



DISPOSAL OF GASES

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DISPOSAL OF GASES

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As part of a programme of harmonisation of industry standards, the European Industrial Gases Association (EIGA) has published EIGA Doc 30, *Disposal of Gases*. This publication was jointly produced by members of the International Harmonisation Council.

This publication is intended as an international harmonised publication for the worldwide use and application by all members of the International Harmonisation Council whose members include the Asia Industrial Gases Association (AIGA), Compressed Gas Association (CGA), European Industrial Gases Association (EIGA), and Japan Industrial and Medical Gases Association (JIMGA). Regional editions have the same technical content as the EIGA edition, however, there are editorial changes primarily in formatting, units used and spelling. Regional regulatory requirements are those that apply to Europe.

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Amendments to 30/13

Section	Change
Terminology	The terms “absorption / adsorption / reaction” have been clarified.
Previous par. 5	The previous paragraph with gas characteristics has been removed as current regulatory information (classification and labeling) is available in the SDS.
5	Schematic arrangement of disposal methods: Drawings have been standardized and completed.
7.3	Indication by colour has been changed to indication by valve outlet connection, pressure relief device and/or valve type.
8.5	The paragraph on hazardous residues has been extended with an additional section (8.5.1) about the hazards of diborane, diborane mixtures and pentaborane.
8.5.1.1	Removal of ACGIH reference
Annex I	The annex has been renamed Annex A and is completely updated. New gases have been added as well as CAS Registry Numbers to ease identification. Disposal methods, key characteristics and operational and safety considerations have been made more consistent.
Previous Annex II	This annex with index to gas names and synonyms has been removed as the data is available from other sources.

NOTE Technical changes from the previous edition are underlined

1 Scope and purpose

1.1 Scope

This publication recommends disposal methods for more than 140 gases and their mixtures and provides safe practices for the disposal of their containers when unserviceable. This publication reflects the concern of the industrial gases industry to ensure that when the need arises for disposal of gases and mixtures, standards of health, safety, and environmental quality continue to be maintained. Only environmentally acceptable methods are proposed.

The principles, recommendations, and requirements in this publication may be applied to both routine and emergency disposal operations; however, emergency disposal operations may dictate special or one of a kind procedures.

1.2 Purpose

Dealing with damaged and / or unidentifiable containers (gas cylinders, drum tanks, and similar transportable and pressurised vessels) is often an integral part of the gas disposal operation, and for this reason guidance on the subject is included. However, such work is potentially dangerous and shall only be performed by experienced and competent personnel following a risk assessment.

This publication should be used as an aid in the training of operators involved in the disposal of gases. The sections have been written with this in mind, and in particular summary checklists have been added for use as training modules.

It is the responsibility of the owner of the gas containers to dispose of the gas container in due time before they cause additional risks for the personnel in charge of the disposal and / or the environment.

1.3 Key operations for safe remediation and / or disposal of contents and / or containers

Key operations may include:

- Identify container contents, see Section 7;
- Select disposal method, see Section 5;
- Safely dispose of container contents, see Section 6;
- Evacuate and / or purge container, see 8.3;
- De-valve container, see 8.4;
- Remove any noxious residues from the container, see 8.5; and
- Render container unserviceable and scrap, see 8.6.

NOTE If doubt exists at any stage in the procedure, specialist advice should be obtained.

2 Definitions

For the purpose of this publication, the following definitions apply.

2.1 Publication terminology

2.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

2.1.2 Should

Indicates that a procedure is recommended.

2.1.3 May

Indicates that the procedure is optional.

2.1.4 Will

Is used only to indicate the future, not a degree of requirement.

2.1.5 Can

Indicates a possibility or ability.

3 Training and safety in the disposal of gases**3.1 Training**

It is essential that all personnel engaged in the disposal of gases shall be properly trained and equipped and their practical competence established before they engage in disposal work. In specific cases, local certification may be required.

In some instances, the emphasis is on using experienced operators and it is important to understand that this publication assumes that the operator's experience has also been reinforced with systematic and recorded training.

All operators undertaking gas disposal work shall:

- be properly trained in practice and theory;
- have written instructions / checklists;
- be properly equipped with personal protective equipment (PPE); and
- be provided with correctly designed disposal plant and equipment, and, if expected to deal with emergency situations, be trained to assemble emergency rigs from readily available materials.

