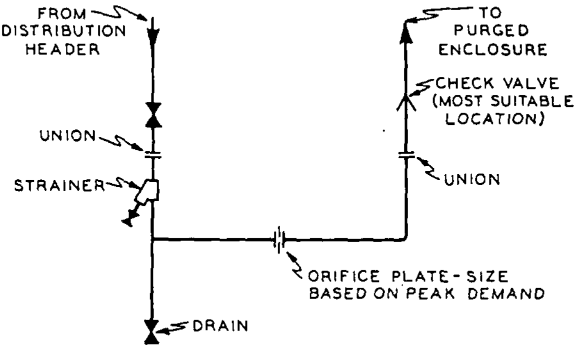

**Fig. 2. Schematic sketch showing method of flow control that may be used with fixed rate application.**

A1129. VARIABLE RATE OR DEMAND APPLICATION. This method involves the introduction of purge gas into an enclosure at a variable rate dependent on demand, based usually on maintaining within the protected enclosure an arbitrarily selected pressure slightly above that of the surrounding atmosphere. Peak supply rate must be computed as covered in Paragraph A1130.

(a) Advantages are that purge gas is supplied only when actually needed, and the ability, when desirable, to completely prevent influx of air.

(b) A disadvantage is that operation depends on the functioning of pressure control valves operating at sometimes very low pressure differentials, which are sometimes difficult to maintain.

(c) FLOW CONTROL. Figure 3 shows a method of flow control which can be used with variable rate application. Figure 4 shows an alternate method applicable where the purge gas requirement during out pumping is a large part of the peak demand.

**A1130. Calculation of Peak Purge Gas Rates.** Peak demand has been defined in Chapter 2 as the maximum, simultaneous rate of application to all elements of the system.

For any one element of the system, the peak demand is controlled by such factors as:

(a) Maximum withdrawal rate.

(b) Temperature change.

(c) Leaks.

(d) Rapid atmospheric pressure changes.

A1131. Cooling of the contents of a vessel containing a vapor or hot liquid presents a special and frequent case of vacuum purging. Condensation of vapor to a liquid, or reduction in pressure of the gas phase can rapidly produce partial vacuum which may impose excessive stresses on equipment or even collapse of the vessel, suck in air from joints which may not leak under internal pressure and may require high supply rates of inert gas. Each situation must be treated individually.

The peak supply rate must be computed for each case with consideration being given to cooling rate, vessel size and configuration which determine the rate of condensation.

If neither the reducing valve nor the source gas can be sufficiently reliable to supply the required amount of inert gas to prevent reduction of pressure below atmospheric, the vessel may have to be designed for full vacuum.

A1132. For a vessel containing a liquid, the purge gas demand from liquid withdrawal, change of liquid composition from mixing, or increasing solubility of purge gas in the liquid, will be the volume equivalent of the capacity of the largest pump which can withdraw liquid, or the maximum possible gravity outflow rate, whichever is greater. Where two tanks are manifolded together, so that one can flow by gravity into the other, a vapor space interconnection is sometimes used to reduce the required purge gas supply from outside sources.

A1133. The maximum demand from temperature change will occur in outdoor tanks operating at near atmospheric pressure, as a result of sudden cooling by a summer thunderstorm. The rate of purge gas supply necessary to prevent vessel pressure falling significantly below atmospheric pressure can be calculated as follows:

(a) For tanks over 800,000 gal. capacity, 2 cu. ft. of purge gas per hour for each square foot of total shell and roof area.

