

# **SAFE HANDLING AND STORAGE OF ACRYLIC ACID**

EBAM \*

European Basic Acrylic Monomer Group

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## Notice

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# 1 INTRODUCTION

This brochure is produced by the European Basic Acrylic Monomer Manufacturers Association (EBAM), which is a Sector Group of the European Chemical Industry Council (Cefic). Member companies are:

**Arkema France,**  
**BASF SE,**  
**Dow Europe GmbH,**  
**Evonik Industries AG,**  
**Momentive Specialty Chemicals a.s.**  
**Sasol Solvents (Pty) Ltd**

The full text of this publication should be consulted for information on the hazards of Acrylic Acid and suggestions for its safe handling, transport and storage.

***Acknowledgement:** EBAM is grateful for the valuable contributions and peer reviewing of this document by the US industry organization Basic Acrylic Monomers Manufacturers Inc. **BAMM**. The member companies of **BAMM** are listed on the website of **BAMM** Inc. (<http://www.bamm.net>).*

EBAM publishes up to date information in between of major revisions of its brochures on (<http://www.petrochemistry.net/basic-acrylic-monomers.html>).

The purpose of this document is to provide general information to all persons who use, handle, store, transport, or may otherwise be exposed to Acrylic Acid and how to appropriately deal with the specific hazards comprising health risks, flammability, the potential of untimely polymerizations and environmental risks. Prior to working with Acrylic Acid the extended Safety Data Sheets (eSDS) should also be consulted.

Properties and characteristics contained in this document refer to Acrylic Acid with a minimum content of 99 weight-%. They conform to the specifications reported in the technical information bulletins issued by the manufacturers. Some of the physical data may vary slightly due to variable concentrations of by-products.

Acrylic Acid is typically stabilized (inhibited) with 200 parts per million (ppm) of monomethyl ether of hydroquinone (MeHQ).





## 2 Names, Classification and Labelling

Chemical name	Acrylic Acid
Commercial name	Acrylic Acid
For Transportation	Acrylic Acid, stabilized
Synonyms	2Propenoic Acid Vinyl formic Acid
CAS number	79-10-7
EINECS number	201-177-9
Chemical formula	$\text{CH}_2 = \text{CH} \text{ COOH}$ Formula $\text{C}_3\text{H}_4\text{O}_2$

### 2.1 Classification according to EU directive 67/548/EC

#### Classification

R10	Flammable.
Xn; R20/21/22	Harmful; Harmful by inhalation, in contact with skin and if swallowed.
C; R35	Corrosive; Causes severe burns.
N; R50	Dangerous for the environment; Very toxic to aquatic organisms.

#### Labelling

C; N	
R:	10-20/21/22-35-50
S:	(1/2)-26-36/37/39-45-61

## 2.2 Classification and Labelling according to Regulation (EC) No 1272/2008 [CLP]

Please be aware of the fact that the below mentioned classification is the status of the CLP as of the printing date of this brochure but is likely to be amended by ECHA. The actual status is found in the Safety Data Sheets.

### Classification

Hazard Statements are mentioned in the Safety Data Sheets.

Flammable Liquid Cat. 3	H226: Flammable liquid and vapour.
Acute Tox. Cat. 4 (oral)	H302: Harmful if swallowed.
Acute Tox. Cat. 4 (dermal)	H312: Harmful in contact with skin.
Acute Tox. Cat. 4 (inhalation - aerosol)	H332: Harmful if inhaled.
Skin Corrosive Cat. 1A	H314: Causes severe skin burns and eye damage.
STOT Single Exposure Cat. 3	H335: May cause respiratory irritation. Affected organs: respiratory tract. Route of exposure: Inhalation (inhalation)
Aquatic Acute Cat. 1	H400: Very toxic to aquatic life.

### Labelling

Signal word: Danger

Hazard pictogram:



GHS02  
flame



GHS05  
corrosion



GHS07  
exclamation  
mark



GHS09  
environment

**Hazard statements:**

H226:	Flammable liquid and vapour.
H302:	Harmful if swallowed.
H312:	Harmful in contact with skin.
H332:	Harmful if inhaled.
H314:	Causes severe skin burns and eye damage.
H335:	May cause respiratory irritation.
H400:	Very toxic to aquatic life.

**Specific concentration limits:**

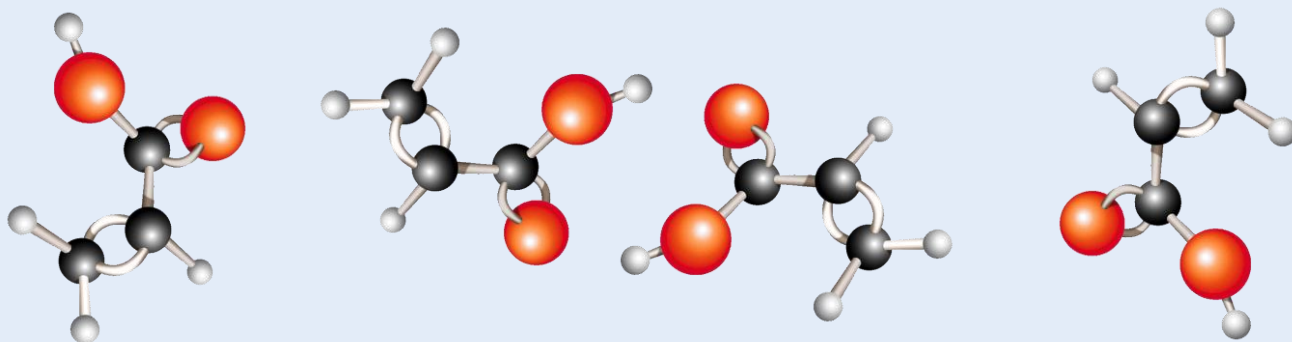
Concentration (%)	Classification
>= 1,0	STOT Single Exp. 3a