3.2 Training procedure

Training shall be based on written instructions and procedures including checklists and shall be carried out by a competent person. The training programme shall be a blend of theory and practice, and each phase of training shall be recorded and signed off on completion, by both the trainer and the trainee. Refresher training at predetermined intervals should also be given.

3.3 Training scope

The training programme should include:

- product and container knowledge, including identification of contents;
- knowledge of standard valve outlet connections, valve types, and pressure relief devices (PRDs), and their applications;
- principles of disposal method selection;
- disposal procedures;

- basic understanding of applicable regulatory requirements for disposal of contents;
- personal protection and general safety; and
- risk assessment.

3.3.1 Product knowledge

The training programme should provide operators with:

- understanding of the general properties of gases; and
- more detailed understanding of the physical and chemical properties of the specific gases they are handling, and particularly their hazardous properties.

The safety data sheets (SDS) shall be available and used during the training.

3.3.2 Container knowledge

Training should include:

- basic knowledge of the containers and how to handle them safely;
- key features of valve design and the purpose of any safety devices fitted;
- identification of cylinder contents.

3.3.3 Selection of disposal method

Even where operators have the disposal method prescribed, it is recommended that they understand the disposal options and the principles of selecting an appropriate disposal method.

3.3.4 Operation of disposal plant / equipment

Training shall be carried out in conjunction with written procedures that shall include coverage of all foreseeable / potential hazards.

Safe handling methods of any chemical reagents and the disposal of any resultant spent chemicals or by-products should also be included.

Emergency procedures in the event of spillage, leak, fire, etc., should be considered, documented, and practised.

3.3.5 Personnel safety

For training in personnel safety to be effective it shall be supported by written, clear, practical, and authoritative rules on the use of personal protective equipment (PPE).

PPE likely to be covered in the training are:

- eye and face protection;
- breathing equipment;
- head protection;
- body protection (chemical resistant and or flame retardant clothing, safety shoes, gloves);

- hearing protection;
- gas monitors; and
- any other PPE that could be required to handle the materials.

The operator shall also be trained in the understanding and use of installed safety features such as special ventilation systems, fire prevention / firefighting equipment, and gas monitoring systems.

3.4 Safety—Design of plant and equipment

Proper design of plant and equipment is a prerequisite for safe operation.

Key features to check are:

- design shall be carried out by a competent person and should be checked by someone other than the designer;
- risk assessment shall be carried out including routing disposal operations;
- all pipes and vessels shall be designed to contain any pressure likely to be experienced and the design and working pressures should be known by the operator; and
- all materials used shall be compatible with the gases to be dealt with.

3.5 Safety checklist

- Are the methods and procedures written down and approved;
- Are the intended disposal processes and the gases covered by the site operating permit;
- Are the written procedures available in the working area;
- Has the equipment been properly designed particularly for materials compatibility and pressure;
- Are adequate warning notices displayed and is the area restricted to authorised personnel;
- Are emergency procedures prepared and understood;
- Has the operator been formally trained and has the training been documented;
- Does the operator have the correct PPE and been trained to use it;
- Should breathing apparatus be available? If yes, is it functioning correctly, properly located, and is the operator trained to use it;
- Are trained first responders and first aid equipment available;
- Have adequate preparations been made for treatment of persons exposed to the gases being handled;
- Have adequate preparations been made for decontamination of persons and equipment exposed to the gases being handled;
- If highly toxic and / or corrosive gases requiring specialist medical treatment are being handled, have the local medical services been informed;
- Are medical treatment protocols available for the products being disposed;

- Is the SDS available for the product to be disposed;
- Is the disposal system capable of handling the quantity and type of gases to be treated; and
- Are spent chemicals appropriately segregated and disposed of according to their properties.

Operators shall not put gases for disposal into the disposal system without first establishing the compatibility of the gas with the disposal system and the capacity and performance of the system. A waste basket approach is prohibited on grounds of safety.

4 Selection of disposal method [1, 2, 3]¹

4.1 Introduction

There are many disposal methods available. It is the responsibility of a competent person to select an appropriate method for the condition that exists. In the absence of a specific procedure, the selection of an appropriate method shall be based on a risk assessment.

