CO_2 TANKER DRIVER MANUAL

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1 Introduction

This document is intended to help companies in training their CO_2 tanker drivers giving general information as background and specific information about CO_2 and its transportation. Drivers will also need training in the particular requirements and regulations in each country.

2 Scope and Purpose

This manual contains detailed information and instructions, which may be used for training drivers of bulk carbon dioxide road tankers. It is clearly in the interest of everyone to ensure that road tankers are loaded, unloaded and operated in a safe manner.

One of the most important parts of the job is trans filling of liquid carbon dioxide between road tankers and the storage vessels at plants, other supplier sites and customers premises.

Most of the information is also valid for training of personnel in charge of loading/unloading CO_2 rail tank wagons, ISO containers for CO_2 and similar containers.

Some of the information and instructions may also be applicable to other bulk gas road tankers.

3 Definitions

Road tanker: tank vehicle built to carry refrigerated liquefied CO_2 by road.

4 Properties of Carbon Dioxide

Name: Carbon Dioxide - also called Carbonic acid gas or CO_2.

A Safety Data Sheet is available from the gas supplier. A short summary of the properties of Carbon Dioxide is given below.

4.1 Physical Properties and Handling

4.1.1 Gaseous State

At normal temperature (+15°C) and atmospheric pressure CO_2 has a density of 1, 87 kg/m^3 and is 1, 5 times heavier than air. It is a colourless and odourless gas (with a slightly pungent odour at higher concentrations) and spreads along the ground, collecting in low-lying areas such as pits and cellars.

Carbon Dioxide is classified as a non-toxic gas but it does start to affect breathing at concentration of about 1 % with affects becoming more serious with increasing concentrations (see APPENDIX B - Physiological effects).

Carbon Dioxide is a non-flammable gas.

4.1.2 Liquid State

CO_2 can exist as liquid below the critical temperature of 31°C and above the triple point with a temperature of -56,6°C and 4,18 bar gauge (barg); see P-T-Diagram, APPENDIX A. CO_2 is transported, stored and handled in liquid form, either at ambient temperature (in cylinders or not insulated storage tanks at a pressure of 45 - 65 barg) or refrigerated (in insulated tankers and storage tanks) at a temperature range of -35 to -15°C and a pressure range of 12 to 25 barg. The CO_2 in this state is liquid at its boiling point.

Below the triple point (4,18 barg and -56,6°C) CO_2 can only exist in the solid and the gas phase.
Therefore liquid CO_2 cannot exist at atmospheric pressure. When the liquid CO_2 is depressurised below the triple point pressure of 4,18 barg to atmospheric pressure it is transformed to dry ice and gas, consequently when the liquid CO_2 is released to the atmosphere a dense white fog of powdery solid carbon dioxide particles and vapour is produced.

4.1.3 Solid State (Dry Ice)

The expansion of liquid CO_2 to atmospheric pressure is used to produce CO_2-snow at a temperature of -78,5°C. The snow is compressed to dry ice blocks or pellets.

Dry ice is handled in non-hermetically closed insulated containers

4.2 Chemical Properties

Carbon Dioxide does not support combustion. When dissolved in water, carbon dioxide and water form equilibrium with carbonic acid (H_2CO_3). The pH-value of carbonic acid varies from 3,7 at atmospheric pressure to 3,2 at 23,4 barg. The carbonic acid provides the biting taste of soda water and it reacts in alkaline solutions producing carbonates. It has only very few vigorous reactions with other substances. It can react under special conditions such as high temperature or pressure with very strong reducing agents such as sodium and magnesium. For this reason carbon dioxide should not be used as a fire extinguishing agent for reactive metals like sodium and magnesium.

5 Hazards of Carbon Dioxide

5.1 Substantial release of Carbon Dioxide

Any substantial release of carbon dioxide is potentially hazardous especially inside a poorly ventilated building. Enclosed low - lying areas, where CO_2 gas could accumulate in high concentration, are particularly hazardous because the gas is slow to disperse unless the spaces are well ventilated, more details about physiological effects are found in APPENDIX B.