**2.3 Transport classification**

ADR / RID	Class 8, Packing Group II
UN	2218
Labelling	8 + 3
Hazardous code	839







### 3 PROPERTIES AND CHARACTERISTICS

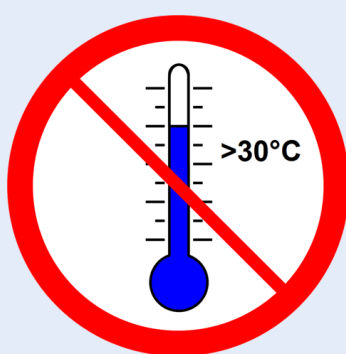
Property	Condition	Value	Unit	Reference
Molecular weight		72,06		
Physical state		Clear, colourless liquid above 13 °C		
Odor		acrid, pungent, penetrating		
Odor Threshold (detect)		0,092	ppm	
Density	at 20 °C	1,05	g/ml	DIN 53169
	at 30 °C	1,04	g/ml	
Specific gravity of vapor (Air = 1)		>2,5		DIN 53169
Refractive index (nD)	at 20 °C	1,418	-	
		1,422		
Freezing point	at 1013 hPa	13	°C	BS 523, 1964
Boiling point	at 1013 hPa	141,3	°C	DIN 51751
	at 20 °C	3,8	hPa	
	at 25 °C	5,29	hPa	
	at 40 °C	13,5	hPa	
	at 60 °C	40	hPa	
	at 100 °C	238	hPa	
Vapor pressure	at 100 °C	238	hPa	
	at 120 °C	500	hPa	
	at 1013 hPa	48,5	°C	DIN 51755
Flash point (closed cup)	at 1013 hPa	48,5	°C	DIN 51755
Explosion limits	Lower (LEL)	at 1013 hPa	2,4	% by volume in air
	Lower Explosion Point		47,5	°C

table continued on the next page ...

Property	Condition	Value	Unit	Reference
Explosion limits	Upper (UEL)	at 1013 hPa	15,9	% by volume in air
	Upper Explosion Point		88,5	°C
Self-ignition temperature	at 1013 hPa	438	°C	DIN 51794
Heat of combustion		19080	kJ/kg	
Heat of polymerization		1075	kJ/kg	
Heat of neutralisation		805	kJ/kg	
Enthalpy of evaporation	(at boiling point)	634	kJ/kg	
Specific heat of liquid		2,05	kJ/kg K	
Dissociation constant pKa	at 25 °C	4,26		
Electrical Conductivity		$4,4 \times 10^{-4}$	mS/cm	DIN 51412
Electrical group classification		T 2 (300 - 450 °C)		IEC-79-8 Class I Div.II Grp. D, NEC (US)
Critical Pressure		5,7	MPa	
Critical Temperature		342	°C	
Solubility	in water		soluble in all proportions	
	water solubility	at 25 °C	1000	g/l
	in organic solvents		soluble in all proportions (in most solvents)	
Surface tension	at 20 °C	69,6	mN/m (concentration 1000 mg/l)	
Partition Coefficient n-octanol/water	Log Pow at 25 °C	0,46		(OECD Guideline 107)
Viscosity (dynamic)	at 25 °C	1,149	mPa s	

Table 3.1: Properties and Characteristics of Acrylic Acid

For specific properties of **Acrylic Acid / Water mixtures** contact your supplier.



## 4 Instability and Reactivity Hazards

### 4.1 Polymerization

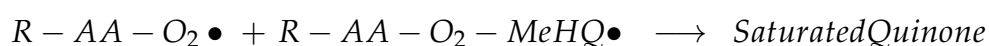
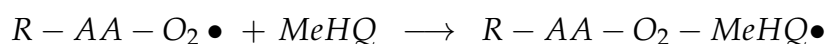
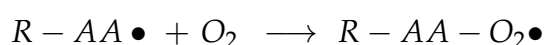
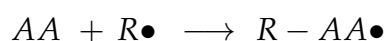
The prevailing characteristic of Acrylic Acid is its high reactivity in the presence of free radicals. Free radicals can be generated by heat, light or irradiation and by activation of radical forming materials.

There are six main causes of unintended polymerization of Acrylic Acid:

- overheating (especially local overheating),
- photo-initiation,
- contamination,
- corrosion,
- inhibitor depletion, and
- inhibitor deactivation (e.g. via dissolved oxygen depletion).

Several case histories of Acrylic Acid explosions were reported when procedures for proper handling or storage were disregarded. Depending on the conditions, the polymerization can proceed with moderate speed associated by a slow temperature increase, or it could become violent under unfavorable conditions. Explosion hazards exist, if polymerizing material is enclosed in a poorly vented or unvented container. Pressure build-up may occur rapidly and can lead to the rupture of pipelines, vessels and other containers. At a very high pressure build-up there is a serious risk of the reacting mass self-igniting.

Acrylic Acid is commonly inhibited with 200 ppm MeHQ (monomethyl ether of hydroquinone synonym: p-methoxyphenol), to ensure protection from an inadvertent polymerization. This protection is only effective at moderate ambient temperatures and for handling conditions described in the following chapters. The presence of oxygen is required for the inhibitor to function.



See also [subsection 9.1.1, page 52](#) for Detection and Response to Incipient Polymerization in a Storage Tank.

A head space containing sufficient air should always be maintained above the monomer to ensure inhibitor effectiveness.



### Attention

Acrylic Acid must never be handled under an inert atmosphere due to potential oxygen depletion.

### 4.1.1 Overheating

Commercially available grades of Acrylic Acid have a shelf life of 1 year if properly handled.

Shelf life is reduced exponentially with increasing temperature.

