HAZARDS
OF
INERT GASES

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1 Introduction

EIGA continues to be very concerned that every year fatalities and serious accidents are reported by industrial gas companies and users of inert gases where the direct cause has been the lack of oxygen leading to asphyxiation. EIGA identified that existing information on the hazards of inert gases was not sufficiently directed at the users who were most at risk. This document sets out the essential information that is necessary to prevent asphyxiation accidents involving inert gases.

2 Scope and purpose

This document is intended to be used as a training package suitable for supervisors, line managers and direct workers at any installations where inert gases are produced, stored or used, or where oxygen depletion could occur.

This document has 4 parts:

The **actual document** is intended for line managers and supervisors and gives the background of the subject, the typical description of oxygen deficiency accidents and the recommended rescue procedure in case of accident.

Appendix A is a resume of the actual document suitable to be produced as a pamphlet to be handed over to workers.

Appendix B lists some actual accidents which have taken place in recent years and which can be used as examples underlining the hazards of inert gases.

Appendix C gives an example of a special sign or poster highlighting the hazards of inert gases.

3 Definition

Inert gas: A gas which is not toxic, which doesn't support human breathing and which reacts scarcely or not at all with other substances. Inert gases are mainly nitrogen and the rare gases like helium, argon, neon, xenon, krypton.

4 General

Accidents due to oxygen depleted atmospheres are often very serious, and in many cases fatal.

In spite of the wealth of information available, such as booklets, films and audio-visual aids, we still have reports of serious accidents due to asphyxia caused by the improper use of inert gases or by oxygen depletion.
It is therefore absolutely essential to draw the attention of our personnel, as well as that of our customers, to the hazards of inert gases and oxygen depletion.
Although carbon dioxide is not an inert gas, most of the information in this document is applicable. The specific hazards of carbon dioxide are more complex than those of inert gases and this document does not cover these aspects. (More details about hazards of carbon dioxide see in IGC Doc. 67/99 "CO2 cylinders at user's premises").

4.1 Oxygen means life

Oxygen is the only gas which supports life. The normal concentration in the air which we breathe is approximately 21 %.

If the oxygen concentration in air decreases or (what amounts to the same), if the concentration of inert gases increases, a situation is rapidly reached where the hazards of asphyxia become very great. Any depletion of oxygen below 21 % must be treated with concern:

NOTE

- The situation is hazardous as soon as the oxygen concentration is less than 18 %.
- The risk of death due to asphyxia is almost certain at an oxygen concentration below 10 %.
- Immediate loss of consciousness occurs with less than 6 % of oxygen.
- Inhalation of only 2 breaths of nitrogen or other inert gas can cause sudden loss of consciousness and death.

4.2 Inert gases give no warning

It is to be strongly stressed that with such inert gases as nitrogen, argon, helium, etc.,
asphyxia is insidious since there are no warning signs. (Lack of oxygen may cause vertigo, headache, speech difficulties but the victim doesn't recognise these symptoms as asphyxiation.)

- Inert gases are odourless, colourless and tasteless. They can therefore be a great deal more dangerous than toxic gases such as chlorine, ammonia, or hydrogen sulphide, which can be detected by their odour at very low concentrations.

- For an unaware person, the asphyxiating effect of inert gases takes place without any preliminary physiological sign that could alert the victim. This action is very rapid: only a few seconds for very low oxygen contents. Stated clearly, “you do not notice that you are passing away!”

4.3 Inert gases act quickly

In the case of an accident, it is to be noted that the rapidity of emergency rescue is particularly critical to save the victim: it is a matter of a few minutes only if the victim is to be saved from irreversible brain damage or even death.

Furthermore, and this is often poorly understood, the emergency rescue procedure to save the victim must be carefully thought out in advance to avoid a second accident, where members of the rescue team can become victims.

4.4 Ambiguity of inert gases

Finally, and especially with customers, one must be aware of the ambiguity of the expression “inert gas” (sometimes called “safety gas”, when it is used to prevent fire or explosion), whereby an “inert gas” is often perceived, understood and wrongly taken to be a harmless gas!

4.5 Watchfulness with regard to inert gases

Considering the hazards mentioned above, it is essential to provide all those who handle or use inert gases (both our own personnel as well as that of our customers) with all the information and training necessary regarding safety instructions. This includes means of prevention and procedures to be respected to avoid accidents, as well as rescue procedures to be implemented in the event of an accident.

5 Typical situations

5.1 Work in confined or potentially confined spaces

Particularly dangerous are these situations when an inert gas has accumulated and has not been vented or purged, and the renewal of air is poor or inadequate.

Examples for such spaces:

- <u>Confined spaces</u>: tanks, vessels, reservoirs, underground galleries, the inside of “cold boxes” of liquefaction equipment, cold storage rooms, spaces, where welding protective gas is used, etc.
- <u>Potentially confined spaces</u>: the internal rooms of a building, laboratory rooms, machine pits, culverts, basements, trenches for piping, or the room where a deep-freezing tunnel has been installed for food freezing, or under a roof where helium (lighter than air) might have accumulated, etc.

5.2 The use of liquid nitrogen

It is to be noted, that the use of liquid nitrogen is accompanied by two hazards:

- Firstly it is a very cold fluid (-196°C), which can cause serious burns on contact with the skin.
- Secondly it becomes, after vaporisation, a big volume of cold inert gas (1 litre liquid nitrogen yields 700 litres gaseous nitrogen) which has a tendency to accumulate in low points.

In processes where liquid nitrogen is handled and vaporisation takes place, special care must be taken to avoid exposure of personnel to oxygen deficiency.