(b) For smaller tanks, 1 cu. ft. purge gas per hour for each 40 gal. of tank capacity, or the rate corresponding to a mean rate of the change of the

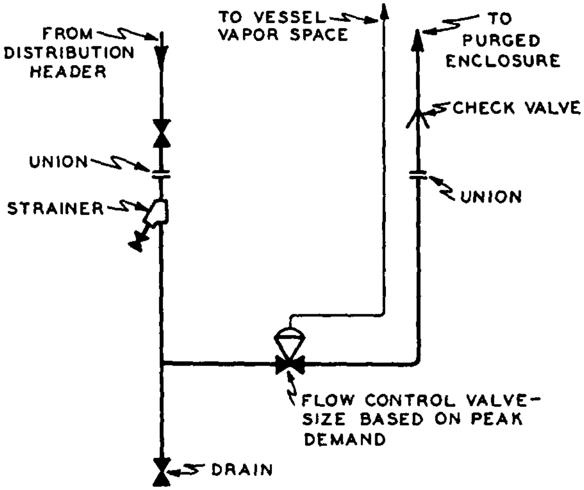

Fig. 3. Schematic sketch showing a method of flow control that can be used with variable rate application. See also Figure 4.

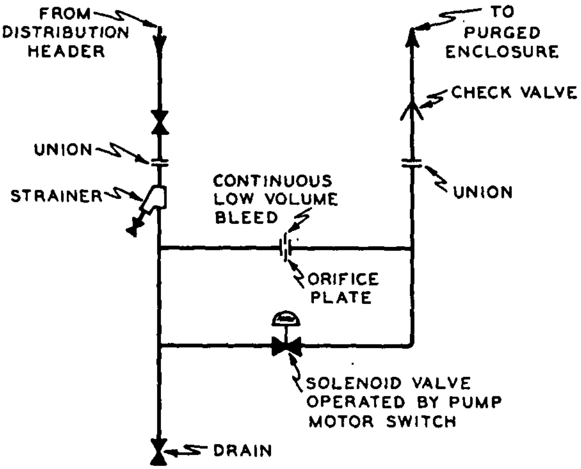

Fig. 4. Schematic sketch showing a method of flow control that can be used with variable rate application. See also Figure 3.

vapor space temperature of 100°F. per hour. (API RP 2000)

The rates for temperature change and liquid withdrawal must be added unless there is some special circumstance which will prevent them from occurring simultaneously.

A1134. In some equipment, such as pulverizers, the rate of purge gas supply necessary to exclude air may be dominated by leakage, and temperature change can be ignored.

A1135. CALCULATIONS. The quantity of inert gas required under paragraphs A1125 may be calculated as follows:

Volume of inert gas required for one inerting cycle:

$$V_2 = \frac{(P_1 - P_2)V_1}{P_1}$$

Oxygen content of enclosure after one inerting cycle, using an oxygen free inert gas:

$$O_1 = O_2 \frac{(P_2)}{(P_1)}$$

Oxygen content of enclosure after one inerting cycle, using a nonoxygen free inert gas:

$$O_1 = O_2 \frac{(P_2)}{(P_1)} + O_3 \frac{(P_1 - P_2)}{P_1}$$

where

$P_1$ = pressure in enclosure (psia), after introduction of inert gas.

$P_2$ = pressure in enclosure (psia), prior to introduction of inert gas.

$V_1$ = total volume of enclosure, cu. ft.

$V_2$ = volume of inert gas required, measured in standard cu. ft. (68°F., 14.7 psia).

$O_1$ = proportion of oxygen in enclosure at end of inerting cycle.

$O_2$ = proportion of oxygen in enclosure at start of inerting cycle.

$O_3$ = proportion of oxygen in inert gas.

Sample Calculation A (Applicable only to vacuum or siphon inerting.)

Assume a 1,230 gal. vessel (total capacity) normally operating at a vacuum of 15 in. mercury:

$P_2$ = 15 in. Hg vacuum

7.37 psi vacuum

$P_2 = 14.7 - 7.37 = 7.33$ psia

$P_1$ = atmospheric pressure (14.7 psia)

$$V_1 = \frac{1230}{7.48} = 164.5 \text{ cu. ft.}$$

Volume inert gas required for one cycle:

$$V_2 = \frac{(14.7 - 7.33) \times 164.5}{14.7} \times \frac{7.37 \times 164.5}{14.7} = 82.5 \text{ ft}^3$$