The recommended storage temperature of Acrylic Acid is 15 °C - 25 °C. Testing and experience at these temperatures have shown no impact on safety, as long as shelf life is not exceeded.

The lower limit (15 °C) is intended to provide a reasonable buffer from the freezing point (13 °C). Low temperature storage also reduces Diacrylic Acid formation, also reducing the Acrylic Acid concentration (active substance).

The upper limit (25 °C) has been identified for safe Acrylic Acid storage to guarantee the aforesaid shelf life (see also [section 4.4, Dimerization: Formation of Diacrylic Acid, page 14](#)).

Overheating - especially local overheating of Acrylic Acid that may not be detected by temperature sensors - must be avoided. This may occur if:

- heat tracing is not applied properly,
- pumps are circulating without temperature monitoring of the circulated product,
- steam being applied to pipe surfaces accidentally or intentionally etc.

Overheating becomes especially critical if inhibitor and dissolved oxygen are not present at saturation levels in the product. Therefore the recommendation is to limit the heating medium temperature to 35 °C whilst a range of up to 45 °C may be safe if proper inhibitor levels are maintained by thoroughly mixing the product or by other means. (please refer to [Inhibitor Depletion, page 12](#) and [Inhibitor Deactivation/Oxygen Depletion, page 12](#)).



### Attention

Product temperatures of 30 °C and higher can be hazardous and must be avoided during warming/heating and especially during thawing operations. The temperature of the heating medium not to exceed 35 °C for safety reasons.

### 4.1.2 Photo-Initiation by UV and X-ray radiation

Acrylic Acid can polymerize as a result of photo-initiation. Where sight glasses or other transparent sections are needed for visual observation in Acrylic Acid

service, they should have covers to exclude light between observations. All containers such as IBC, drums, and bottles etc., used for storing Acrylic Acid should be kept from direct UV radiation.

### Please note

**Never expose Acrylic Acid to direct sun or UV or X-ray radiation.**

There is the specific example of inspecting cargo with X-rays that can be done safely. The evaluation was done for mobile scanners with an energy dose of 0,03 mSv using a single scan. The level of X-ray energy absorbed by Acrylic Acid for such inspections, using mobile X-ray scanners, is far below the level that could alter the shelf life recommendations of Acrylic Acid.

### 4.1.3 Contamination

Good housekeeping must be exercised to avoid contamination of Acrylic Acid. Many compounds can promote polymerization, such as:

- peroxides and
- compounds which form peroxides and free radicals,
- including aldehydes, ethers, amines, azides, and Nitric Acid

(see also Appendix 11.1, **Incompatible Substances**, page 69)

Catalytic traces of mineral Acids or strong bases enhance dimer formation (see section 4.4, page 14). Accidental addition of mineral Acids or strong bases to Acrylic Acid will catalyze an exothermal oligomerization with potentially subsequent polymerization and is, therefore, a safety concern.

Care must be exercised to avoid contamination of monomer by polymerizing Acrylic Acid. Such polymer "seeds" could be generated in localized or hot stagnant areas, such as dead-headed pumps, and heated transfer lines.

Polymer that has formed due to a contamination may cause further polymerization.

The formed polymer (Polyacrylic Acid) is insoluble in the monomer. It can be easily detected and filtered.

### Please note

**Dedicated lines and unloading equipment, including hoses, pumps, transfer lines etc., are the best way to avoid cross contamination with incompatible materials.**

### 4.1.4 Corrosion

Metal ions can initiate polymerization. Acrylic Acid, especially in the presence of water, will easily corrode carbon steel and similar metals (see Appendix 11.1 **Incompatible Substances**, page 69). Corrosion and subsequent polymerization initiated by metal ions cannot only be caused by improper material but also by accidental introduction of incompatible metals into the system such as gaskets, maintenance tools, carbon steel bolts and nuts (see subsection 6.2.10, page 29).

**⚠ Attention**

Inspect the compatibility of all construction materials with Acrylic Acid.  
Avoid accidental corrosion in any case.

**4.1.5 Inhibitor Depletion**

Inhibitors (stabilizers) are depleted with time. Elevated temperatures will accelerate this process. Observe the recommended storage time and temperature to prevent depletion of the inhibitor as well as premature depletion of oxygen (see [subsection 4.1.6, page 12](#)).

Elevated temperatures can accelerate inhibitor depletion (see [subsection 4.1.1, page 10](#) and [subsection 7.4.2, page 37](#)).

**⚠ Attention**

Observe shelf life and proper storage conditions of Acrylic Acid to avoid inhibitor depletion.

**4.1.6 Inhibitor Deactivation/Oxygen Depletion**

Dissolved oxygen is essential for the effective functioning of inhibitors (MeHQ). The inhibitor-oxygen adduct acts (is acting) as initial, and very efficient, radical scavenger. Once the dissolved oxygen is consumed, polymerization will start. Therefore, never handle Acrylic Acid under pure nitrogen or any other oxygen-free atmosphere. An air-nitrogen mixture may be used which also avoids flammability concerns.

An air-nitrogen mixing station can be designed to yield a gas containing a minimum of 5 Vol.-% oxygen. Equipment measurement tolerances must be carefully considered to ensure the operating range remains comfortably between the LOC and the minimum recommended oxygen concentration (5%). For example if analysis of the proposed mixing station design shows that the tolerance is  $\pm 1,5\%$ , then the set point of the system must be 6,5% in order to ensure that the oxygen concentration is always above 5 Vol.-%. The design of the mixing station should be reviewed with local safety personnel to ensure that both criteria are met: sufficient oxygen supply during regular and emergency cases and protection from flammability.

Oxygen is consumed slowly during storage.

Therefore the level of dissolved oxygen should be periodically replenished with air (or an oxygen/nitrogen gas mixture, "lean air mixture").