In case of a substantial release of carbon dioxide in confined areas, evacuate all personnel immediately. Never enter such areas before they are properly ventilated.
When confined spaces must be entered before they are properly ventilated, the person entering such areas must be well trained and wear self - contained air breathing apparatus.
Canister respirators give no protection in atmospheres containing dangerous concentrations of Carbon Dioxide.
A second, also well trained person should be connected with a rope to the person entering the gas filled area, for rescue purposes.
Substantial releases of carbon dioxide may occur through:

- Failure of the storage vessel or pipe-work containing liquid carbon dioxide.
- Tow away of the flexible hoses through movement of the road tanker while the hoses are still connected between road tanker and storage vessel.
- Release from a relief device.
- Inadvertent opening of a drain valve while the system contains liquid CO_2.

- Failure of connections, e. g. flexible hoses, flanges etc.
- Failure to open valves according to proper procedure

Uncontrolled release of Carbon Dioxide from any opening (Valve or Fracture/Crack) can be violent, and may lead to serious injury upon impact.

Uncontrolled and violent release of Carbon Dioxide may also cause considerable noise, which may lead to hearing damage.

5.2 Low Pressure in Storage Vessels

When compressed gas is allowed to expand or liquid to evaporate, the temperature of the system falls. Should larger quantities of carbon dioxide gas be rapidly lost from the storage vessel either accidentally or through automatic or manual relief, or excessive withdrawal of CO_2 the temperature in the vessel could fall below the minimum permitted operating temperature.

If the temperature falls to the „triple point“ (4,18 barg at -56,6 °C) solid CO_2 forms in the tank. If the pressure is reduced to atmosphere pressure, the temperature of the dry ice will be -78,5 °C. At this temperature many materials may become brittle and fail if highly stressed. Under normal conditions the pressure should remain above 8 barg. Should the pressure fall below this, the customer should stop withdrawal to avoid dry ice formation and contact the gas supplier immediately.

5.3 Low Temperature of Product: Extreme Cold

The snow produced from leaks of liquid carbon dioxide is extremely cold (-78,5°C) and may cause frostbite if touched with bare hands. If carbon dioxide snow comes into contact with the eyes it may cause severe eye injury.
Touching pipes and connections containing liquid carbon dioxide may cause frostbite.
Where there has been a major release of gas, the atmosphere will be very cold and visibility is likely to be limited due to the fog formed by the condensation of water vapour in the air. These factors can make escape or rescue difficult.

5.4 Failing Hoses and Tow Away Accidents

If a hose connection fails during the transfer of liquid carbon dioxide, the hose may flail and endanger people and equipment in the vicinity. The use of safety slings during filling, securing each end of the hose to fixed points on the tanker and the storage tank, is strongly recommended for non-steel hoses. A system to prevent tow-away accident should be used so that the road tanker cannot be moved while hoses are still connected.

5.5 Dry Ice Plugs in Pipes and Hoses

Dry ice plugs can be formed inside hoses and piping when liquid carbon dioxide pressure is decreased below its triple point pressure of 4,18 barg. The dry ice can be compacted into a plug which can trap gas. The pressure behind or within a plug may increase as the dry ice sublimes until the plug is forcibly ejected or the hose or pipe ruptures. A dry ice plug may be ejected from an open end of hose or pipe with enough force to cause serious injury to personnel, both from the impact of the dry ice plug and/or the sudden movement of the hose or pipe as the plug ejects. (See APPENDIX E).
Liquid carbon dioxide must be purged from the hose or pipe before reducing the pressure

below 4,18 barg. This can be done by supplying carbon dioxide vapour to one end of the hose or piping system to maintain the pressure above the triple point while removing the remaining liquid from the other end.

6 Checks before starting the journey

6.1 Tanker

6.1.1 Pressure

Check :

- the pressure of the tanker - it should be at least 2 barg below the maximum working pressure. When the pressure is too high, reduce pressure or vent gaseous CO_2 through the gas valve;
- the presence of frost or ice on the outside of the tanker and safety devices. The presence of frost or ice may indicates a defect of the tanker insulation and should be reported;
- special attention shall be paid to vehicles equipped with high pressure delivery pumps. Refer to company instructions against over pressurising customer tanks.

6.1.2 Leaks

Check :

- the presence of abnormal build-up of ice on the valves. Excess ice can impede the operation of the valves and should be removed;
- that pipe-work and flange connection under pressure are leak tight;
- that all valves including pneumatic and/or hydraulic actuators are in the position, they have to be in for the journey.

