ANNEX A - VENTILATION IN CONFINED SPACES

a. **Introduction.** Frequently, confined spaces contain atmospheres that are flammable, toxic or whose oxygen level has been depleted or enriched. Natural ventilation is generally insufficient to remove contaminated air from the inside space and to exchange it for fresh air from the outside. The lack of air exchange occurs particularly in confined spaces that have few openings for access and due to the configuration of the confined space itself. They can be effectively ventilated with apparatuses that move the air and remove the contaminated air from the confined space introducing clean, breathable air, and controlling the level of danger created by the contaminants in the space or that arise from the operations carried out inside the same.

b. **Basic Requirements.** Although a single rule or group of rules is unlikely to cover all of the ventilation requirements applicable to confined spaces, the objectives of ventilation in confined spaces are the following:

1) To remove contaminated air (flammable or toxic) from the space and maintain safe concentration levels in terms of permissible exposure level (PEL) or lower explosive limit (LEL), using the most convenient one.

2) To provide fresh and breathable air inside the space.

3) To create a more comfortable environment inside the space.

These objectives can only be achieved after a thorough evaluation of the requirements, based on the confined space under discussion, its content, and the operations that will be performed in the space. Ventilation requirements may be calculated based upon space and operational aspects. The evaluation of ventilation must be based on the measurements that are taken of the ventilation system or the atmosphere of the space to guarantee that safe conditions are achieved and that they can be maintained. In this chapter, minimum requirements are stipulated and guides for the application of ventilation in confined spaces are provided. Any specific questions must be directed to the industrial hygiene personnel of your area (RHSH).

c. **Ventilation before Entering or Working.** Confined spaces must be ventilated before entering or working to the degree necessary to reduce flammable and toxic substances to acceptable levels and to provide adequate oxygen content inside the space.

d. **Ventilation to Enter and Work**. Ventilation requirements to enter and work in confined spaces depend on the nature of the space, its content, and the operations that will be performed inside the same. The operations that are performed inside a confined space may require the application of a single type of ventilation, such as general ventilation, or may require the application of two types, such as general ventilation combined with a local exhaust ventilation system. These principles must be applied in order to fulfill the objectives stipulated in paragraph “b.” of this section.

1) **General Ventilation** – General ventilation is often used, alternating it with air dilution. However, we will refer to general ventilation as the action of exhausting or supplying air for breathing and for climate control inside the space, that is, ventilation to control the heat.

2) **Local Exhaust Ventilation** – A local exhaust system consists of an arrangement in which the exhaust intake (opening with a duct or bell) is placed near the point of work where the contaminants are generated. A local exhaust system captures the contaminants as they are generated, carries them to the duct of the system and expels them from the work site.

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To remove the contaminants that are generated in a single point, as in welding, or in localized clean-ups with solvents, local exhaust systems are more effective.

3) **Dilution Ventilation** – This is done by incorporating uncontaminated air inside a space to dilute the contaminated air that is inside until an acceptable level is achieved. Dilution ventilation refers to dilution of contaminated air with uncontaminated air in a general area, room or building, with the purpose of controlling any hazard or discomfort to health. However, usually **dilution ventilation is not a control for a hazard to health as satisfactory as local exhaust ventilation**. However, occasionally, this ventilation mechanism must be used in circumstances where the operation or the process performed prohibits the use of local exhaust ventilation.

The use of dilution ventilation has the following limiting factors:

- The amount of contaminant generated must not be excessive because, if it is, the volume of air needed for the dilution would not be practical.

- Workers must be sufficiently far from the place where the contaminant is generated, or this generation must be of a concentration sufficiently low so that the exposure of the workers is not greater than the threshold limit value (TLV).

    - The contaminant must be of low toxicity.

    - The evolution of the contaminant must be reasonably uniform.

Dilution ventilation is applied rarely with success to gases and dusts because:

- The high toxicity often found requires air dilution in large quantities;

- The speed and rhythm in which they are generated are generally very high;

- It is difficult, if not impossible, to obtain data about the production amount of dusts and vapors. (Dust is formed when solid materials crumble, as when drilling, sanding or grinding. Vapors occur when a metal or plastic is heated and cools rapidly, while welding, melting or working with cauldrons, etc.)

When dilution is used to control the vaporization of toxic or flammable substances and personnel may be exposed, the atmosphere may be diluted to less than the permissible exposure level (PEL) or lower explosive limit (LEL), that is, to whichever is the lower of the two. If the atmosphere cannot be diluted to less than the PEL, the worker must be protected with personal protection equipment.

Unless the sample tests and evaluations establish clearly that the concentrations of the contaminants are at acceptable levels of exposure, personnel must be equipped with respiratory protection apparatuses certified by NIOSH and approved by the Industrial Hygiene Section, adequate for the exposure under consideration.

4) **Dilution and Exhaust Ventilation (entry and exit / Push/Pull)** – This type of ventilation consists of incorporating uncontaminated air inside a space to dilute contaminants, combining them with an exhaust localized at the area of greatest generation of contaminants, utilizing flexible ducts.