5.3 Stay in areas where inert gases can flow out

Asphyxiation risk can arise in the vicinity of

- gas leaks,
- vent exhausts,
- outlet of safety valves and rupture disks,
- openings of machines in which liquid nitrogen is used for freezing,
- in rooms, where dewars are filled and/or stored.

5.4 Erroneous use of nitrogen instead of air

In factories, there are often compressed nitrogen distribution networks used for safety purposes, e.g. inerting/purging or using nitrogen as a pressure source to operate pneumatic tools (such as jackhammers) or as instrument fluids.

Pneumatic tools can be operated either with compressed nitrogen or compressed air, as is also the case for instrument fluids.

In the case of instrument air it's worth noting that, if the instrument air compressor fails, nitrogen gas is often used as a substitute. One must not forget that most pneumatic operated instruments vent continuously and that the vented nitrogen accumulated behind the control panel presents a serious asphyxiation risk.

Should a need arise for breathing air, and proper training and information have not been given, there is a risk that the breathing apparatus is connected into the nitrogen system with fatal results.

6 Preventive measure

6.1 Information, training

The very first preventive measure is to inform all persons who handle or who use inert gases:

- of the hazard represented by the depletion of oxygen in the atmosphere,
- of preventive measures to be adopted,
- of procedures to be observed should an accident occur.

This information and training should be systematically and periodically renewed in order to maintain a state of watchfulness with regard to these hazards.

6.2 Installation and operation

Apparatus used for manufacture, distribution or use of inert gas must be installed according to the recommendations of the industrial gas industry and must comply with all applicable regulations.

Newly assembled equipment for inert gas service must be leak-checked by a suitable procedure.

Each inert gas pipeline entering a building should be provided with an isolation valve outside the building.

Discontinued inert gas lines shall be physically disconnected from the supply system when not in use.

At the end of each work period, all valves which stop inert gas supply, shall be securely closed to avoid possible leakage between work periods.

6.3 Ventilation and atmosphere monitoring

There are typically 3 situations where the type and quantity of ventilation must be determined in order to avoid asphyxiation accidents.

6.3.1 Areas where people regularly work or enter

Examples of this category would include:

- Rooms in which liquid nitrogen food freezers are operated.
- Rooms in which cryogenic deflashing equipment is operated.
- Control rooms (control/analyser panels).
- Compressor houses (inert gases).
- Rooms containing inert gas pipelines with possible leaks.
- Rooms in which dewars are filled and/or stored.

Building size, ventilation capacity, system pressures, etc. must each be determined for specific cases to which the following guidelines apply:

- Ventilation must be continuous. This can be achieved by interlocking the ventilation system with the process power supply.
- Ventilation system design should ensure adequate air flow around the normal operating areas.
- Minimum ventilation capacity of 6 air changes per hour.
- Other indicating devices may include:
  - warning lights
  - "streamers" in the fan outlet,
  - flow switches in the suction channels (ideally monitoring should not rely only upon secondary controls like "power on" to the fan motor).
- Exhaust lines containing inert gases to be clearly identified, and piped to a safe, well ventilated area.
- Consideration should be given to the use of atmosphere analyser, e. g. personal oxygen analyser or an analyser in the work area.

6.3.2 Entry into enclosure or vessels

These would include enclosures or vessels which:

- are not routinely entered and
- are known to have contained inert gas or
- may contain inert gas

Examples in this category would include:

- vessels designed to contain compressed or liquefied gases,
- filter vessels,
- any vessel not known and verified to contain atmospheric air.

In these cases the following guidelines apply prior to entry:

- The vessel or enclosure must be adequately purged with air (i. e. remove the inert gas and substitute with air).
- It is necessary to have at least 3 air changes within the enclosure involved.
- Purging shall continue until analysis confirms that the quality of the vessel atmosphere is safe for personnel entry. If there is any doubt that effective purging has taken place, the analysis should be made in the interior of the vessel by taking a sample at several locations by probe, or if this is not possible, by a competent person using a self contained breathing apparatus.
- The purge system must ensure turbulence for adequate mixing of air and inert gas to take place (to avoid “pockets” of dense or light inert gases remaining or to avoid “channelling” of gases due to inadequate purging).
- Removal of argon or cold nitrogen from large vessels and deep pits can be difficult due to the relatively high density of the gas compared with air. In that case the gas should be exhausted from the bottom of the space.
- Ventilation should never be carried out with pure oxygen, but exclusively with air.
- Another method of removing inert gases is to fill the vessel with water and allow air to enter when the water is drained off.
- A work permit must be issued and signed before entry is allowed.
- Sources of inert gas must be positively blinded or lines disconnected. Never rely only on a closed valve.
- Oxygen content of the atmosphere in the enclosure/vessel should be monitored continuously or repeated at regular intervals.
- Consideration should also be given to the use of personal oxygen monitors.

6.3.3 Entry into confined spaces

A confined space is a space which has any of the following characteristics:

- limited opening for entry and exit,
- unfavourable natural ventilation,
- not designed for continuous worker occupancy.

In the majority of cases the presence of inert gases is not expected when entry into areas below ground level is required.
The one essential safeguard, in all cases, is to sample the atmosphere in the trench, pit, etc. prior to any entry.
The fact that a problem is not normally anticipated is the greatest danger.

Notes:

The data for air change mentioned above is valid where nitrogen is the inert gas involved because its density is very near to that of air and oxygen.

If the gas to be purged has a density very different from the density of air, such as helium, argon or carbon dioxide, etc. the ventilating air may not adequately mix and the purge may be inadequate.