It is important when disposing of a gas that new safety problems are not created. For example, it is of little value to dispose of a gas by burning if the products of combustion sent to the atmosphere are just as toxic as or more than the gas being treated. Nor is it helpful if the disposal of a gas by scrubbing results in a chemical equally as toxic and difficult to get rid of as the original gas.

There are four principal methods of disposal listed by order of preference:

- recycling;
- absorption / adsorption / reaction;
- burning or incineration; and
- venting to the atmosphere.

These methods are further detailed and described in Section 5.

In Appendix A, recommendations are made for the methods of disposal of all gases listed. When selecting a method, there are three important considerations:

- characteristics of the gas being treated;
- local conditions, regulatory requirements, and operational constraints; and
- quantity of gas to be disposed.

For most gases, several methods are recommended. The person responsible for the disposal operation shall select a method and prepare instructions taking local conditions, regulatory requirements, and operational constraints into account. When designing equipment and selecting disposal methods, due care and attention should be exercised.

Venting to the atmosphere by dilution should be avoided for gases that cannot be vented in pure form because of environmental considerations.

¹ References are shown by bracketed numbers and are listed in order of appearance in the reference section.

4.2 Gas characteristics

It is essential that the operator be fully aware of the main characteristics of the gases being disposed. Of particular importance is if they are toxic, flammable, oxidising, harmful, or corrosive. Each of these characteristics can dictate which methods of disposal are practical and effective.

Other characteristics that need to be known are whether the gases have any warning properties by smell or sight, what materials they are compatible with and which materials are prohibited, whether the gases are liquefiable or permanent, and the possible reactions with the atmosphere.

Information on the physical properties is also important. Density of the gas relative to air, boiling point, and vapour pressure should be known when dealing with liquefied gas.

Because certain key gas characteristics are so important to the disposal operation, they have been listed in in Appendix A. More information on the gases shall be obtained from the SDS of the suppliers and from the publications referenced in Section 9.

4.3 Local conditions, regulatory requirements, and operational constraints

While the fundamental requirement not to damage the environment is of overriding importance, it shall still be acknowledged that local conditions can affect the choice of method used. Where disposal has to take place in the midst of other activities, the precautions may be more stringent than when disposal is carried out in an open and isolated region. In the former case, weather conditions can also play a part. Precautions may have to be taken when windless and inversion conditions prevail.

This publication has tried to take into account legislation / regulation; however, it is the responsibility of the operator to ensure awareness of and compliance with all regulations and legislation applicable to the location.

4.4 Quantity of gas

Quantity of gas to be disposed of is an important consideration when designing and operating the system. The system shall be operated so the quantity of gas being disposed of shall not exceed system capacity.

4.5 Disposal checklist

Considerations when choosing method of disposal:

Gas characteristics	Local conditions and constraints	Quantity (kg)
Toxic Flammable Oxidant Corrosive Pyrophoric Harmful to the environment Warning properties Pressure / vapour pressure Liquefiable / compressed Boiling point Density relative to air Compatible materials Combination of the previous characteristics	Available space Other activities in vicinity Weather conditions Availability of expertise and equipment Condition of container and valve Legislation / regulation	Small Medium Large

5 Methods of disposal [1, 2]

5.1 Introduction

This section describes the basic principles of the four disposal methods:

- recycling;
- absorption / adsorption / reaction;
- burning or incineration; and
- venting to the atmosphere.

In the case of mixtures, more than one method can be necessary. Recovery and recycling of the gases should be considered in all cases provided it is safe to do so.

Each disposal method is named and detailed under the following headings:

- illustrative example of the disposal method;
- description of method;
- application;
- equipment design;
- operation; and
- operational precautions.

5.2 Index to methods

Method	Section
• Method 1 Recycling of gases	5.3.1
• Method 2 Disposal of gases by absorption / adsorption / reaction	
○ 2A—Direct discharge into simple scrubber	5.3.2.1
○ 2B—Discharge into counterflow scrubber	5.3.2.2
○ 2C—Discharge into solid-state adsorber	5.3.2.3
• Method 3 Disposal of gases by burning or incineration	
○ 3A—Direct combustion (gas phase)	5.3.3.1
○ 3B—Combustion / incineration (liquid phase)	5.3.3.2
○ 3C—Incineration (gas phase)	5.3.3.3
• Method 4 Disposal of gases by venting to the atmosphere	
○ 4A—Direct discharge from container valve	5.3.4.1
○ 4B—Direct discharge from container valve into fume cubicle or hood	5.3.4.2
○ 4C—Controlled release through vent line	5.3.4.3
○ 4D—Controlled dilution in forced air stream	5.3.4.4

5.3 Methods

Do not dispose of flammable or oxidant gases as mixed batches of cylinders.