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e. **Ventilation of Flammable Atmospheres**. The fans, exhausts, motors and other equipments that are use to ventilate atmospheres that contain vapors, emanations, fogs, dusts, etc., flammables or explosives, must be equipments that are essentially safe by design, such as fans with pressured air jets, eductors, or vapor ejectors, etc. The equipment must be properly insulated and grounded, as appropriate, to control the accumulation of electricity and discharges.

f. **Ventilation System Arrangements**. Ventilation systems must be arranged to provide the best possible air distribution to all the space and the air must be of breathable quality so that it replaces the contaminated air that is removed from the space.

1) **Air Circulation** – The location of the exhaust and air intakes for the exchange is extremely important to achieve a proper distribution of air throughout the confined space. Very little is achieved by placing an exhaust fan without a duct or with a short duct at the top of a confined space with a single deep opening (where the replacement air enters the space through the same opening where the fan is located). This would short-circuit the movement of the air, since the exhaust fan would remove most of the replacement air entering the space, before it has circulated throughout the space. In this case, the air distribution could be improved a lot by extending the duct from the exhaust fan intake to the furthest end of the space. Air distribution and circulation can improve greatly when the replacement air and the air that is extracted are moved through separate openings inside the space.

2) **Replacement Air** – The replacement air that is fed to a space to replace the contaminated air must be clean and contain normal levels of oxygen that can be breathed. The replacement air intakes must not be located near air exhaust outlets or engine exhaust emissions, since this may cause the recirculation of contaminated air inside the space. When replacement and exhaust air are moved through the same opening, ducts must be provided to carry exhaust air to a distance sufficiently far from the opening, so as to avoid the recirculation of contaminated air. The direction of the wind is a critical factor in preventing the recirculation of contaminated air.

3) **Exhaust Air Outlets** – Exhaust air containing flammable or toxic substances must be ventilated to the exterior atmosphere to a place where the contaminants can be diluted and dispersed. Exhaust air outlets must not be placed in areas where the air may contaminate adjacent spaces, or accumulate or form pockets in low areas, or expose personnel to toxic or hazardous atmospheres. Exhaust air must be discharged in the direction of the wind, far from air intakes and possible sources of ignition. Certain systems may require the filtration of the exhaust air (as in the case of sand-blasting), before releasing the air to the exterior atmosphere. Such systems must be equipped with their own filtration or separation apparatuses, according to the contaminant involved.

4) **Lighter or Heavier than Air Contaminants** – In a confined space, contaminants that are lighter or heavier than air tend to accumulate in greater concentration in higher or lower areas, respectively. There may be a certain amount of diffusion that will disperse the contaminant in diverse degrees of concentration, but the greatest concentrations will occur in the higher or lower portions of the space. The higher temperatures that occur with hot processes or by natural causes increase evaporation and convection, causing vapors or gases to diffuse or rise to the top portions of the space. These characteristics must be considered while making ventilation arrangements and placing exhaust air outlets and replacement air intakes. When contaminants, heavier that the replacement air, are

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present the exhaust air outlet must be placed near the farthest end of the space and the replacement air intake on the top part of the confined space. When the contaminants are lighter than the air or when temperatures are very high, the system must be inverted to place the exhaust outlet on the top of the space and the replacement air intake on the farthest end of the space. These arrangements will allow the ventilation system to capture and remove the contaminants at the point of greatest concentration, with minimal dispersion of contaminants in the space.

g. **Ventilation Requirements for Specific Operations.**

1) **General Aspects** -

a) In this section, there is a description of the ventilation requirements of certain operations. However, it must be emphasized that these are minimum requirements and only serve as guidance. The only way to determine if the ventilation is effective for reducing and maintaining safe levels of flammable and/or toxic substances, and to provide adequate air for breathing, is to take adequate samples of the atmosphere inside the space. Compliance with the minimum requirements of ventilation does not guarantee, in itself, that there are not going to be hazards of flammable or toxic substances, because there are many variables that can affect any work situation in particular. In many cases, it may be necessary to use ventilation together with the respiratory protection equipment. For example, ventilation with air dilution may be used to keep flammable vapor at a concentration of 10% or less than the lower explosive limit (LEL). The ventilation provided may not be sufficient to dilute the contaminant until acceptable levels for exposure of personnel are achieved, because normally a much larger volume of air is needed to dilute the values until the permissible exposure level (PEL) is reached. In such cases, ventilation may be used to control the concentrations of flammable vapors and approved equipment for personnel protection may be used to protect personnel from exposure to toxic substances. Competent, qualified personnel or the industrial hygienist must evaluate each work situation to ensure that the ventilation provided is achieving the desired effect.

b) In certain cases the structural configuration of a confined space impedes the safe ventilation to extract the toxic or flammable contaminant, so it may be necessary to reduce the scope of the work to keep the generation of contaminants within acceptable levels.

The Competent Person will perform the tests, take the measurements and make the corresponding evaluations, according to the nature of the operation and the contaminants. The ventilation provided in any operation will be acceptable when the tests and evaluation show that the ventilation provided is sufficient to keep the prescribed levels of clean and breathable air as well as the appropriate levels of lower explosive limit (LEL) and permissible exposure level (PEL). Class II, III, and IV competent person will ventilate the confined space prior to access even if the instrument readings indicate normal conditions.