For inert gases of this type the volume of gas to be displaced (air changes) must be at least 10 times that of the volume involved. The preferred method of removal of very dense gases (e.g. argon or cold nitrogen vapour) is to suck out the gas from the bottom of the space.

In the presence of toxic or flammable gases, it is mandatory to perform an analysis of the gases present in the confined space, before entry of personnel. For obvious reasons, the measurement of only the oxygen content is not sufficient in this case. All other dangerous or toxic gases must also be analysed.

In the specific case of flammable gases, a nitrogen purge must be used first to prevent any explosion risk and then subsequently purge with ventilating air.

6.4 Testing of oxygen content

Historically, the need to check that an atmosphere is respirable has been considered to be of the greatest importance. In the past, simple means were employed, such as, for example, the lighted candle or the canary bird.

At present, various types of oxygen analysers are used, which are often simple and reliably to operate. The selection of the type of apparatus depends on the nature of the work in the place to be monitored (presence of dust, temperature and humidity, multiple detectors, portable equipment, etc.).

- Testing of the oxygen content is necessary, although attention must be drawn on the fact that an analyser alone is not an absolute protection, since such equipment can malfunction or be unexpectedly out of calibration, or detectors can be improperly positioned. Testing of oxygen content should therefore only be considered as an aid to the detection of a lack of oxygen.
- A simple check to confirm that an oxygen analyser is operating properly is to check the oxygen content of the open air (21%). This check should be part of work permit requirements.
- All oxygen analysers should be fitted with an alarm device to indicate possible defects (e.g. low battery).

6.5 Work permit

- For certain types of work, safety instructions and a special work procedure must be set up in the form of a work permit, in particular for confined spaces entry.
- This procedure is also necessary during work carried out by subcontractors in air separation plants, or where vessel entry is required.
- One of the important points that such a document should deal with is detailed information that must be given to the personnel and contractor employees before the start of work. This should include contractual conditions together with documented training to site workers before starting the job.

6.6 Lock-out procedure

A stringent implementation of a formal lock-out procedure is necessary before entry to a confined space.

6.7 Protection of personnel

Depending on the type of work to be performed, and the layout of the premises, the decision to provide additional protection for personnel may be taken on the initiative of the person in charge. Such additional protection may involve:

- The use of warning signs against the presence of an asphyxiation hazard (An example is shown in appendix C). The warning sign shall be associated with protective measures.
- The placing of a person on watch on the outside in the case of work in a confined space.
- Having a self contained breathing apparatus on stand by.
- The wearing of a harness so that the worker can be easily and rapidly taken out of an enclosed space in the case of an emergency. Preferably, this harness is to be connected to a hoist to facilitate removing the victim. In fact, it is very difficult for one person to lift up another person in the absence of a hoist.
- The provision of an alarm system in case of an emergency.
- The wearing of a self contained breathing apparatus (not cartridge masks, which are ineffective in a case of lack of oxygen).
- The wearing of protective goggles and gloves when handling liquid nitrogen to avoid cold burns.
- The wearing of all other means of protection, such as safety shoes, helmet, etc., depending on the circumstances.

7 Rescue and first-aid

Training in rescue work is fundamental since quickly improvised rescue without the respect of a formal procedure, often proves to be ineffective, if not catastrophic. (The rescue worker lacking foresight becomes a second or even a third victim).

It is recommended that where rescue is to be performed, there is in place an annual programme of training and rescue drills.

7.1 Basic rules

If a person suddenly collapses and no longer gives any sign of life when working in a vessel, a partially enclosed space, a trench, a pit, a small sized room, etc., assume that the person may lack oxygen due to the presence of an inert gas (which is, as we mentioned, odourless, colourless and tasteless),
but

WARNING. *Do not hurry to help him without thinking!*

The risk is that you will become the second victim, which obviously must be avoided at all costs.

You can only be the person who will save the victim if you proceed in an orderly manner and if you have the necessary equipment and restrain yourself against your natural impulses.

Get proper assistance and support.

7.2 Equipment

For a successful rescue action you need in whole or in part:

- A self-contained breathing apparatus for the rescue worker. ***WARNING****: Cartridge masks for toxic gases are not suitable.*
- A resuscitation kit supplied with oxygen for the victim. In general, such a kit includes a small oxygen cylinder, a pressure regulator, an inflatable bag, and a mask to cover both the nose and mouth of the victim (not compulsory).
- A safety belt or harness connected to a line on a hoist to attach to the victim.
- A portable audible alarm device, e. g. personal horn, whistle, klaxon etc. to alert nearby people that assistance is required.
- Possibly a source of air or oxygen, such as, for example:
  - a compressed air hose connected to the plant compressed air network,
  - an oxygen cylinder from an oxyacetylene work station, which might be located in the vicinity of the victim (only to be used in this special case of emergency rescue).
  - A ventilation device.

It is to be noted that all this equipment is necessary for emergency rescue in places where the rescue work might prove difficult due to the narrow space. Where this equipment is not available, a rescue should not be undertaken.

7.3 Procedure

The procedure to be followed (as described with illustrations in pages 8 to 13) includes 3 distinct situations:

<u>1st situation</u> It is possible to take the victim out into the open air in a few minutes (less than 3 minutes) without any additional assistance and without penetrating into the dangerous atmosphere.
Be aware that it is almost impossible for one person to lift another person out of a vessel. So in this situation a lifting device is necessary.

<u>2nd situation</u> It is possible to take the victim out into the open air in a few minutes (less than 3 minutes) without any additional assistance, although it is necessary to penetrate into the dangerous atmosphere. In this situation the rescuer must use self contained breathing apparatus when entering the confined space.