5.3.1 Method 1—Recycling of gases

General principles—This is not a disposal method, as usually understood, but a technique for reclaiming residual gases and returning them safely to suitable containers for re-use.

As a solution to dealing with residual gases, it is strongly recommended both in the interests of the environment and the conservation of materials and energy. Recycling is a particularly favoured technique when dealing with high value gases, or gases that are expensive to dispose of due to their nature or because of the quantity involved. Most recovered product may have to be reprocessed and purified before being re-used, and the cost of such treatment should be taken into account when considering a recycling system.

It shall be stressed that recycling of gases is best carried out by the supplier of the material who has the necessary product handling and container filling expertise. Material shall not be returned to a container without the written authority of the owner of the container. The owner shall specify, or have agreed to, the method, equipment, and procedures to be used.

Different transfer methods can be used. Liquefiable gases can be transferred to the recovery container in the liquid phase either by pressurising the container to be emptied with a compatible inert gas, by pumping, or by creating a vapour pressure gradient.

Gases can be recompressed into the recovery container using a gas compressor or by liquefying the gas cryogenically into a suitable cryogenic receiver. It is important to ensure that any carbon steel container or pipework is not used in contact with cryogenic liquids as they can become brittle at temperatures less than $-20\text{ }^{\circ}\text{C}$ ($-4\text{ }^{\circ}\text{F}$). The cryogenic liquid is then allowed to warm and the resultant gas passed into the recovery container [4, 5].

When recycling gases, care shall be taken to ensure that the product to be recycled is not contaminated with any material that could have a detrimental effect on the safety of the operation or subsequent use of the recycled material. Care shall be taken when recovering liquefied gases that the recovery vessel will not be overfilled or exceed the ADR filling ratio. For gases that can polymerise or that can decompose, ensure that the product is pure, stable, or contains sufficient amount of stabiliser.

5.3.2 Method 2—Disposal of gases by absorption / adsorption / reaction

General principles—Disposal of certain reactive gases can be achieved by absorption / reaction in a liquid (scrubbing) or by adsorption in a solid-state medium. The resultant solution and / or suspension or other absorption product should be less harmful and more conveniently disposed of than the original gas.

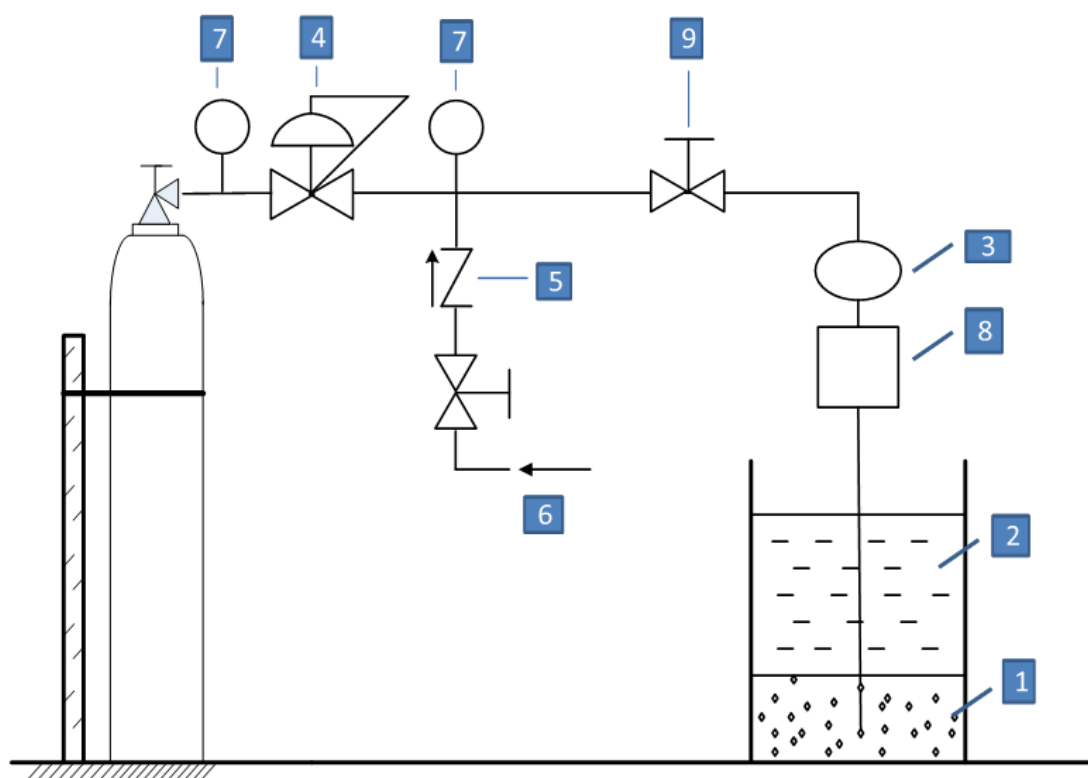
This method can be used in conjunction with methods where harmful combustion products are evolved.