IMPORTANT: *Never attempt to tighten any screwed connections whilst under pressure.*

6.1.3 Equipment

Check that all equipment necessary for the transfer of carbon dioxide is present on the vehicle and in particular,

- hoses
- safety cables or slings, if necessary
- spanners for the hose connection nuts
- personal protective equipment
- wheel chocks

If fitted, check the function of the anti-tow away system before use of the vehicle and its combination especially in the case of a trailer each time it is coupled-up.

6.2 Vehicle

Check the operating conditions of the vehicle, in particular,

- the brakes
- the condition of tyres
- the lighting
- the cleanliness of the headlights, parking lights, sidelights, stoplights and all traffic indicators
- the visibility (driving mirror, windscreen)
- the presence of the fire extinguishers in their fittings and their plumbing
- the required warning signage
- the emergency equipment (e. g. warning triangle)
- the use of a routine safety checklist is highly recommended, see.TN 03/14/E – Pre-Trip Checklist for Prime Movers and Cryogenic Road Tankers

Check that all documentation required for the trip are available, such as:

- written instructions
- driver manual
- transport documents

As a final check walk around the combination to make sure that no obstacles hinder its free movement and remove the wheel-chocks.

7 Road instructions

7.1 In general

All tanker drivers must fully observe the traffic regulations, in particular,

- the specific speed limits and routing imposed for the transport of dangerous goods
- restricted sections will be indicated by special traffic signs (underground passages, tunnels, etc.)

In addition:

- avoid driving through large cities and or parking in congested areas, unless the customer location obliges you to do so;
- do not park in front of houses or near petrol stations;
- do not leave the vehicle on the public highway or in any place where the public can have access;
- when stopped, even for a short period, e. g. for lunch;

- stay in the vicinity of the vehicle;
- switch off the engine if climatic conditions permit;
- check that there is neither leakage nor abnormal pressure rise in the tanker;
- make a check before leaving;
- indicate your whereabouts by leaving a note behind the windscreen of the vehicle;
- lock the doors of the cab and the control cabinet of the tanker;

• prepare the itinerary carefully in advance to allow for safe parking of the tanker on long journeys;

• follow authorities - instruction, e. g. through radio news (e. g. in case of adverse weather conditions).

7.2 Incident or Accidents on the Road

The actions required in the event of incidents or accidents involving CO_2 tankers will depend on the circumstances.

The following is given as guidance on the type of action which will be required from the drivers.

Wherever practicable Company guidance should be obtained before any major action is taken and co-operation with the Police and other emergency services should be given at all times.

7.2.1 Breakdown

If it is necessary to stop on the roadside at any time due to breakdown:

• where practicable, look for a road widening as far away as possible from built-up areas;

• stop the engine;

• switch on hazard warning lights;

• set triangular warning sign on the roadway at rear of vehicle;

• if the position of the vehicle is likely to cause a serious traffic hazard or obstruction, notify the Police;

• if breakdown cannot be repaired, report to Company for instruction on further action required, which may involve;

- arrangements for assistance with repairs;
- or change of tractor;
- or transfer of CO_2 from the vehicle to another tanker depending on the circumstances.

7.2.2 Accident

If you are caught in an accident, stay calm, give first aid if necessary and if it can be done without risk. Also take the following measures:

- stop the engine;
- no naked lights, no smoking;
- switch on hazard warning lights;
- put on your warning clothing;
- set warning signs in roadway;
- notify the police and if necessary the ambulance and/or the fire brigade;
- keep bystanders at a distance;
- report to company;
- check tank pressure frequently.

Whenever practicable, use bystanders to summon assistance or pass messages and try to avoid leaving tanker unattended for any length of time.

7.2.3 Pressure Venting

Check tanker pressure and vent CO_2 gas to atmosphere if necessary to bring pressure down below maximum allowable pressure, try to find a safe place for venting if possible.

7.2.4 Product Spills

Put on personal protective equipment before attempting to deal with any leakage of carbon dioxide.

Inspect leakage.

(a) Minor Leakage

Where possible, without risk, check and close any valves to isolate point of leakage.

If there appears to be no damage to CO_2 tank or pipe work likely to develop into more serious failure:

- report to Company and unless instructed otherwise;
  - drive tanker to the nearest Company premises;
  - check tank pressure regularly during journey;
- if leakage appears to be increasing or tank pressure is likely to drop below 8 barg

  before arrival, stop in a suitable place away from built-up areas and take action for major leakage below.