<u>3rd situation</u> It is impossible to take the victim out into the open air in a few minutes and without additional help.

In all situations, if there is in the immediate vicinity of the victim a source of air or oxygen (see above) and if it is possible for you to very rapidly use it, then inject the compressed air or oxygen into the enclosed space where the victim is to be found.
WARNING: *Inject oxygen only, if there is no ignition source.*

8 Conclusions

At this time, it is necessary to recall the essential two points relative to accidents due to inert gases:

- Accidents due to inert gases always happen unexpectedly and the reactions of personnel may be incorrect. Because of this awareness of personnel with regard to the hazards of inert gases must be permanently maintained.
- Furthermore, when such an accident does occur, it is always serious, if not fatal and hence, the absolute necessity to carry out regularly and periodically training and awareness sessions for personnel, as well as rescue work drills.

Use this document to train your employees and your customers.

9 References

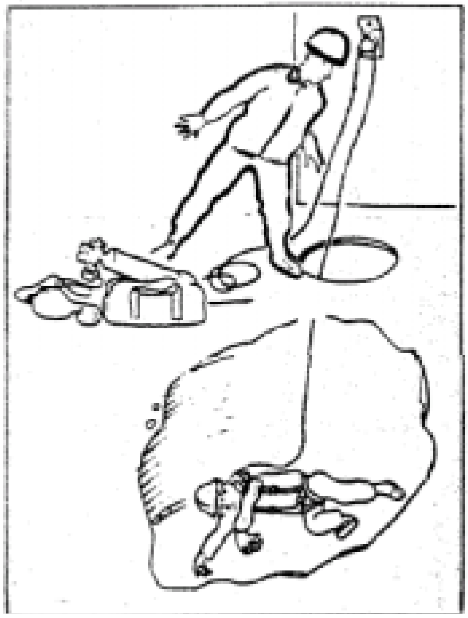
[1] <u>Accident prevention in oxygen-rich and oxygen-deficient atmosperes</u>
CGA Doc. P14, 1992

[2] <u>Oxygen deficiency awareness training package</u>. Overhead slides series.
EIGA, 1997

[3] <u>Oxygen deficiency hazards</u>. Video tape.
EIGA, 1997

RESCUE PROCEDURES

1st Situation
It is possible to **TAKE THE VICTIM OUT** into the open air **IN A FEW MINUTES, WITHOUT ASSISTANCE,** and **WITHOUT PENETRATING** into the dangerous atmosphere.



For example:
- the victim is inside a **CONTAINER;**
- the victim is wearing the **HARNESS;**
- the **LINE** and **HOIST** are in place.

Then: Keep your head out of the confined space and....

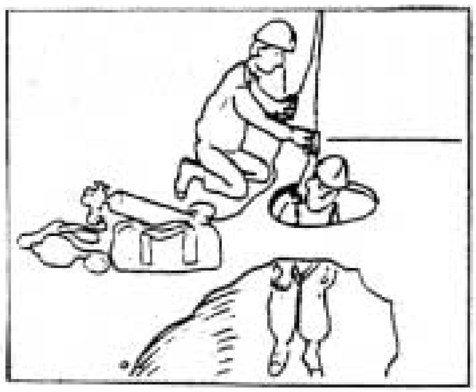
WITHOUT LOSING ANY TIME

TAKE THE VICTIM OUT into the open air.
Place him on his back.

CALL FOR HELP.
It is necessary for someone to **ALERT** as quickly as possible **SPECIALIZED RESCUE PERSONNEL** (Medical Emergency Vehicle Service, Doctor, Nurse)

TELEPHONE No.

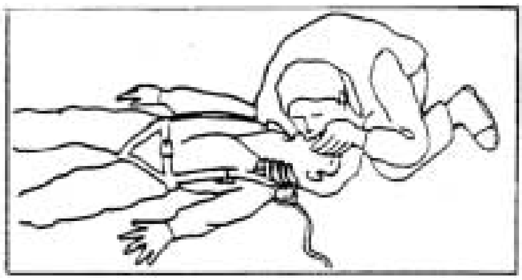
ORGANIZATION



If you have resuscitation equipment.
WHETHER THE VICTIM IS BREATHING OR NOT, open the valve of the cylinder (flowrate between 3 and 5 litres/min.), put the mask over the face of the victim.

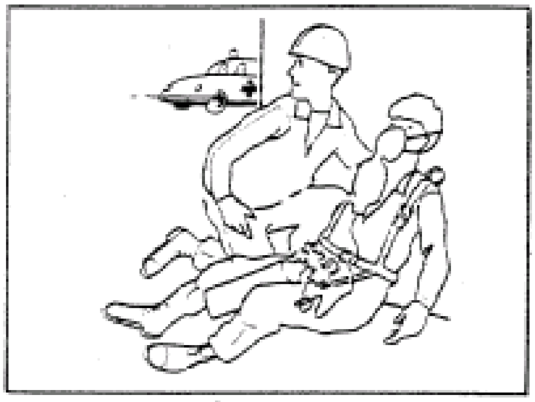
If the victim is no longer breathing, squeeze the inflatable bag according to the rhythm of your own respiration, and **CONTINUE UNTIL THE VICTIM STARTS BREATHING AGAIN**

If you do not have resuscitation equipment and **IF THE VICTIM IS NO LONGER BREATHING;** carry out **MOUTH TO MOUTH ARTIFICIAL RESPIRATION, UNTIL THE VICTIM STARTS BREATHING AGAIN.**



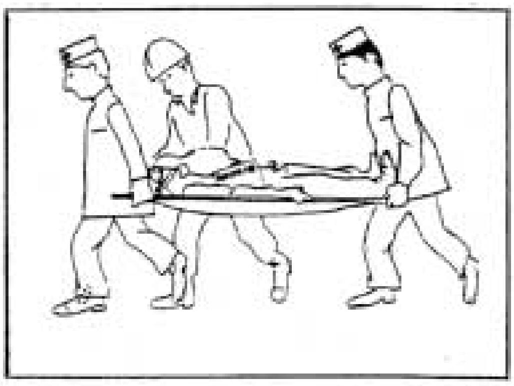
If resuscitation equipment has been used**,** the victim should keep it on **UNTIL THE ARRIVAL OF SPECIALIZED EMERGENCY RESCUE**

PERSONNEL, even if the victim starts breathing again.