See [subsection 6.2.3, Recirculation and Tank Filling, page 25](#) for oxygen replenishment in storage tanks and pipelines. Sufficient oxygen levels in drums or IBCs can be achieved by agitating and moving them from time to time.

The consumption rate of oxygen in water diluted Acrylic Acid is much higher than in pure Acrylic Acid. It is recommended to replenish oxygen levels more frequently when water is present.

### Attention

Never handle Acrylic Acid under an inert atmosphere. Make sure that oxygen is always >5 Vol.-% in the gaseous atmosphere.

## 4.2 Freezing

Water free Acrylic Acid freezes at 13 °C. During the crystallization process the inhibitor is separated and concentrated in the liquid phase. Dissolved oxygen concentrations are also reduced.

Appropriate engineering design and operating measures must be taken to avoid freezing of Acrylic Acid (heat tracing, insulation, emptying stagnant pipelines etc.).

### Attention

Never remove liquid from partially frozen or partially thawed Acrylic Acid!

This will result in insufficient stabilization/inhibition (see [subsection 7.4.2, page 37](#)).

## 4.3 Acrylic Acid / Water Mixtures

Water is sometimes added to Acrylic Acid (Acrylic Acid concentration 80-90 wt.-%) in order to lower the freezing point and to increase the flashpoint. This procedure has to be done following best practices since it may otherwise affect the safe handling aspects of these mixtures:

- Tap water must not be used to dilute Acrylic Acid. De-ionized water should be used instead. Due to a high a content of trace metals compared to deionized water this may cause inadvertent polymerization.
- Adding water to Acrylic Acid results in a decrease of the shelf life. A water concentration of 20% reduces the shelf life to about 3 months. Acrylic Acid-water solutions should be consumed shortly after preparation or receipt.
- Water lowers the solubility of oxygen which is needed for inhibition/stabilization. It is recommended that storage occurs with a minimum of 21 Vol.-% of oxygen in order to maintain the dissolved oxygen concentration in diluted Acrylic Acid at a safe level.
- The stability of diluted Acrylic Acid when exposed to high temperatures (e.g. non-insulated storage tanks being exposed to strong sun radiation or fire) is further decreased as compared to stability of non-diluted Acrylic Acid when exposed to such temperatures.
- The formation rate of Diacrylic Acid (2-Carboxyethyl acrylate) increases with increasing water levels.



- Corrosion rates to lower grade stainless steel like DIN 1.4541 are much higher compared to DIN 1.4571. The recommendation therefore is to use 316L or DIN 1.4571 for storage of diluted Acrylic Acid.
- Pipelines containing Acrylic Acid / Water Mixtures need to be emptied or purged immediately after use due to the increased oxygen depletion.

Water concentrations above 20% are not recommended due to the fact that the maximum achievable oxygen concentration is too low and is likely to cause a premature polymerization.

Therefore dilution of Acrylic Acid with additional water cannot be recommended as an emergency practice.

### 4.4 Dimerization: Formation of Diacrylic Acid

Acrylic Acid undergoes a nucleophilic addition to the double bond of a second Acrylic Acid molecule (Michael reaction). This reaction is an acid catalyzed equilibrium reaction. The rate of dimer formation (Diacrylic Acid, 2-Carboxyethyl Acrylate) is dependent on temperature. For typical storage conditions of pure Acrylic Acid, the increase in Diacrylic Acid concentration per hour as a function of temperature (T in Kelvin) can be estimated by the following equation (water conc. <500 ppm):

$$\text{Diacrylic Acid formation rate (wt.\%/hr)} = 5,055 * 10^{12} \exp(-10808/T)$$

The reaction proceeds rather slowly at ambient temperatures and cannot be stopped. Dimer formation is not considered to be a safety hazard but reduces the amount of active substance Acrylic Acid. The upper temperature limit for storage for Acrylic Acid of 25 °C is selected to retard dimer formation.

The addition of water (Acrylic Acid-water solutions) has the following effects:

- With increasing water content the rate of Diacrylic Acid formation increases. A maximum reaction rate was found at 10% (g/g) water.
- At 25 °C the Diacrylic Acid formation rate is about 6 times higher for 10% (g/g) water in Acrylic Acid as compared to pure Acrylic Acid.

#### Please note

Dimer formation cannot be suppressed and is faster when water is present.





## 5 Health and Safety Factors

### 5.1 Toxicity

Absorption of Acrylic Acid can occur through the skin or lung after dermal or inhalation exposure. It is rapidly metabolized by normal oxidative catabolic pathways and is eliminated mainly as expired carbon dioxide.

#### 5.1.1 Local Effects

Acrylic Acid causes severe burns to skin and eyes and severe irritation in the respiratory tract.

In a skin corrosion/irritation test (OECD Guideline 404) with rabbits, Acrylic Acid proved to be corrosive after a 3-min semi-occlusive exposure. It also caused serious irreversible eye damage in rabbit. In standard acute inhalation tests, there was evidence that Acrylic Acid vapors were severely irritating to the eyes and respiratory tract of rats. Permanent tissue damage may result if prompt and appropriate emergency response is not provided (see [section 5.4, page 17](#)).

Pure Acrylic Acid does not show skin sensitising properties in animal sensitisation tests.

#### 5.1.2 Acute Toxicity

Acrylic Acid is of pronounced toxicity after acute inhalation (LC<sub>50</sub> >5,1 mg/L (rat, vapor saturated atmosphere)). Although ingestion is not an expected route of human exposure, Acrylic Acid is of moderate toxicity after a single ingestion (LD<sub>50</sub> = 1500 mg/kg or 146-1405 mg/kg bw (rat) depending on the concentration tested) and swallowing of Acrylic Acid may cause severe irritations or burns of the mouth, throat, oesophagus, and stomach.