(b) Major leakage

If leakage is of a more serious nature but the tanker can still be safely moved:

- report situation to company;
- then whenever practicable, drive to a suitable place well away from built-up areas, major roads, railways, tunnels or hollows and park such that prevailing wind will carry any CO_2 gas further away and allow it to disperse without danger;
- notify the Police;
- then, if the nature of the leakage and tanker location at the time is such that safe

  repair or transfer of CO_2 to another tanker appears to be impracticable;

  - open liquid valve carefully and discharge liquid CO2 at a controlled rate, keeping tank pressure above 8 barg until all liquid has discharged;
  - if leakage is such that the liquid valve cannot be safely opened, then open gas valve and discharge CO2 gas until tank pressure has been completely blown down, leave the valve open to prevent pressure build up from dry ice sublimation.

Stay in attendance throughout any discharge of CO_2 and keep all bystanders upwind at a safe distance. If the tanker cannot be moved and is in or near a built-up area or tunnel or near a major road or railway line where such leakage is likely to present additional danger, then

- notify the Police;
- report situation to Company;
- warn others of danger;
- ensure no one in the vicinity is working in cellars, basements or trenches etc;
- stay upwind and at a safe distance;
- keep bystanders upwind and well away;
- make no attempt to discharge CO_2 by opening liquid or gas valves;
- inform Emergency Services of the nature of the leakage on arrival and await their further instructions.

(c) Tanker Roll Over

If a tanker has overturned, or is on its side, it is possible that the gas and liquid valves will be reversed, so that liquid CO_2 discharges from the gas valve and vice versa.

Depending on the position after the overturning, it is possible not to have a gas phase, neither from liquid valve nor from gas valve.

If, for whatever reason, CO_2 leakage allows the pressure in the CO_2 tank to drop below 4,18 barg, then the remaining liquid will immediately turn to solid, which will remain in one part of tank and may give an unbalanced load when attempts are made to restore an overturned tanker to the upright position. The material of the tank will also have become very cold and under these circumstances no attempt should be made to move the tanker without further technical advice from the Company. Emergency Services should therefore be informed accordingly.

In case of product transfer into another tanker, hoses should be securely fastened and protected from flailing by safety cables.

Valves partly opened may become temporarily blocked with CO_2 snow, which may periodically be ejected at high velocity.

After discharge of CO_2, the liquid or gas valve should be left in the fully open position to relieve any further pressure, which may develop from solid which remains in the tank.

7.2.5 Fire

- If totally safe, drive the vehicle away from all inhabited areas and main roads.
- Use the fire extinguishers for minor fire.
- If the fire cannot be extinguished alert the fire brigade and police and report to company.
- Assist the fire brigade by giving information about the nature and properties of the product.

7.2.6 First Aid

Inhalation

In high concentrations may cause asphyxiation. Symptoms may include loss of mobility/consciousness, but victim may not be aware of asphyxiation.
Low concentrations of CO_2 cause increased respiration and headache. Remove victim to uncontaminated area wearing self-contained breathing apparatus. Keep victim warm and rested. Call a doctor. Apply artificial respiration if breathing stopped.

Skin/Eye Contact

Immediately flush eyes thoroughly with water for at least 15 minutes. In case of frostbite spray with water for at least 15 minutes. Apply a sterile dressing. Obtain medical assistance.

8 Loading/Unloading of Tankers

8.1 General

In APPENDIX C schemes of typical filling installations are given.

When filling and emptying tankers, the general safety instructions below should be observed in addition to the operating instructions for particular equipment used by the company:

- Position the tanker:
  - in the open air;
  - as level as possible.
- Position the tanker so that it will be possible to move away without difficulty.
- Put the wheel chocks in position, immediately after stopping the tanker and the engine.
- Examine the stationary bulk tank and its accessories in accordance with the check list.

  If the pressure of the stationary tank is below 10 barg, the customer and also the gas company has to be informed. The filling procedure should not be started.
- Check that this equipment has no serious defects that can affect the normal refilling operation, namely:

- safety devices jammed by ice;
- control equipment, such as pressure gauges, level controls or weighing machine out of order;
- significant leakage of carbon dioxide gas or liquid: Any serious defect should be reported and advice obtained before starting refill. Minor defects should be reported and recorded for any eventual action.