Inform very clearly the Medical Emergency Vehicle Service doctor or nurse that it is a matter of **ANOXIA** (for example, pin on the clothing of the victim a **LARGE LABEL** with the wording **ANOXIA* LOSS OF CONSCIOUSNESS AT ....O'CLOCK).**

*Anoxia is the medical term for lack of oxygen.

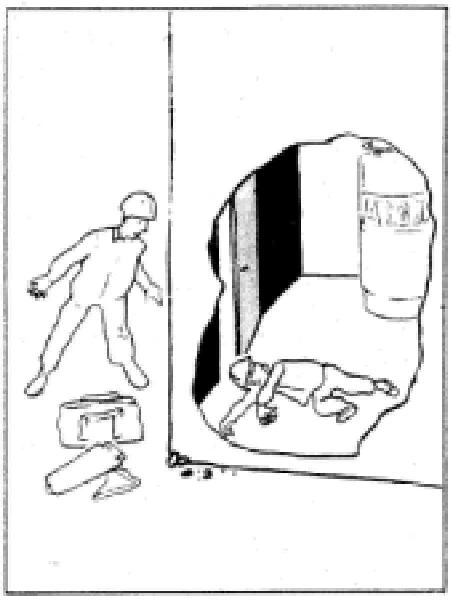


RESCUE PROCEDURES

2nd Situation

It is possible to **TAKE THE VICTIM OUT** into the open air.

IN A FEW MINUTES, and **WITHOUT ASSISTANCE;**
with the need to penetrate into the dangerous atmosphere
If possible **CALL** for **HELP** before penetrating with the breathing equipment.



Then

PUT ON THE RESPIRATOR
(Check that it is operating properly) and then go to the victim.

TAKE HIM OUT into the open air. Put him on his back and remove your mask.

CALL FOR HELP: It is necessary to **ALERT** as quickly as possible SPECIALIZED **RESCUE PERSONNEL** (Medical Emergency Vehicle Service – MEVS, doctor, nurse)

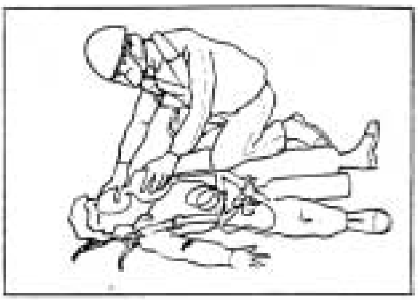
TELEPHONE No.

ORGANIZATION

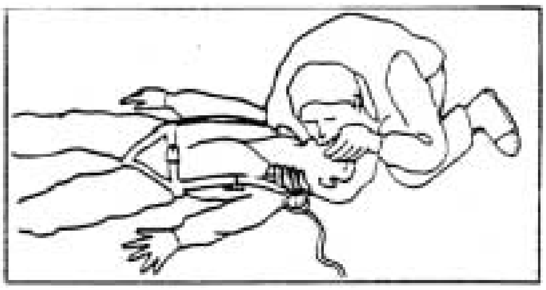
If you have resuscitation equipment

WHETHER THE VICTIM IS BREATHING OR NOT, open the valve of the cylinder (flowrate between 3 and 5 litres/mn); put the mask over the victim's face.

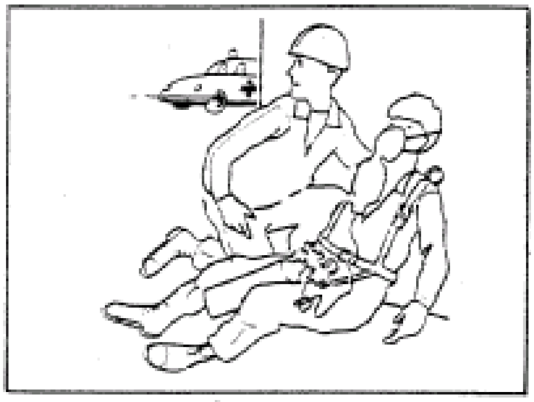
If the victim is not breathing, squeeze the inflatable bag according to the rhythm of your own respiration and **CONTINUE UNTIL THE VICTIM STARTS BREATHING AGAIN.**



If you do not have resuscitation equipment
and
IF THE VICTIM IS NO LONGER BREATHING;
carry out **MOUTH TO MOUTH ARTIFICIAL RESPIRATION UNTIL THE VICTIM STARTS BREATHING AGAIN.**

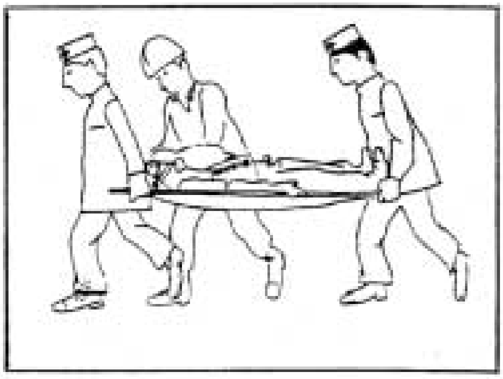


If resuscitation equipment has been used, the victim is to keep it on **UNTIL THE ARRIVAL OF SPECIALIZED MEDICAL RESCUE PERSONNEL,** even if the victim starts breathing again.