Since the vessel initially contained no oxygen, the final oxygen content would depend on the oxygen in the venting gas. Assume an inert gas containing 3 per cent oxygen:

Final Oxygen content:

$$O_1 = O_2 \frac{(P_2)}{(P_1)} + O_3 \frac{(P_1 - P_2)}{P_1}$$

$= 0.0 + \frac{.03\ (14.7 - 7.33)}{14.7} = .01495$

$O_1\% = 1.5\%$

Sample Calculation B

Assure a 1,230 gal. vessel designed to withstand full vacuum. A vacuum pump is available which will reduce the pressure in the vessel to 21 in mercury.

$P_2 = 21$ in. Hg vacuum

10.3 psi vacuum

$P_2 = 14.7 - 10.3 = 4.4$ psia

$P_1 =$ Atmospheric, $= 14.7$ psia

$V_1 = \frac{1230}{7.48} = 164.5$ cu. ft.

Volume inert gas required for one cycle:

$V_2 = \frac{(14.7 - 4.4)\ 164.5}{14.7} = \frac{10.3 \times 164.5}{14.7}$

$= 115.3$ std. cu. ft.

Assume the vessel initially full of air, and an inert gas having an oxgyen content of 4 per cent:

$O_1 = .209\ \frac{4.4}{14.7} + .04\ \frac{10.3}{14.7}$

$= .0625 + .028 = .0905$

$O_1\% = 9.05\%$

If a lower oxygen content is desired, the cycle must be repeated. The oxygen content will then be:

$O_1 = 0.905\ \frac{4.4}{14.7} = .04\ \frac{10.3}{14.7}$

$= .0271 + .028 = .0551$

$O_1\% = 5.51\%$

**A1140. Ventilation.** Ventilation is defined as the process of supplying or removing air by natural or mechanical means, to or from any space. This term is usually applied to occupied spaces, but it is basically the same as that previously discussed in A1127, and is subject to all of the same principles and limitations. Whether ventilation is accomplished by supply or removal of air, it is obvious that a corresponding volume must either escape or enter the ventilated spaces, either through leakage or via deliberately supplied openings.

The purpose of ventilation is to remove or dissipate some undesired contaminant in the atmosphere within the space. For the purpose of this Standard the undesired component will be a flammable gas, mist, or dust.

A1141. GENERAL VENTILATION means that the points of ingress or egress of air are not chosen with respect to the point of release of the contaminant. Under these conditions more or less complete mixing within the space will occur.

A1142. LOCAL VENTILATION means that the point of egress has been chosen with respect to the point of release of the contaminant so as to safely exhaust a mixture containing the maximum possible amount of the contaminant. Hoods or equivalent may be employed, and the "capture velocity" has been determined for a large variety of conditions. (See American Society of Heating, Refrigeration and Air Conditioning Engineers Guide, Chapter 52.)

General ventilation has certain limiting factors:

(a) The quantity of combustible released into the space must not be too great, as diluting air volumes may become impractical.

(b) The evolution of combustibles must be reasonably uniform.

(c) Toxic combustibles may pose insurmountable problems.

General ventilation is usually not as satisfactory for removing combustibles as is local ventilation. There are, however, occasional circumstances in which general ventilation must be used because the operation or process prohibits local ventilation. Circumstances may be found in which general ventilation provides an adequate amount of control more economically than a local ventilation system. One should be careful, however, not to base the economical considerations entirely upon the first cost of the system, since general ventilation frequently exhausts large quantities of heat from a building.

One problem in the design of a general ventilation system involves estimating the period of time required to dissipate airborne combustibles *suddenly released* as a result of equipment failure or spill. The concentration at any time is related to the initial concentration and to the number of effective air changes that have occurred, as shown in Figure 5. Once the peak concentration and the allowable dissipation time have been selected, the required effective air change rate can be calculated.