The choice of absorption / adsorption reagent medium and equipment used depends on a number of factors including:

- reactivity of the absorption / adsorption medium with the gas;
- quantity of gas to be disposed of and frequency of disposal operations; and
- ease of treatment of the spent absorption / adsorption medium.

These factors shall be considered when selecting absorption / adsorption reagent medium and method.

5.3.2.1 Method 2A—Direct discharge into simple scrubber



- | | |
|---|--------------------------------------|
| 1. Packing medium (shingle) | 6. Inlet gas purge (optional) |
| 2. Absorbent chemical (reacting chemical) | 7. Pressure indicator |
| 3. Sight glass/ rotometer (optional) | 8. Suckback trap |
| 4. Pressure control valve | 9. Flow control valve (needle valve) |
| 5. Non-return valve | |

NOTE—This is an illustrative example and not intended for design.

Figure 1—Method 2A: Direct discharge into simple scrubber

5.3.2.1.1 Description of method

The gas to be disposed of is fed directly into the absorbent chemical. Under certain circumstances, liquefied gas can be fed into the scrubber in the liquid phase following a risk assessment.

5.3.2.1.2 Application

This method is recommended where absorbent chemical is available that strongly and readily absorbs the gas or reacts with it. Simplicity and portability can favour the choice of this method under emergency conditions. This method should be restricted to gases that are not acute toxic category 1 ($LC50_{rat.1h} < 200ppm$) or acute toxic category 2 ($LC50_{rat.1h} < 1000ppm$) nor carcinogenic, mutagenic, or reprotoxic because of the risk of exposure to the release of non-reacted toxic gas.

5.3.2.1.3 Equipment design

Equipment should be kept as simple as possible, should be suitable for the required working pressure, and compatible with the gas and the absorbent chemical. It is desirable to maximise the contact of the gas with the absorbent chemical. This can be achieved by constricting the end of the pipe dipping into the absorbent chemical (to reduce the gas bubble size) and / or by submerging the pipe in a layer of coarse sand at the bottom of the scrubber vessel.

A flow control system (incorporating a pressure regulator, if necessary) should be installed in the gas feed to enable the gas flow to be matched to the capacity of the scrubber or by use of a sparger.

A suckback trap or a vacuum breaker should be incorporated in the line before the scrubber pot. A sight glass or length of transparent pipe may also be installed between the regulated gas supply and scrubber to indicate suckback conditions. A continuous inert gas purge also reduces the risk of suck back.

5.3.2.1.4 Operation

- a) Purge air from the system with an inert gas if the gas or gas mixture is flammable;
- b) Check that the flow control valve is closed;
- c) Open the gas supply valve and adjust pressure regulator as appropriate (if fitted);
- d) Slowly open the flow control valve until the scrubber capacity is achieved (i.e., maximum flow rate compatible with complete gas absorption);
- e) Renew the absorbent chemical as necessary. Dispose of spent scrubber chemical safely according to legislation / regulation; and
- f) When the disposal operation is complete (or when renewing absorbent chemical), close the gas supply valve. Purge the system with inert gas (where installed) and close the flow control valve.

5.3.2.1.5 Operational precautions

This operation should be carried out in a well ventilated or open area.