- Any minor defect should be reported and recorded for eventual action.
- Check that the hydraulic connections do not leak if applicable.
- Check that the electrical socket is in good condition before making the electrical connection and switching on the tanker pump if applicable.

8.2 Connecting Hoses and Loading / Unloading Operation

- Wear protective equipment:
  - shoes, helmet with ear protection, protective shield or safety goggles, gloves when handling and connecting.
- Check that the gaskets and screwed connections are in good conditions before connecting the hoses.
- Always use the special tools for connection hoses.
- Connections must not be hammered or hit with the spanners.
- After connecting of the hoses and before opening any valve fit the hose safety cables, if applicable.

  For the preparation of the unloading operation and the unloading itself, follow the individual company instructions: Connection of the hoses, pressurising with gaseous CO2 etc.
- Never attempt to tighten a screwed connection while under pressure.
- Operate the valves slowly.
- Remain near the control cabinet of the tanker throughout the whole period of transfer, ready to take any action required in the event of any problems arising e.g. overfilling, leakage pump problems.

8.3 Purging and Disconnecting Hoses

The purging procedure is very important to prevent formation of dry ice plugs (see APPENDIXD). Company instructions should be followed carefully, a general procedure should include:

- After completing the transfer, close the valves and firstly purge the liquid hose only through one valve and if possible the one at the lowest point.
- It is suggested to have a bypass line between the liquid and the gas phase to pressurise the liquid line with gaseous CO_2.

- After purging and depressurising has been completed, check that the hose is flexible on its whole length (i.e. no dry ice has been formed inside the hose) and disconnect it with the special tools.
- Remove the safety cables only after disconnection, if applicable.

8.4 Checking the filling quantity

- Check the weight or volume content of the tanker after every refilling to make sure that it is not overfilled.
- Check the weight or volume of the stationary bulk tank after every filling to make sure that it is not overfilled.

8.5 Potential Incidents or Accidents during Refilling

8.5.1 Dry Ice Plug Formation

It may be difficult to determine if a dry ice plug has been formed. If such an incident is suspected follow carefully your company instructions. Company instructions should include a procedure for dealing with dry ice plug formation.

This procedure should include:

- closing the purging valve;
- warming the hose by ambient temperature;
- checking the build up of pressure with the purge valve;
- do not pressurise a disconnected hose with the objective of ejecting ice plugs.

8.5.2 Leakage of CO_2 Liquid or Gas

Follow the instructions given in the section “Incidents or Accidents on the road“.

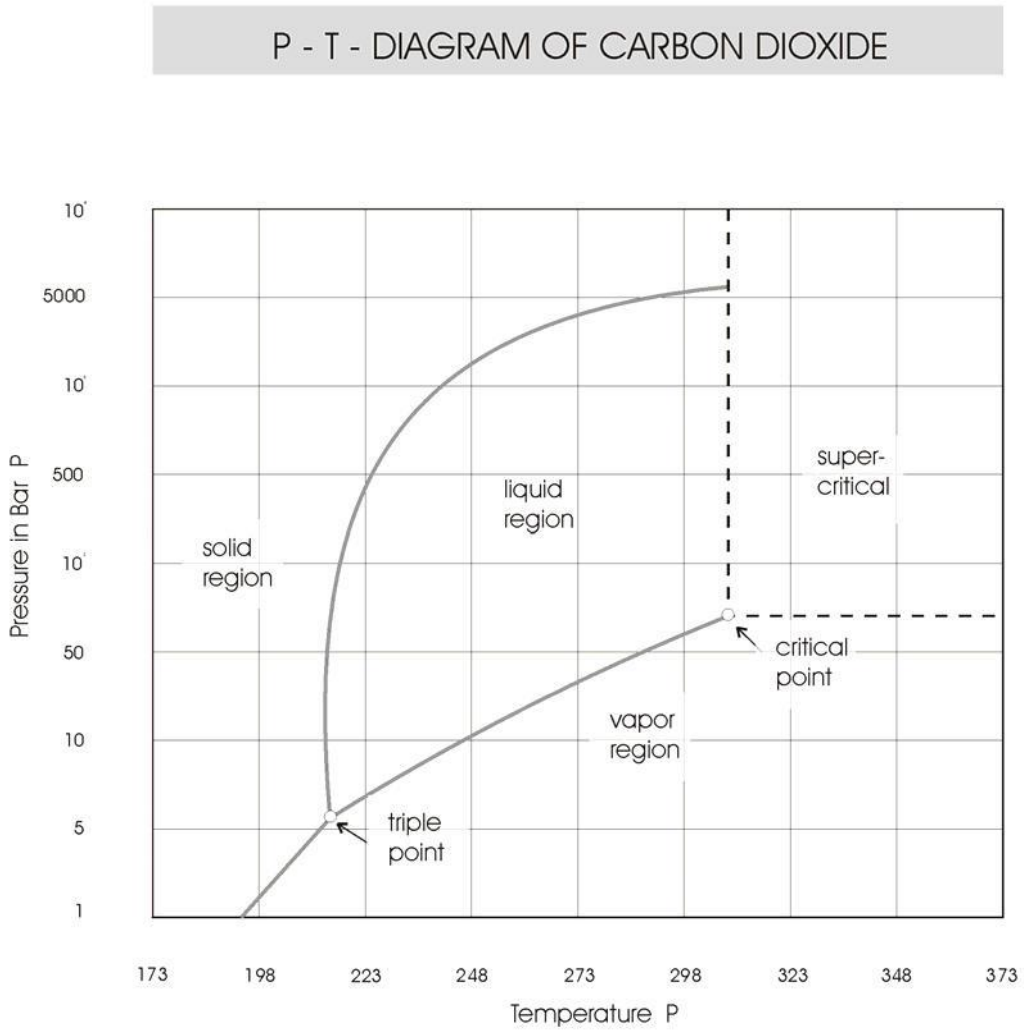
Suspend refilling if necessary and inform a responsible person on the premises, depending on the circumstances.