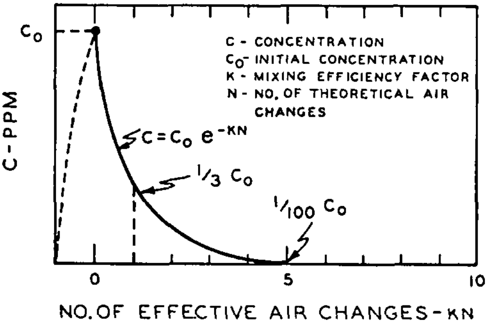

**Fig. 5. Combustible decay curve. General ventilation: instantaneous release.**

If the release of combustibles is continuous, the relationships are somewhat different, as shown in Figure 6.

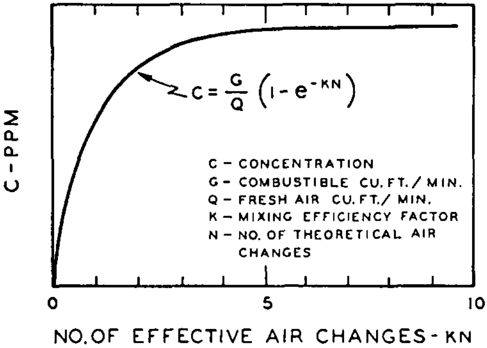

**Fig. 6. Combustible buildup curve. General ventilation: continuous release.**

After a continuous release begins, the combustible concentration increases rapidly until about three effective air changes have occurred. During this period, the concentration depends on air change rate—specifically, cubic feet per minute of fresh air divided by room volume. After about three effective air changes, the bracketed term in the equation on Fig. 6 approaches unity and concentration does not change greatly. Thus, the steady-state concentration is independent of air change rate and depends solely on the volumetric flow rate of fresh air. In other words, room volume is not a factor. Consequently, general ventilation systems to control continuous release of contaminants should be specified on the basis of cubic feet per minute, not on air changes per hour. For design purposes, estimates of the release rate may be obtained from material balances on similar units, from information by the equipment manufacturer, or from previous experience with the process.

The efficiency of the ventilation process depends on many variables, but, for practical purposes, the most important variable is the arrangement of air intake and exhaust. The effectiveness of various arrangements is described by mixing efficiency factors. These factors are a measure of the degree of mixing within the room. Consequently, all are less than 1.0. Table A lists several of these factors for common ventilation arrangements.

**Table A. Mixing Efficiencies for Various Ventilation Arrangements**

**Values suggested for estimating required air flow rates.**

| | **Efficiency, K Values** | |
|---|---|---|
| **Method of Air Supply** | **Single-Exhaust Opening** | **Multiple Exhaust Opening** |
| No positive supply | | |
| Infiltration through cracks | 0.2 | 0.3 |
| Open doors or windows | 0.2 | 0.4 |
| Forced air supply | | |
| Grilles and registers | 0.3 | 0.5 |
| Diffusers | 0.5 | 0.7 |
| Perforated ceiling | 0.8 | 0.9 |

Although general ventilation is helpful in removing air-borne combustibles, better control can be achieved in many cases by supplementing general ventilation with local ventilation.

Local ventilation can be used when the source of emission can be predicted. For example, local ventilation rather than general ventilation is recommended when:

(a) The operator or ignition sources must be very close to the point of combustible release.

(b) The combustible escape rate is uncertain.

(c) Controlling combustible dusts.

Local exhaust ventilation captures the combustible at its source, and a properly designed system achieves almost 100% effectiveness provided that the local exhaust pickup can be placed close to the point of release.

Information relating to ventilation and protection for certain specific systems and industries is covered in NFPA codes and reports. These standards are listed as such along with a list of references concerning ventilation.

NFPA No. 91—Blower and Exhaust Systems.
NFPA No. 33—Spray Finishing using Flammable Materials.

NFPA No. 86A—Ovens and Furnaces.

A. R. Jones and D. J. Hopkins, Controlling Health Hazards in Pilot Plant Operations, Chemical Engineering Progress (Vol. 62-no. 12) December 1966, pp 59–67.