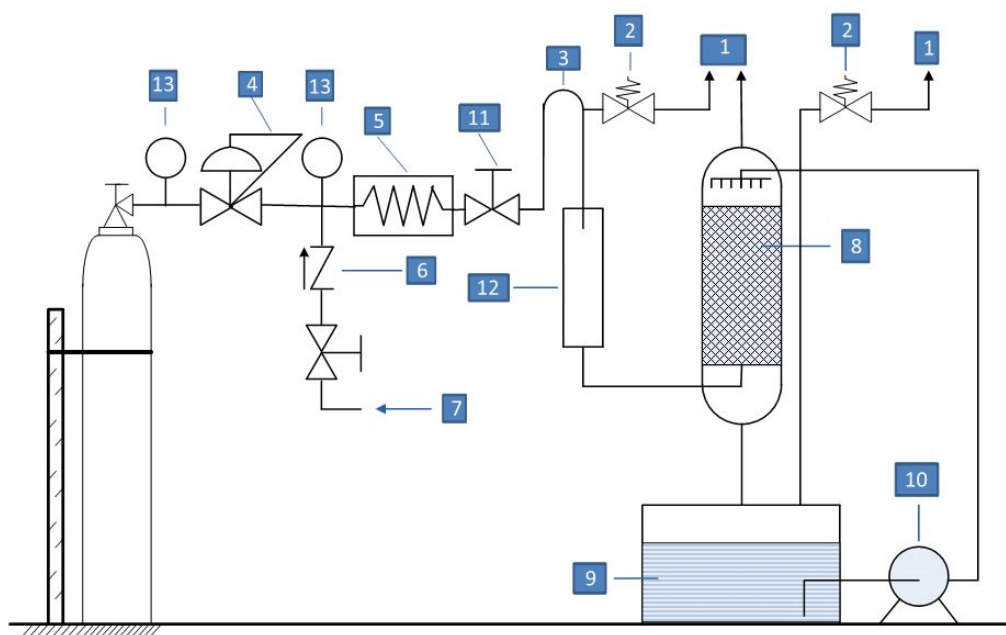
Ensure that the absorption / reaction is taking place effectively and safely throughout the disposal operation. Constant vigilance is necessary to ensure no blockage, breakthrough, overheating, or chemical suck back occurs.

Particular attention shall be paid to personal protection when handling reactive absorbent chemicals such as caustic or acids.

Ignition sources (including open flames, electrical equipment, static discharge) should be excluded if the gas is flammable or if flammable gases can be produced. Care should be taken to avoid build-up of potentially explosive flammable gas / air mixtures in and around the system. The temperature of the chemical should be checked to avoid a hazardous situation arising. The capacity of the absorption / reaction vessel and the quantity of chemical shall be sufficient to absorb all of the gas to be discharged.

After concluding disposal operations, all equipment should be decontaminated and / or neutralised. Equipment shall be maintained as many gases can be damaging to equipment.

5.3.2.2 Method 2B—Discharge into counterflow scrubber



- | | |
|--|--|
| 1. Vent to a safe place | 8. Inert packing |
| 2. Pressure relief valve (if required) | 9. Absorbent chemical (reacting chemical) |
| 3. Barometric leg | 10. Pump |
| 4. <u>Pressure control valve</u> | 11. <u>Flow control valve (needle valve)</u> |
| 5. Vaporiser (if required) | 12. Suckback trap |
| 6. Non-return valve | 13. <u>Pressure indicator</u> |
| 7. Inert gas purge (if required) | |

NOTE—This is an illustrative example and not intended for design.

Figure 2—Method 2B: Discharge into counterflow scrubber

5.3.2.2.1 Description of method

The gas to be disposed of is fed into the counterflow scrubber. The gas can be fed directly as illustrated in Figure 2. The source of gas can also be a fume cubicle or hood (see 5.3.4.2) or an incinerator (see 5.3.3.3). Under certain circumstances, liquefied gas in its liquid phase can be fed into the counterflow scrubber following a risk assessment but note that the pipework configuration shown in Figure 2 is not suitable for this.

5.3.2.2.2 Application

This method is recommended where a suitable absorbent or reacting chemical is available and where there is an ongoing disposal requirement.

5.3.2.2.3 Equipment design

Equipment should be specifically designed by a competent person for its intended service. Materials of construction should be compatible with the gas and absorbent chemical. Due account should be taken of operating pressures and possible temperature rises from reaction between the gas and absorbent chemical. Pumping alkaline absorbents present special problems. Pumps may have to be running continuously to prevent the shaft sticking to pump housing.