8.5.3 Fire in the filling area

Stop the filling, if possible according to the normal procedure; disconnect and move the vehicle away.

APPENDIX A - PRESSURE – TEMPERATURE – DIAGRAM OF CARBON DIOXIDE

ANNEX I



Triple point: T_t=-56,6°C (216,55K) P_t=5,18 bar abs.

Critical point: T_c=31°C (304,15K) P_c=73,83 bar abs.

APPENDIX B - PHYSIOLOGICAL EFFECTS OF CARBON DIOXIDE

Carbon Dioxide is classified as a non-flammable, non-toxic liquefied gas. It is normally present in atmospheric air at a level of approximately 380 parts per million (0.038 %). It is a normal product of metabolism being held in bodily fluids and tissues where it forms part of the bodies' normal chemical environment. In the body it acts in the linking of respiration, circulation and vascular response to the demands of metabolism both at rest and in exercise.

The effects of inhaling low concentrations of carbon dioxide are physiological reversible but in high concentrations the effects are toxic and damaging.

NB : The effects of carbon dioxide are entirely independent of the effects of oxygen deficiency.

The oxygen content in the atmosphere is therefore not an effective indication of the danger. It is possible to have an acceptable low oxygen content of 18% and a high carbon dioxide content, being 14 % very dangerous.

Individual tolerances can vary widely, dependent on the physical conditions of the person and the temperature and humidity of the atmosphere, but as a general guide, the effects of inhaling varying concentrations of carbon dioxide are likely to be as follows:

Concentrations by Volume - Likely Effects

1-1,5% Slight effect on chemical metabolism after exposures of several hours.

3% The gas is weakly narcotic at this level, giving rise to deeper breathing, reduced hearing ability, coupled with headache, an increase in blood pressure and pulse rate.

4-5% Stimulation of the respiratory centre occurs resulting in deeper and more rapid breathing. Signs of intoxication will become evident after 30 minutes exposure.

5-10% Breathing becomes more laborious with headache and loss of judgement.

10-100% When the carbon dioxide concentration increases above 10%, unconsciousness will occur in under one minute and unless prompt action is taken, further exposure to these high levels will eventually result in death.