Industrial Ventilation, American Conference of Governmental Industrial Hygienists, Committee on Industrial Ventilation, P.O. Box 453, Lansing, Michigan.

**A1150. Determination of Purge Gas Supply Source and Installation Method.** Purge gas for fire and explosion prevention shall be obtained from a dependable source which is capable of either (1) supplying peak demands or (2) supplying average demands with storage capacity sufficient for peak demands. Purge gases shall be properly conditioned or purified for the intended use and shall be distributed in conformance with accepted piping standards, capacity, protection against mechanical damage, and system contamination. Piping, instrumentation, valving and other mechanical parts of the system shall be in accordance with requirements of the equipment protected and shall be properly identified.

**A1160. Determination of Start-Up Measurements and Test Data to Conform to Design and Installation.** Purge gas measurements and test data are often needed to establish the proper functioning and design of purge systems. Test data compared with design data establish both good engineering and installation. It may also be necessary to establish proper control settings and capacity limitations.

A1161. Delegation of responsibility for controlled purge gas usage shall be defined.

A1162. Operational control is considered very important in that the degree of protection afforded is dependent on purge gas generating equipment, distribution facilities, instrumentation and proper conformance to prescribed operating procedures. Cross-connections with other piping systems (for example, compressed gas or air) must be prohibited to prevent contamination of the purge gas system or vice versa.

A1163. Personnel employed for the process operation should be properly informed of the possible hazards associated with the equipment, as well as the methods employed to guard against fire and explosions. Monitoring equipment and its indications of the development of hazardous conditions should be fully understood by employees. It should be emphasized that steps be immediately taken to correct any developing hazardous condition indicated by the monitors or signals (audible or visual).

A1164. LARGE SCALE UNITS. Large scale purge gas systems should be designed, installed, operated, and maintained consistently with normal practice for other utilities. Plans should show all essential details. Information which may be required includes design purpose of system, description and estimated reliability of purge gas supply source, detailed layout of piping instrumentation and supplementary details of each specific hazard to be protected. Calculations to determine the amount of purge gas required should be filed for future reference.

A1165. SMALL SCALE UNITS. For individual unit or local systems designed for protection of a single group or single item of equipment, plans should show all essential piping and instrumentation detail. Calculations to determine the amount of purge gas required should be filed for future reference.

## PART II—INERT GAS SUPPLY

### A2100. Classification of Supply Sources.

### A2110. General.

A2111. Inerting media for fire and explosion prevention shall be obtained from a dependable source capable of supplying continuously the amount required to maintain the desired degree of purging within the enclosure protected.

A2112. If multiple sources of supply are used they should be independent of process operations and of such total capacity that loss of one unit shall not bring available capacity below peak requirements. Gas holders, in addition to generating capacity are recommended.

### A2200. Types of Inert Gas Supply.

**A2210. General.** There are a number of sources of inert gas which are suitable within prescribed limitations set forth in Appendix A1000 for the reduction of fire and explosion hazards.

**A2220. Hydrocarbon Combustion** (e.g., natural gas, propane.) In many cases the inert gas generated by the combustion of hydrocarbons is of sufficient purity to use without further treatment. The composition of this gas is approximately 87 percent nitrogen, 12 percent carbon dioxide, small amounts of carbon monoxide, and about ½ percent oxygen, and this mixture is saturated with water vapor. If a purified gas is necessary, undesired constituents should be removed.

**A2230. Ammonia Combustion.** This method consists of the catalyzed oxidation of ammonia with air to produce directly a high purity nitrogen which contains less than 0.02 percent carbon dioxide, 0.25 percent hydrogen, 0.001 percent residual ammonia, and merely a trace of oxygen. Unless specially treated, such gas will be nearly saturated with moisture from the combustion process.

**A2240. Air Fractionation.** This method consists of the liquefaction of air and subsequent fractionation to produce nitrogen. Several companies are now producing "package" units for various capacities using air fractionation techniques.