Suitable arrangements should be made to ensure the system is monitored and shut down in the event of gas breakthrough. To ensure safe and efficient performance, consideration should be given to monitoring the following:

- gas input flow;
- efficacy of absorbent chemical (for example, pH);
- concentration of gas in scrubber vent; and
- temperature of absorbent chemical.

A barometric leg should be installed in the supply line to the scrubber to minimise the risk of absorbent chemical sucking back.

Consideration can also be given to the provision of an anti-suckback device such as a liquid interceptor vessel fitted with level switch actuating a solenoid valve.

A flow control system (incorporating a pressure regulator if necessary) should be installed in the gas feed to enable the gas flow to be matched to the capacity of the scrubber.

An inert gas purge facility should be installed.

The scrubber vent should discharge to a safe well ventilated place away from personnel.

Consideration should be given to area electrical classification where gas is flammable [6, 7].

5.3.2.2.4 Operation

- a) Check scrubber unit is operating correctly:
 - efficacy of absorbent chemical
 - operation of mechanical units such as recirculating pumps, agitators, fans, etc.
 - operation of monitoring equipment
- b) Purge air from the system with an inert gas if the gas or gas mixture is flammable;
- c) Adjust the feed rate until specified gas flowrate is achieved;
- d) Unless automatic shutdown arrangements are installed, supervise the disposal operation, correcting flowrate, replenishing absorbent chemical, etc., as necessary;
- e) When the disposal operation is complete, purge the system with inert gas and close the flow control valve; and
- f) Shut down scrubber system and dispose of spent absorbent chemical safely.

5.3.2.2.5 Operational precautions

Ensure that the scrubbing system is operating correctly throughout the disposal operation either by automatic monitors or by personal supervision.

Ensure that as flowrate and quantity are controlled so the scrubber does not overheat and breakthrough does not occur.

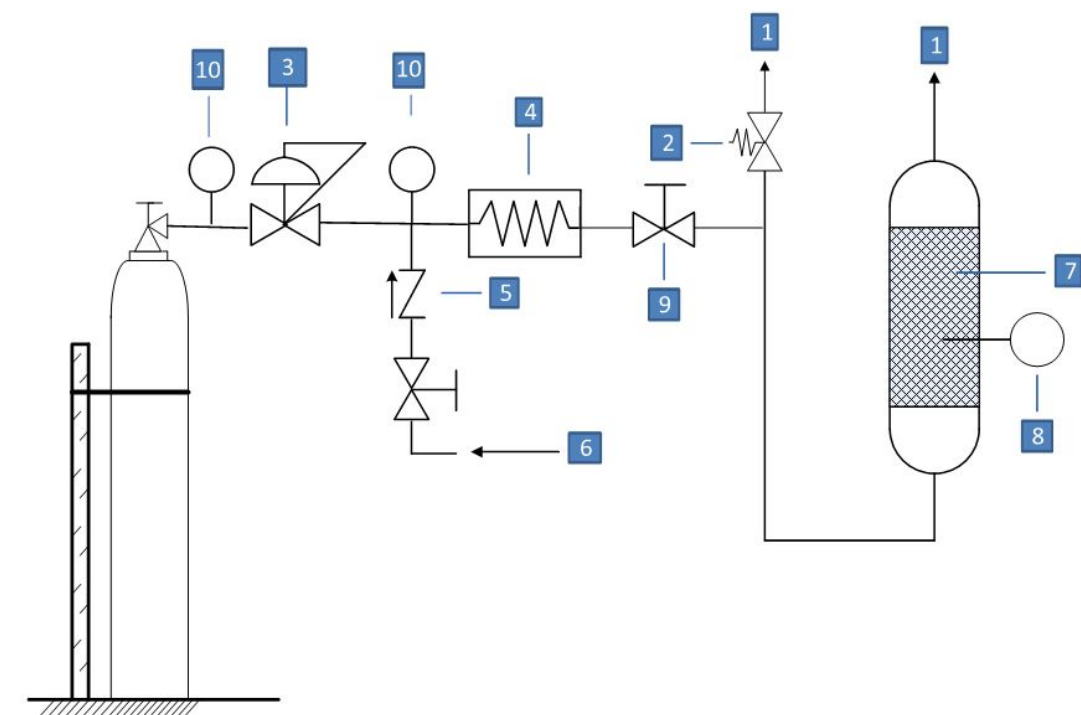
Particular attention shall be paid to personal protection when handling reactive absorbent chemicals such as caustic or acids.