Inform very clearly the Medical Emergency Vehicle Service doctor or nurse that it is probably a case of **ANOXIA** (for example, pin on the clothing of the victim a **LARGE LABEL** with the wording **ANOXIA* LOSS OF CONSCIOUSNESS AT ....O'CLOCK).**

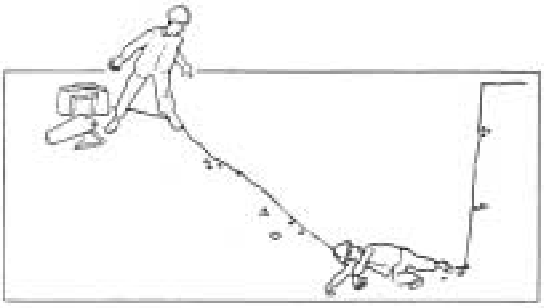
*Anoxia is the medical term for lack of oxygen



RESCUE PROCEDURES

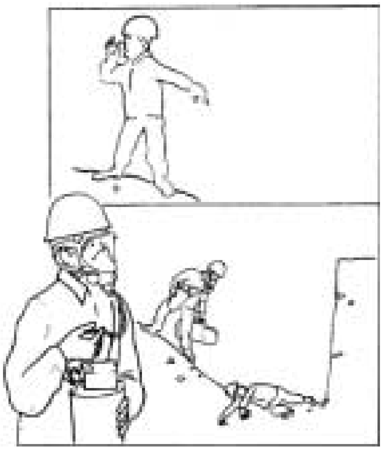
3rd Situation

It is **IMPOSSIBLE TO TAKE THE VICTIM OUT** very quickly and without assistance.



Then
WITHOUT LOSING ANY TIME

CALL FOR HELP, as you will surely **NEED ASSISTANCE**



PUT ON THE RESPIRATOR (check that it is operating properly).

If necessary attach yourself to a line.

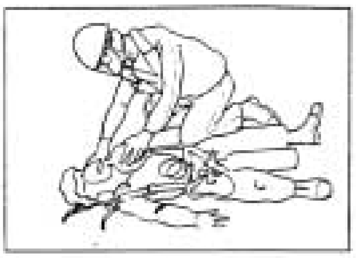
Take the **RESUSCITATION EQUIPMENT** as it is indispensable.

Without losing any time, go to the victim.

Open the valve of the resuscitation equipment (flowrate between 3 and 5 litres/min.) ; put the mask over the victim's face (as soon as you can, attach **VERY FIRMLY** the head strap).

IF THE VICTIM IS NO LONGER BREATHING, squeeze the inflatable bag according to the rhythm of your own respiration and **CONTINUE UNTIL THE VICTIM STARTS BREATHING ONCE AGAIN.**

HOWEVER, IF YOU HEAR THE CYLINDER OF YOUR MASK WHISTLE, YOU MUST RETURN TO THE OPEN AIR WITHOUT DELAY



RESCUE WORKERS who have come to provide **ASSISTANCE** and remain **IN THE OPEN AIR ARE TO ALERT** immediately **SPECIALIZED RESCUE SERVICES:** Medical Emergency Vehicle Service doctor or nurse.

TELEPHONE No.

ORGANIZATION

They will do what is necessary to **BRING** the victim **BACK OUT** into the open air.

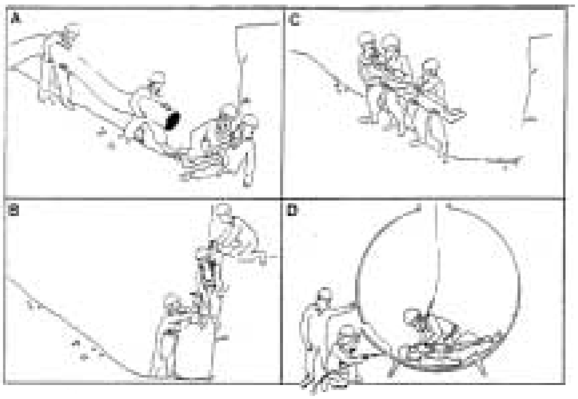
For example:

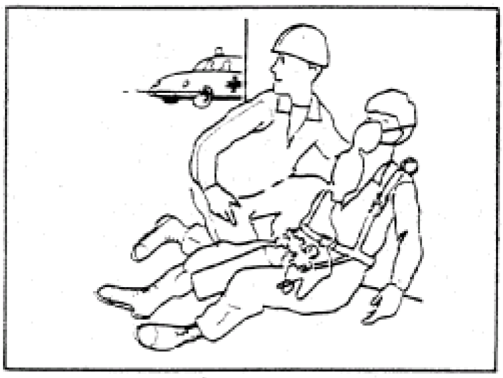
A. If this is possible, make the atmosphere respirable by sending in **LARGE QUANTITIES OF AIR** with a large fan.