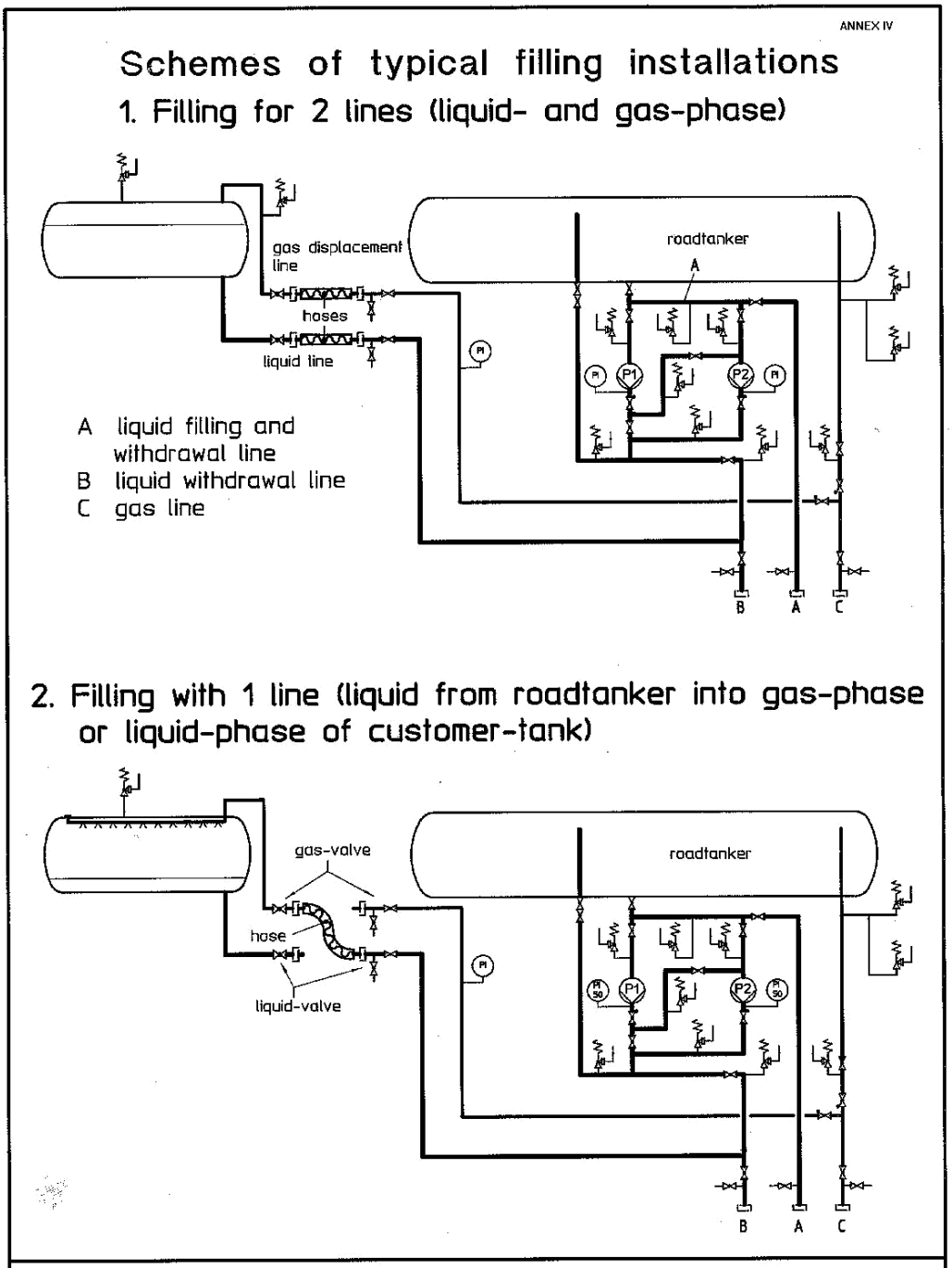
The recommended exposure limit for carbon dioxide is 5.000 parts per million (0,5%) by volume, calculated on an 8 hour time weighted average concentration in air.

Depending on regulations in individual countries carbon dioxide concentration peaks up to 30000 parts per million (3%) in air are allowed, where by the duration of exposure is between 10 minutes and 1 hour.

Cardiac or respiratory defects are likely to increase the hazards of inhalation.

Wherever any doubt exists, the recommended exposure limit of 5000 parts per million carbon dioxide in air should be regarded as the maximum level of the individual concerned.