#### 5.1.3 Repeated Dose Toxicity

The toxic profile of Acrylic Acid is dominated by its local irritation effects irrespective of the way of application. Prolonged inhalation of concentrations from 5 ppm or higher in mice and 75 ppm in rats induced degeneration of the olfactory mucosa. Long-term exposure of the skin to Acrylic Acid at a concentration of >1% resulted in irritation whereas no effect on the skin was evident at 1%. Following dermal or inhalation administrations no other systemic toxic effects were detected.

### 5.1.4 Carcinogenicity, Mutagenicity and Reproductive Toxicity

Results from a number of long-term carcinogenity studies with Acrylic Acid are available. Taking into account all of the information, there is no indication that the substance is carcinogenic.

Conflicting results were obtained from in-vitro genotoxicity assay with Acrylic Acid and indicated a potential effect on the chromosome integrity (clastogenicity). However, in-vivo assays, Acrylic Acid did not induce clastogenic effects in either rat bone marrow cells or mouse germ cells after oral administration. Based on the available data and taking into account data on structurally-related acrylic compounds, it is unlikely that Acrylic Acid is mutagenic in vivo.

There is no cause for concern over the effects of Acrylic Acid on the fertility and the development based on the available animal data.

### 5.1.5 Occupational Exposure Level OEL

The current indicative occupational exposure limit in the EU (OEL) is 10 ppm (time weighted average for 8 hours).

## 5.2 Industrial Hygiene

Industrial hygiene involves the recognition, evaluation, and control of workplace health hazards. When Acrylic Acid is used in the workplace, it is important to evaluate the conditions of use (where, how, how often), to determine the potential for employee exposure. Since Acrylic Acid can be inhaled, ingested, or absorbed through the skin, each of these potential routes of exposure must be assessed and managed appropriately. Please refer to the extended eSDS of your supplier.

Inhalation of Acrylic Acid can occur when conditions cause the material to become airborne. Concentrations of Acrylic Acid in the air can be determined through air sampling and analysis. Air sampling results are compared to the work- place exposure limit in order to determine the need for ventilation or respiratory protection. While it is recommended that Acrylic Acid always be used in closed systems which can prevent occupational exposure, there may be times when this is not possible. When other control measures are not available, impractical, or fail (i.e. spill or leak or maintenance work), respiratory protection may be necessary to prevent exposure to airborne concentrations of Acrylic Acid. Respiratory protection is further addressed in [subsection 5.5.4, page 20](#).

Keeping work and break areas separate and clean should prevent accidental ingestion of Acrylic Acid. All food, drinks, tobacco products, and cosmetics should be kept away from chemical work areas. Once out of the area where Acrylic Acid is used (or stored), employees should remove all personal protective equipment, and thoroughly wash their hands and face prior to eating, drinking, smoking, or applying cosmetics.

Exposure to Acrylic Acid can also occur from skin contact. Skin contact can be avoided by keeping all surfaces clean and free from Acrylic Acid contamination, and by wearing personal protective equipment to provide a barrier between the employee and the material. Personal protective equipment includes among other

items, gloves, clothing, goggles (eyes absorb most chemicals faster than other parts of the body), respirators, and footwear. The selection and use of personal protective equipment is addressed in [section 5.5, page 19](#) of this document.

Sound industrial hygiene practice should be built into the daily operating procedures for Acrylic Acid handling. It must also be applied to the non-routine events such as spills, leaks, and other emergency situations, that can create potential for employee exposure. During non-routine events, there may not be time to initially measure Acrylic Acid concentrations. If Acrylic Acid is known to be present, but the concentration is unknown, the highest levels of personal protective equipment should be worn (self-contained breathing apparatus, full body protective clothing, etc.).

Proper procedures should be established and followed when an employee comes into direct contact with Acrylic Acid. Such procedures should include first aid and further medical treatment.

## 5.3 Medical Management

Medical management should establish procedures to be followed if an exposure incident occurs.

An important issue to be considered is the medical approval to work with a respiratory mask. Since the use of respiratory protection may be required in the work area, respiratory fitness must be evaluated regularly to determine the employees' ability to wear a respirator. The use of contact lenses, in areas where Acrylic Acid is handled even wearing goggles, should be carefully evaluated. Please see [subsection 5.1.2, page 15](#) on acute exposure and [subsection 5.4.2, page 18](#) on eye protection for assistance in developing policies and procedures.

## 5.4 First Aid

### 5.4.1 General Considerations

Every employee working in a potentially dangerous environment (with chemicals, machinery, etc.) should know a few basic first aid steps to follow in case of emergency. In the event of an emergency, it is important that the scene be surveyed to determine what occurred, and to ensure that there is no danger to self while assistance is provided. The location of all emergency eyewash stations and showers should be known. The phone number(s) to call for emergency medical services and all workplace specific emergency procedures should be readily accessible.

When providing first aid to a person who has been exposed to Acrylic Acid, the person should be removed from the area to prevent further exposure. The type of exposure the person has experienced should be determined by eye or skin contact, inhalation or ingestion.

If possible, do not leave an injured person alone. A co-worker should be instructed to call for help while assistance is being provided to the affected individual.

In the event of an accidental exposure to Acrylic Acid while working alone, the worker should follow procedures to remove contaminated clothes and wash

away the contamination before leaving the area. If possible, the worker should alert a co-worker using a radio or intercom system, but the first priority is decontamination.

Basic first aid procedures for Acrylic Acid exposure are given in 5.4.2 through 5.4.5.