**A2250. Purification of Furnace or Boiler Flue Gas, or "Blow-Off Gas" from Certain Chemical Oxidation Processes.** In some cases the gas available from boilers, furnaces or processing units is of sufficient quality for immediate use. These gases can be purified if desirable but in the case of the furnace and boiler gas, the economics of the purification may not be favorable.

**A2260. Commercially Available Inert Gas.** Liquefied or gaseous inert gases, such as carbon dioxide, nitrogen, argon and helium are available in bulk or may be procured in cylinders.

### A2300. Location of Generator or Supply Facility.

**A2310.** The facilities for the generation, purification, and centralized storage of inert gas shall be located in a safe area.

A2311. Care must be exercised to insure against fire exposure or other plant operating condition causing loss of inert gas production or storage capacity.

A2312. Where the combustion method of producing inert gas is used, the existence of the facility constitutes an ignition source in itself; therefore, its location with respect to hazardous operations is important.

## A2400. Capacity and Reliability.

**A2410.** The expected rate of application of inert gas under most unfavorable conditions shall serve as a basis for calculating generation or storage capacity.

A2411. The most reliable supply of inert gas is from a system of gas holders or storage tanks of such capacity as to assure a continuous supply under peak demands.

A2412. If inert gas is obtained only from storage tanks or gas holders, provision shall be made to maintain the supply while recharging the tank or tanks. A duplicate set of tanks may be necessary unless the system is arranged so that a sufficient reserve supply can be maintained to provide protection during the recharging period.

A2413. If gas producers are used without storage tanks or gas holders, their combined capacity shall be such that loss of a single unit will not reduce the supply below the peak demand requirements.

A2414. When inert gas is obtained from boilers or special furnaces, provision shall be made to maintain the supply at all times. If the gas supply should fail and the process protected is continuous, a reserve supply in storage tanks should be available. If gas is obtained from the breeching of a battery of boilers, provision shall be made through the use of dampers or valves to prevent dilution of the flue gas with fresh air drawn through the grates or openings of any boilers which are idle or shut down.

A2415. The utilities provided for the inert gas generating equipment should be reliable under adverse conditions. For example, potential loss of natural gas supply for combustion process should justify storage of propane or other fuel.

## A2500. Gas Conditioning Equipment.

**A2510. General Requirements.** Inert gas used to protect any process or equipment must be conditioned to insure freedom of contamination that would be injurious to the gas distribution system or to the product or material being protected.

A2511. When exhaust gases from an internal combustion engine are used, precautions shall be taken to insure that the exhaust gases do not contain objectionable amounts of oxygen or unburned fuel.

A2512. Suitable filters or spray washers should be used to remove dust, soot, and cinders from flue gases used for inerting.

A2513. Inert gases obtained from a combustion process should normally be cooled to approximately atmospheric temperature before being introduced into a vessel being protected. This is to avoid interference with the process or reduction of pressure as the inerting gas cools within the vessel.

A2514. Periodic sampling of large scale inert gas installations at suitable points throughout the system affords protection against inadvertent cross-connections.

A2515. The metering of inert gas supplies to specific groups of equipment under inert gas protection may be advantageous from the standpoint of operating control and as an indicator of system efficiency.

**A2520. Instrumentation.** Suitable analyzing (indicating or recording) equipment shall be provided to indicate the quantity and quality of the inert gas available. Some of the factors which may require measurement are: pressure, temperature, rate of flow, dew point, oxygen content, and purity. Purity is determined by measuring such undesired contaminants as may be present.

## PART III—DISTRIBUTION OF PURGE GAS

### A3100. General.

**A3110. Distribution Facilities.** Facilities for the distribution of purge gas to various specific points to be protected shall be designed and installed in accordance with good engineering practice and specific requirements as set forth below.

### A3200. Piping.

**A3210. Size.** Piping shall be of ample size to deliver the required volume of purge gas at adequate pressure to points of use. Expected peak rates of purge gas usage shall be the basis for determining pressure drop in the distribution system.