B. Or organize REMOVAL with a **LINE** and **HOIST**.

C. Or organize the **TRANSPORTATION** in the **ARMS** of rescue workers **EQUIPPED** with **RESPIRATORS**

D. Or drill an **OPENING** in a **GOOD PLACE** in a container.

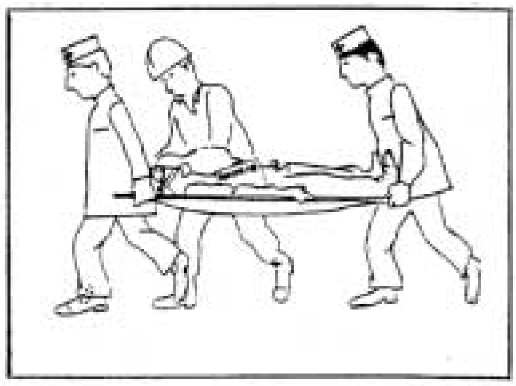




If resuscitation equipment has been used, the victim is to keep it on **UNTIL THE ARRIVAL OF SPECIALIZED RESCUE PERSONNEL,** even if the victim has started breathing again.

Inform very clearly the **MEVS,** doctor or nurse that it is probably a case of **ANOXIA.**

(For example, pin onto the clothing of the victim a **LARGE LABEL** with the wording **ANOXIA* LOSS OF CONSCIOUSNESS AT ......O'CLOCK).**



SUMMARY FOR OPERATORS

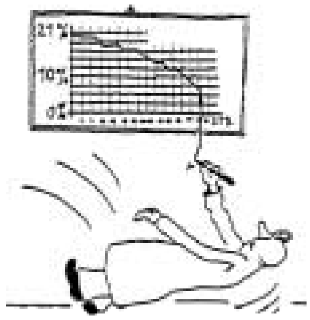
1 Why do we need oxygen?

OXYGEN IS LIFE

WITHOUT ENOUGH OXYGEN YOU CANNOT LIVE

When the natural composition of air is changed, the human organism can be affected or even severely impaired.

If gases other than oxygen are added or mixed with breathing air, the oxygen concentration is reduced and oxygen deficiency occurs.



If oxygen deficiency occurs by the presence of **inert gases** (e. g. **nitrogen, helium, argon,** etc.) a drop in physical/mental efficiency occurs **without the person's knowledge**; at about 10 % oxygen concentration in air (instead of the **normal** 21 % concentration) fainting occurs **without any prior warning.**

Below this 10 % concentration death due to asphyxia occurs **within a few minutes**, unless resuscitation is carried out **immediately.**

2 Causes of oxygen deficiency

a) When liquefied gases (such as liquid **nitrogen**, liquid **argon**, liquid **helium**) evaporate, one litre of liquid produces approximately **600 to 850 litres of gas.** This enormous gas volume can very quickly lead to **oxygen deficiency** unless there is adequate ventilation.

b) **In** the event of gases other than oxygen leaking out of pipework, cylinders, vessels, etc., **oxygen deficiency** must always be expected. Checks should be made periodically for possible leaks.

Spaces with inadequate ventilation (e.g. vessels) **must not be entered unless air analysis has been made and a work permit has been issued.**

c) **If** work has to be carried out in the vicinity of ventilation openings or vent pipes, personnel must be prepared to encounter gases with upper case **low oxygen concentration** or **without oxygen at all** leaking out of these openings.

d) Oxygen deficiency will always arise when plant and vessels are purged with **nitrogen** or any other inert gases.

Detection of oxygen deficiency

HUMAN SENSES CANNOT DETECT OXYGEN DEFICIENCY

Measuring instruments giving an audible or visual alarm in case of oxygen deficiency only indicate the **oxygen content.**

These instruments should **always** be tested in the open air **before use**.

If the presence of toxic or flammable gases is possible, specific instruments should be used.

3 Breathing equipment

Breathing equipment **must be used** in situations where **oxygen deficiency** has to be expected and which cannot be remedied by adequate ventilation.

Cartridge gas masks necessary for use in the presence of toxic gases (such as ammonia, chlorine, etc.) are **useless** for this purpose.

Recommended type of **breathing equipment** are:

- Self contained breathing apparatus using compressed air cylinders;
- Full face masks with respirator connected through a hose to a fresh air supply.

NOTE:

- ➢ It should be born in mind that when wearing these apparatus, particularly with air filled cylinders, it may sometimes be difficult to enter manholes.
- ➢ **Periodic inspection** of the correct functioning of the equipment shall be carried out in accordance with local regulations.
- ➢ Practice in handling of the equipment shall be carried out regularly.

4 Confined spaces, vessels, etc.

Any vessel or confined space where **oxygen deficiency** is expected and which is connected to a gas source shall be **disconnected** from such a source:

by the removal of **a section of pipe;**
or
by inserting a blanking plate before and during the entry period.

NOTE. Reliance on the closure of valves **alone might be fatal.**

A space or vessel should be thoroughly ventilated, and the **oxygen content shall be measured periodically before and during entry period**.

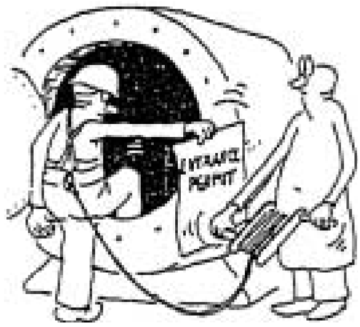
If the atmosphere in such a vessel or space is not breathable, breathing equipment shall be used by a qualified person.

Permission to enter such a space shall be given **only after** the issue of an **entry permit** signed by a **responsible** person.

As long as a person is in a vessel or confined space, a **watcher** shall be present and stationed **immediately** outside of the confined entrance.

He shall have a self contained breathing apparatus readily available.

A harness and rope shall be worn by the person inside the confined space to facilitate rescue. The duty of the watcher should be clearly defined. A hoist may be necessary to lift an incapacitated person.