### 5.4.2 Contact with Eyes

In case of eye exposure to Acrylic Acid at any concentration, the person should immediately go to the nearest eyewash station and flush his/her eyes with water for at least 15 minutes while holding eyelids open and away from the eyes. A physician should be contacted immediately for further medical attention. If a physician is not immediately available, the process of flushing the eyes with water should be continued for a second 15 minute period. Do not put any ointments or medication on a person's eyes unless specifically instructed by a physician.

#### Attention

| Do not rub the eyes.

### 5.4.3 Contact with Skin

If Acrylic Acid comes in contact with a person's skin or clothing, the individual should immediately go to the nearest safety shower and rinse off the Acrylic Acid. Once under the shower, all contaminated clothing and shoes should be removed. The affected area(s) of the person should be washed continuously with large quantities of water for at least 15 minutes or longer if odor persists. A physician or emergency medical services should be contacted for further assistance. No ointments or medication should be applied to the skin without specific instruction from a physician.

All contaminated clothing should be disposed of immediately.

#### Attention

| Do not take contaminated items home for laundering. Contaminated shoes must be discarded.

### 5.4.4 Inhalation

Personnel affected by Acrylic Acid vapors must be moved at once to a well-ventilated area. If an individual is not breathing, administer artificial respiration. Obtain a physician's assistance or that of another trained emergency health professional as soon as possible and transport to a clinic or hospital. If breathing is difficult, trained personnel should administer oxygen.

#### Attention

| Do not leave the person unattended.

### 5.4.5 Ingestion

Ingestion of any quantity of Acrylic Acid should be treated by having the person drink about one glass (0.2 liters) of water.

#### Attention

Do not induce vomiting!

Vomiting of an Acid can potentially cause burns to the oesophagus and other internal organs. Immediately contact local emergency medical services or the local poison control center for assistance.

## 5.5 Personal Protective Equipment (PPE)

### 5.5.1 General Considerations

PPE is not an adequate substitute for technical or organizational measures such as ventilation. Nevertheless there may be situations when the only practical means of preventing employee exposure is through the effective use of PPE. Employees must be trained in the appropriate use of PPE.

PPE is available in a variety of sizes, and should fit the employee wearing it. Improperly sized and uncomfortable PPE may compromise its effectiveness and create additional safety hazards.

Personal protective equipment should be selected on the basis of potential exposure via a job safety analysis.

### 5.5.2 Eye Protection

Splash goggles should be worn for eye protection against Acrylic Acid splashes. In addition a face shield could be worn for facial skin protection. Contact lenses are acceptable for use when worn in combination with goggles.

### 5.5.3 Skin Protection

Wearing chemical resistant and gas tight safety gloves over an extended period can be stressful to your skin. It requires appropriate action to protect the skin from damage or even skin diseases. It is therefore recommended to use a skin protection program covering

- prophylactic skin protection products prior to work,
- skin cleansing products,
- skin care products for application after work or during breaks.

Skin protection is found in many forms: Chemical resistant gloves, protective arm sleeves, aprons, full body overalls, rubber boots, and face shields are among the types available.

The material must be impervious and resistant to Acrylic Acid.

Butyl rubber of 0,4 mm to 0,6 mm is a good example providing a breakthrough time exceeding 480 min.



 **Attention**

Do not touch handles or handrails with contaminated gloves! Do not store contaminated gloves in your hard hat!

Table 5.1: Glove materials and breakthrough time

Glove material	suitability / break through time
PVA	Not resistant to aqueous systems
Butyl 0,56 mm	>480 min
Viton 0,5 mm	>480 min
Nitrile 0,51 mm	32 min
Neoprene 0,43 mm	116 min
PVC 1,1 mm	30 min
Natural Rubber Latex	40 min
Laminate Glove, PE+EVOH	>480 min

Laminate gloves do not provide sufficient mechanical firmness but an excellent chemical stability. Combination of laminate glove and elastic, mechanically durable glove can overcome this risk.

Butyl Rubber with 0,7 mm thickness is the recommended material in the Chemical Safety Report for the REACH dossier. Butyl rubber gloves are provided by several suppliers even with an in-liner for improved wearing comfort.

Single-use aprons and full body protection suits are available as laminate materials with breakthrough times exceeding 480 min.

Chemical resistance and breakthrough times of PPE can be different, even with identical materials. Therefore: For further information, please contact your PPE supplier.

#### 5.5.4 Respiratory Protection

Respiratory protection is available in two basic varieties: air purifying and air supplied. Both are suitable to avoid exposure to organic vapor. Both types, however, have their particular advantages and limitations. The appropriate type of respirator must be selected to provide the best level of protection for the anticipated degree of exposure (vapor or mist) and the amount of breathable oxygen available. Air purifying respirators provide less protection than air supplied respirators but a higher flexibility. Respiratory protective equipment must be carefully maintained, inspected and cleaned. All employees required

to wear respiratory protection must be medically cleared on a regular basis and trained to use the equipment.







## 6 STORAGE OF ACRYLIC ACID

### 6.1 General Considerations

Commercially available grades of Acrylic Acid have a shelf life of up to one (1) year from production date when stored and handled under recommended conditions. A “First In First Out” principle should always be followed.

The recommended storage temperature is 15°-25 °C.

- The lower limit (15 °C) is intended to provide a reasonable safety margin from the freezing point (13 °C).
- The upper limit of 25 °C has been identified for safe Acrylic Acid storage and reduces Diacrylic Acid formation (See Chap 4.4. “Dimerization: Formation of Diacrylic Acid”). It also allows time to detect and react to a potential inadvertent polymerization.

Adequate inhibition is necessary to avoid polymerization when storing Acrylic Acid. The standard inhibitor concentration of commercial Acrylic Acid is approximately 200 ppm MeHQ. Phenolic inhibitors (stabilizers) like MeHQ require the presence of dissolved oxygen for stabilizing effect.