Ignition sources (including open flames, electrical equipment, static discharge) should be excluded if the gas is flammable or if flammable gases can be produced. Care should be taken to avoid build-up of potentially explosive flammable gas / air mixtures in and around the system.

Some gases, especially halogen acid forming gases, form a mist with moist gases that is not readily absorbed by most types of scrubbers. These gases should either be fed to the scrubber in high concentration or diluted with a dry gas to low concentration. The temperature of the chemical (Figure 2, no. 9) or in the scrubber (Figure 2, no. 8) should be checked to avoid a dangerous situation arising. The capacity of absorption / reaction of the absorbent / reacting chemical shall be calculated to be large enough for the quantity of gas to be discharged.

After concluding disposal operations, all equipment should be decontaminated and / or neutralised. Equipment shall be maintained as many gases can be damaging to equipment.

5.3.2.3 Method 2C—Discharge into solid-state adsorber



- | | |
|--|-------------------------------|
| 1. Vent to a safe place | 6. Inlet gas purge |
| 2. Pressure relief valve (if required) | 7. Adsorbent |
| 3. Pressure control valve | 8. Temperature control unit |
| 4. Vaporiser (if required) | 9. Flow control valve |
| 5. Non-return valve | 10. <u>Pressure indicator</u> |

NOTE—This is an illustrative example and not intended for design.

Figure 3—Method 2C: Discharge into solid-state adsorber

5.3.2.3.1 Description of method

The gas to be disposed of is fed into a vessel containing a bed of solid-state adsorbent. The gas can be fed directly as illustrated. The source of gas can also be a fume cubicle or hood (see 5.3.4.2) or an incinerator (see 5.3.3.3).

5.3.2.3.2 Application

This method is recommended where a solid adsorbent is available that strongly and readily adsorbs the gas. Simplicity and portability of a small solid-state adsorber can favour the choice of this method under certain emergency conditions.

5.3.2.3.3 Equipment design

Equipment should be constructed from materials compatible with the gas and solid-state adsorbent. Due account should be taken of operating pressures and possible temperature rises from reaction between the gas and adsorbent medium.

Factors to be taken into account when establishing the size of the solid-state adsorber include:

- required disposal rate;
- quantity of gas for disposal; and
- acceptable frequency of changing / regenerating the adsorbent.

These factors will determine the dynamic and static capacity of the chosen adsorbent.

A distribution system should be incorporated in the adsorber to ensure good distribution of the gas in the bed of adsorbent. Poor gas distribution can result in channelling and premature breakthrough.

The adsorbent particle size is an important consideration when establishing the design of a solid-state adsorber. Generally, small particles give a high contact area and hence greater adsorbing efficiency; however, small particle sizes can lead to clogging or high pressure drops and tendency for channelling through the bed.

Provision should be made to monitor the gas input flow and concentration of gas in the adsorber vent. Consideration should also be given to monitoring the temperature of the adsorber and the need for a cooling system.

A flow control system (incorporating a pressure regulator if necessary) should be installed in the gas feed to enable the gas flow to be matched to the capacity of the solid-state adsorber.

An inert gas purge facility should be installed if practicable.

The solid-state adsorber vent should discharge to a safe, well ventilated place away from personnel.

5.3.2.3.4 Operation

- a) Purge the system with an inert gas to remove air if the gas or gas mixture is flammable;
- b) Check, as far as practicable, that adsorbent is not spent, for example, from the operating log, which records cumulative throughput;
- c) Adjust the feed rate until the specified gas flowrate is achieved;
- d) Unless automatic shutdown arrangements are installed, supervise the disposal operation, monitor adsorber vent for breakthrough, and adjust flowrate as necessary. When the disposal operation is complete, close the gas supply valve; and
- e) Purge the system with inert gas (where installed) and close the flow control valve.

Dispose of or regenerate solid-state adsorbent safely.

5.3.2.3.5 Operational precautions

Ensure that the solid-state adsorber is operating correctly throughout the disposal operation either by automatic monitors or by personal supervision.

Ensure that gas flow rate and quantity are controlled so the scrubber does not overheat and breakthrough does not occur.