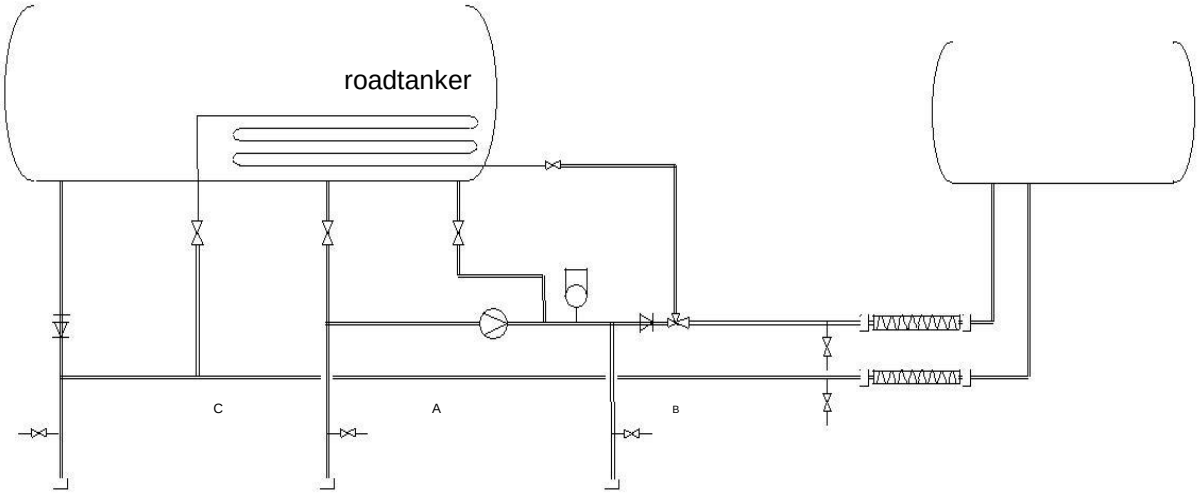
APPENDIX C - SCHEMES OF TYPICAL FILLING INSTALLATIONS



1. Always drain the liquid hose in one side only and in the lower point.

2. It is required to have always drain valves for both phases.

3. Filling with thermo-balanced system

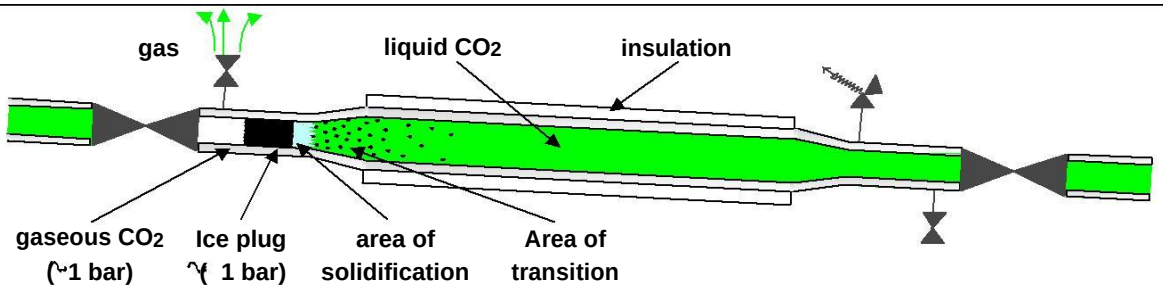


1. Always drain the liquid hose in one side only and in the lower point.
2. It is required to have always drain valves for both phases.
3. 3The gas from the storage tank is cooled down in the road tanker thermo balanced system and send back to the storage tank.

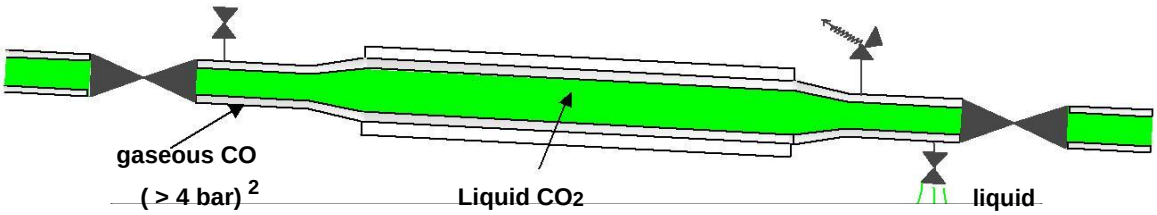
APPENDIX D- SAFE DEPRESSURIZATION OF CO2 LINES AND HOSES

SAFE DEPRESSURIZATION OF CO2 LINES AND HOSES

Clogging with dry ice when purging a line or hose



depressurization of gas phase = clogging with ice (p ~ 1 bar)



no depressurization of gas = no clogging with ice

DRAIN OUT THE LIQUID CO_2 AT A LOW POINT