5 Emergency Measures

In the event of a person having fainted due to oxygen deficiency, he can only be rescued if the rescue personnel are equipped with breathing apparatus enabling them to enter without risk the oxygen deficient space.

Remove the patient to the open air and without delay administer oxygen from an automatic resuscitator if available or supply artificial respiration.

Continue until patient revives or advised to stop by a medical doctor.

ACCIDENTS INVOLVING OXYGEN DEFICIENCY

1. An argon tanker had its top access manhole cover removed. An apprentice accidentally dropped a securing nut inside the tank. He entered the tank to recover it and died from lack of oxygen.

2. A new pipeline in a trench was being proof tested with nitrogen. A chargehand entered the trench to investigate the cause of an audible leak. He was overcome by nitrogen and died.

3. A workman was overcome by lack of oxygen after entering a large storage tank which had been inerted with nitrogen. Two of his workmates who went to his aid, without wearing breathing equipment, were also overcome and all three died.

4. A man was overcome on entering a steel tank which had been shut up for several years. The atmosphere inside the tank was no longer capable of supporting life due to removal of oxygen from the air by the rusting of steel.

5. A worker from a contractor company had to carry out welds inside a vessel. The vessel had been under a nitrogen blanket, but was ventilated with air before work started. In order to be on the safe side, the welder was asked to wear a fresh air breathing mask. Unfortunately a fellow worker connected the hose to a nitrogen line and the welder died from asphyxiation.

   This accident happened because the nitrogen outlet point was not labelled and had a normal air hose connection.

6. Welding work with an argon mixture was performed inside a road tanker. During lunchtime the welding torch was left inside the tank, and as the valve was not properly closed, argon escaped. When the welder re-entered the tank, he lost consciousness, but was rescued in time.

   Equipment that is connected to a gas source, except air, must never be left inside confined spaces during lunch breaks, etc. Merely closing the valves is not a guarantee against an escape of gas. If any work with inert gas is carried out in vessels, etc. take care with adequate ventilation or the use of proper breathing equipment.

7. A driver of a small-scale liquid nitrogen delivery service vehicle was making a delivery. He connected his transfer hose to the customer installed tank which was situated in a semi-basement. After he had started to fill, one of the customer’s employees told him that a cloud of vapour was forming around the tank. The driver stopped the filling operation and returned to the area of the tank to investigate. On reaching the bottom of the stairs, he collapsed, but fortunately he was seen by one of the customer’s staff who managed to put on breathing apparatus, go in and drag the man to safety. The driver fully recovered.

   Unknown to the driver, the bursting disc of the storage tank had failed prior to the start of his fill and as soon as he started filling, nitrogen escaped in the vicinity of the storage tank. He was overcome by the oxygen deficient atmosphere when he went down to investigate without wearing his portable oxygen monitor which would have warned him of the oxygen deficiency

   The installation has been condemned and is no longer being used. Not only was the tank situated in a semi-basement, but the relief device was also not piped to a safe area.

8. In a gas mixing unit the glass of a nitrogen flow meter ruptured while nobody was inside the room. When passing that room, a worker heard the noise of the escaping gas and he entered the room to see what had happened. As he immediately felt unwell, he tried to leave the room. He fell outside the door and called for help just in time.

   In order to prevent a repetition, all-metal flow meters will be used in future and a shut-off device that trips at a rapid pressure drop will be installed in the fill line.

9. During a routine overhaul of an ASU plant, a maintenance technician had the task of changing the filter element on a liquid oxygen filter. The plant was shut down and a work permit was issued each day for each element of work. In spite of these precautions, the technician collapsed when he inadvertently worked on the filter after it had been purged with nitrogen. The fitter collapsed apparently asphyxiated by nitrogen. All efforts to revive him failed.

10. A paint sprayer's breathing air hood was connected to a nitrogen supply instead of air. Saved by mouth to mouth resuscitation.

11. Reaching inside a refractory lined vertical vessel under nitrogen purge to remove a grating for maintenance, a man collapsed and was saved by mouth to mouth resuscitation.

12. Two contractors entered an enclosure under nitrogen purge to start work without permission. Both saved by cardiac massage and mouth to mouth resuscitation.

13. Two fatalities at a hospital during freezing of a pipe with liquid nitrogen for maintenance.

14. Two men became dizzy and nearly collapsed while descending into a sewage ejector pit operated by nitrogen instead of compressed air.

15. Two fatalities from asphyxiation when two technicians went to investigate, why a natural gas pipeline they were pressure-testing would not hold nitrogen pressure.

16. A food freezing machine did not properly vent off the waste nitrogen because a plastic bag was wrapped around the fan blades. Oxygen deficiency alarm from the analyser warned personnel.

17. At a cryogenic application, the equipment pressure relief valve located on the equipment **inside** the building opened because the pressure in the storage tank **outside** increased above the setting of the equipment pressure relief valve. Personnel about to enter the room the next morning were warned by the frosted appearance and did not enter.

18. At a customer location where liquid nitrogen dewars were filled from a storage tank, the customer built a shed to protect personnel against wind and rain. In the closed shed one person lost consciousness.

19. A customer was supplied with 2 low temperature grinding machines which were located in the same area in the factory. The customer installed a joint nitrogen extraction system between the two machines.

    One machine was switched off for cleaning while the other machine was left running. One of the operators who had entered the unit for cleaning fell unconscious and was asphyxiated before help arrived.

    The linked extraction system had allowed exhausted nitrogen from the operating machine to flow into the unit to be cleaned.

These examples from the recent past, highlight that it is **absolutely essential** to regularly draw the attention of our **personnel,** as well as those of our **customers**, to the **hazards of inert gases and oxygen deficiency.**