Retain samples can be stored up to one (1) year in a cool dark place with however increasing dimer levels and decreasing Acrylic Acid concentrations if stored above the melting point (13 °C).

Amber glass bottles are recommended for handling and storing small amounts of Acrylic Acid.

### 6.2 Bulk Storage – Design Consideration

The design of bulk storage facilities has to be accompanied by a risk analysis using methodologies like HAZOP, or similar. The ultimate goal is to reduce the risk (risks have been outlined in [chapter 4, Instability and Reactivity Hazards, page 9](#) ). This should preferably be done by detection and protection through electric and electronic devices following the IEC 61508 and IEC 61511 guidelines. The risk has to be controlled wherever possible by appropriate design but requires the implementation of appropriate, additional procedures where automation is not feasible.

Certain incidents with Acrylic Acid resulted in injuries and even fatalities. Root cause analysis stipulated the implementation of temperature recording(s) to

detect an early temperature increase which might indicate a beginning polymerization reaction with subsequent rupture of a tank or a vessel and a potential Boiling Liquid Expanding Vapor Explosion (BLEVE).

It is recommended that fail-safe positioning of automated valves and emergency backup power for critical instrumentation be included in the design. Follow all codes and regulations applicable to the geographic location of the facility. Design features of an Acrylic Acid storage facility are given in [section 10.2, page 61](#)). Contact your Acrylic Acid supplier for additional guidance.

### 6.2.1 Detection of Critical Conditions inside Bulk Storage Tanks

Critical conditions are typically detected by a temperature increase. A minimum of two independent temperature probes is recommended for storage tanks (check tanks, weigh vessels, and charge vessels) equipped with high temperature alarms provided in SIL 3 quality.

The temperature probes should be located in the liquid phase near the bottom of the vessel (preferably 180 degrees apart on the circumference of the tank). The temperature signal should be recorded and monitored continuously (trend analysis) in the control room.

An inexplicable temperature increase could be an early warning sign of potentially unsafe conditions and allows leeway for corrective actions.



#### Attention

**Start immediately to investigate an inexplicable temperature increase!**  
(see [subsection 9.1.1, Polymerization Detection, page 52](#) ).

Circulating the tank contents prevents temperature variations inside the tank (see [subsection 6.2.3, page 25](#)).

The cause of a pressure build-up:

- A plugged flame arrestor or
- A plugged vent system (clogging by polymer or frozen monomer).

The tank should therefore be equipped with a pressure gauge.

Pressure relief cannot be achieved via a rupture disk in the event of a runaway polymerization. A weak seam roof design is recommended instead. Floating roof design should not be used for Acrylic Acid storage (please refer to [subsection 6.2.3, page 25](#) and [section 4.1, page 9](#)).

### 6.2.2 Temperature Control of Bulk Storage Tanks and Accessories

Commonly used temperature control systems for bulk Acrylic Acid tanks are:

- External heat exchanger with recirculation line and pump (Acrylic Acid: tube side; heat transfer liquid: shell side). Dimensioning of the heat exchanger should consider the heat input of the recirculation pump, the energy losses during unusually cold weather and the heat input from sun

radiation. The design of heating devices must include control instruments that are suitable to reliably prevent overheating the Acid in SIL 3 quality. Tank and piping containing liquid Acrylic Acid must be insulated and heat-traced.

Freeze protection: the heat exchanger is operated with warm water (controlled, secondary system).

Cooling device: the heat exchanger can be operated with cooling water reducing dimer formation.

- Tempered water circulated through a heat transfer jacket on the outside tank wall.
- Tempered water circulated through a heat transfer coil inside the tank.
- Tank located inside a building with a reliable room heating system for freeze protection. The design of indoor bulk storage facilities and accessories must address the special laws and regulations for fire, health and hazard protection. Indoor storage tanks ventilation must be routed to the outside.

Tanks and piping systems located outdoors (including valves, pumps and filters) should be insulated and heat-traced to avoid freezing or plugging of pipe systems by frozen Acrylic Acid.

For heat tracing, tempered water systems or controlled electrical systems are commonly used. Electrical systems must be carefully controlled since locally high surface temperatures can initiate polymerization (see [subsection 4.1.1, page 10](#)). The maximum temperature of the heating medium is controlled and limited to 35 °C.

The minimum temperature for cooling should be 15° due to the freezing point of Acrylic Acid (13 °C).

Higher temperatures might be required for heat tracing of vapor phase lines to avoid condensation of Acrylic Acid.

An independent high temperature shutdown at  $\leq 35$  °C may be required as an additional safety feature to guard against failure of self-limiting electrical tracing systems.

### Attention

Never use steam or steam condensate as direct heat transfer medium!

## 6.2.3 Recirculation and Tank Filling

Bulk storage tanks typically have either a dip tube ending shortly above the tank bottom or a side entry nozzle near the bottom as tank inlet.

- Dip tubes are normally tack welded to the bottom to assure static grounding and have an antisiphon hole near the top.
- Side entry nozzles must be located below the minimum liquid level of the tank in order to avoid splashing into the vapor phase and subsequent electrostatic discharges.

If entry nozzles are equipped with an eductor for improved mixing, the nozzle must always be submerged with sufficient liquid layer when in use to avoid the possibility of forming a stable aerosol and ignition from static charge development (please consider installation in SIL 3 quality).

Acrylic Acid mist caused by splashing and spraying can be ignited well below the flashpoint.

Recirculation is beneficial for mixing tank inventory, replenishing dissolved oxygen and homogeneous temperature distribution throughout the liquid phase. The dissolved oxygen content of the inventory must be maintained to keep the inhibitor working. Recirculation of the contents on a regular basis will keep adequate oxygen dissolved in the liquid as long as the gas atmosphere consists of 5-21 Vol.-% of oxygen.