2) **Ventilation requirements for soldering, cutting, burning or similar works (hot work)** are the following:

a) **Local exhaust ventilation:** When operations involving soldering, cutting, burning, or similar are carried out inside confined spaces, local exhaust ventilation must be

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provided whenever possible to capture and remove the contaminants from the point in which they are generated.

Personnel must be equipped with respiratory protection apparatuses certified by NIOSH and approved by the Industrial Hygiene Section; appropriate for the exposure, unless the tests and evaluations of the samples establish clearly that the concentrations of contaminants inside the zones where the workers are breathing are within the permissible exposure limits (PEL).

When the operation has highly toxic metals or other materials, it is possible that greater air flow in the suction may be needed to guarantee that the contaminants are captured properly and to provide a greater dilution. Personnel must always be equipped with respiratory protection apparatuses, approved by the Industrial Hygiene Section, when they have to work with highly toxic materials, since even the slightest interference or failure of the ventilation system may cause a significant exposure to the personnel. These toxic materials include, among others, the following:

- Lead
- Mercury
- Beryllium
- Cadmium (use of respirators with air line is mandatory)
- Zinc
- Chromium
- Fluoride compounds
- Cleaning compounds and degreasers, stainless steel with chemical flux, iron dust, shielded metal arc welding or inert gas metal arc welding.
- Halogenous hydrocarbons

b) **Air Dilution Ventilation**:

(1) Whenever effective local exhaust ventilation cannot be provided due to the location, configuration or nature of the space or similar restrictive factors, air dilution ventilation must be provided. In such circumstances, personnel must be equipped with respiratory protection equipments certified by NIOSH and approved by the Industrial Hygiene Section, that are appropriate for the exposure, except when the sample tests and evaluations establish clearly that the concentrations of contaminants are within acceptable levels of exposure.

3) **Paint, coating, use of solvents** – Frequently paint and cleaning solvents, liquid dissolvents for paints and coatings for preservation, and similar material are toxic or flammable. When the operations in which those materials are used are carried out in confined spaces, ventilation must be used to control the hazards. Generally, the contaminants that these types of operations generate are dispersed over a broad area instead of a fixed point of generation. In such operations, ventilation with local exhausting is not as effective to control the contaminants. If possible, air dilution and exhaust ventilation (entry and exit, better known as push-pull) should be used.

a) **Ventilation until Permissible Exposure Levels (PEL)**: When using air dilution and exhaust ventilation to control exposure to toxic substances, ventilation must be designed to lower the levels of contaminants to 25% or to less than the permissible levels (PEL). Due to the nature of ventilation problems in confined spaces, as described in paragraph “g.1)” of this section, personnel must be equipped with

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respiratory protection apparatuses certified by NIOSH and approved by the Industrial Hygiene Section; except in the case in which the tests and evaluations of industrial hygiene that are made to the samples establish clearly that the concentrations of contaminants are maintained uniformly and reliably within acceptable levels.

b) **Ventilation until Lower Explosive Limit (LEL)**: When sufficient air flows cannot be provided in a reliable manner to reduce the contaminants to the established permissible exposure limits, air dilution and exhaust ventilation must be provided up to 10% or less than the lower explosive limit (LEL) of the material involved. Personnel must be equipped with adequate equipment certified by NIOSH and approved by the Industrial Hygiene Section. Ventilation must be continuous during operations, and must continue after operations have ceased, until the flammable materials have evaporated and the space is free of gases. After the ventilation system has been closed for at least 10 minutes a final test of the space will be made. Frequent tests of the space must be made during operations to ensure that flammable atmospheres do not arise. Operations must be suspended and personnel must be withdrawn from the space if the concentrations of flammable vapors are more than 10% of the lower explosive limit (LEL). Operations shall not resume until the ventilation deficiencies have been corrected or the application rate has been adjusted to keep the flammable vapors to less than 10% of the LEL. For this purpose one must acknowledge that in operations such as spray painting, flammable concentrations will exist to a certain degree within the cone-shaped space starting from the spray nozzle. The existence of these flammable concentrations inside the spray cone is not a reason to suspend operations. The type of operations and the effect of the ventilation system in the total atmosphere inside the space must be considered. When flammable concentrations are found at significant distances outside the spray cone, one must suspect the ventilation system and take the measures described previously.

c) **Ventilation Flow Indices**: Air dilution and exhaust ventilation flow indices must be determined and calculated according to the ACGIH Industrial Ventilation Manual to maintain the levels of permissible exposure limits (PEL) or 10% of the lower explosive limits.

4) **Abrasive Cleaning**: The contaminants produced by abrasive cleaning in confined spaces cannot be controlled reasonably through ventilation. Personnel performing these operations must be equipped with respiratory protection apparatuses certified by NIOSH and other personal protection equipment approved by Competent Person in agreement with the Industrial Hygiene Section. Ventilation with sufficient air flow must be provided to remove suspended dust particles from the atmosphere to increase visibility inside the space.