A shortcut between inlet and outlet of the recirculation should be avoided e.g. by separating the tank inlet from the tank outlet. Submerged nozzles and pipes can plug if not frequently utilized.

Level monitoring instrumentation is recommended to avoid spills when filling a storage tank. A minimum void volume of about 10% of blanket gas containing oxygen should be maintained above the liquid. Ensure that the inlet nozzle or eductor is submerged in liquid. It is recommended that this level monitoring instrumentation include device(s) which alarm if the tank is filled above or emptied below a safe level. The tanks should be equipped with high level switches, which shut off the unloading pump before a potential spill. If a differential pressure level indicator (bubbler type) is installed, a gas containing 5 to 21 Vol.-% of oxygen must be used. Dry, oil free air is recommended for this service.

### 6.2.4 Pumps and Protection of Pumps from Overheating

It is highly recommended that reliable engineering safeguards, such as redundant instrument interlocks, be provided to prevent accidental overheating of Acrylic Acid pumps.

Deadheaded pumps can quickly overheat and cause a violent polymerization (see [section 4.1, page 9](#)).

Starting a pump which contains frozen Acrylic Acid (see [section 4.2, page 13](#)) could be dangerous.



#### **Attention**

**Overheating of Acrylic Acid pumps can cause polymerization which may result in serious injuries and / or loss of property.**

Some options to prevent overheating of pumps are:

- A flow detection element on the discharge line that activates an alarm and shutdown switch when low flow is detected.
- A temperature sensor placed inside the magpot of a magnetic drive centrifugal pump which activates an alarm and shutdown switch if a high temperature is detected avoids polymerization inside the magpot.

- A power monitor that senses low power consumption and activates an alarm and shutdown switch. Deadheading a centrifugal pump usually results in an immediate reduction in power consumption.
- A liquid sensor element placed in the suction line or feed vessel that activates an alarm and shutdown switch when liquid is not detected. This sensor can be used to help avoid running a pump dry but does not give deadhead protection. Centrifugal pumps quickly overheat if operated dry.

Two different types of sensors are recommended in order to provide redundant protection from pump overheating.

Other considerations associated with pumping Acrylic Acid are given below:

Magnetic drive and double mechanical seal centrifugal pumps as well as double diaphragm type pumps can reduce fugitive emissions and the risk of spills. Double mechanical seals are commercially available using a liquid (such as a glycol) or a gas (such as oil free air) as the barrier fluid.

- Double mechanical seal and magnetic drive centrifugal pumps are commonly used for Acrylic Acid service. These pumps require instrument interlocks to prevent dangerous overheating in case deadheading accidentally occurs.
- Seals and bearings in contact with Acrylic Acid should be flushed for adequate cooling and lubrication.
- Pump seals/glands, flanged fittings, and valve stems should always be provided with splash collars.
- Truck mounted pumps should not to be used for unloading Acrylic Acid because of the potential for contamination, leaks and overheating.
- Your supplier may be contacted for additional guidance on the selection and safety of Acrylic Acid pumps.

### 6.2.5 Tank Vapor Phase and Vent System

MeHQ requires the presence of dissolved oxygen for stabilization. Therefore, an atmosphere containing 5 to 21 Vol.-% of oxygen should be maintained above the Acrylic Acid. Oxygen concentration levels below 9 Vol.-% ensure that there is no flammable atmosphere in the tank vapor phase.

#### Attention

**Never use an inert atmosphere when storing or handling Acrylic Acid**  
(see [subsection 4.1.5, page 12](#) and [subsection 4.1.6, page 12](#)).

Typically the maximum tank level allows for 10% void volume. This provides adequate oxygen containing gas to keep the MeHQ inhibitor activated. The storage tank should be connected to an off-gas treatment system. Off-gas treatment can either be done through scrubbers, incinerators, or thermal oxidation units. Local, state, and federal regulations may apply. Contact your supplier for additional guidance.



** Please note**

**It is essential to avoid by any means the accidental entry of incompatible substances into an Acrylic Acid storage tank via the vent system.**

It is recommended to have emergency vacuum and pressure relief valves installed. A combination pressure-vacuum relief valve, sometimes referred to as conservation vent valve, is frequently employed to help minimize the multiplicity of equipment and nozzles.

Precautions should be taken to minimize condensation of Acrylic Acid in vent nozzles and lines. Acrylic Acid condensed from vapor does not contain MeHQ stabilizer and is prone to form polymer. Polymer can plug critical pressure and vacuum relief lines.

1. Insulate and heat trace vent nozzles/lines to help keep the temperature above the dew point. For tracing, use tempered water or electrical heat tracing.
2. Slope vent lines to drain condensed liquid back to a vessel and provide liquid drains where stagnant Acrylic Acid may occur. Polymer formation is likely in stagnant pockets.

Routine inspections of the conservation vent system and the flame arrestors are recommended. This is to ensure effective functioning and to remove any polymer.

It is suggested that vapor return lines be installed to reduce emissions during unloading or loading of transport vessels such as rail cars or tank trucks. These lines should be kept free of polymer and the vent conservation valves should be correctly adjusted so that Acrylic Acid vapors during unloading and loading are contained.

### 6.2.6 Avoiding Polymer Formation in Pipelines

Empty and drain liquid filled pipelines or replenish oxygen by occasional circulation or clearing the lines with a gas containing 5 to 21 Vol.-% of oxygen (no inert gas! See [subsection 4.1.6, page 12](#)).

** Attention**

**Do not to leave stagnant lines or nozzles liquid-full for more than 3 days.**

Residues in transfer lines and other stagnant areas should be blown out. It is preferred that transfer lines be designed to be self-draining.

### 6.2.7 Indoor Acrylic Acid Storage Facilities

Indoor Acrylic Acid storage facilities should be well ventilated to prevent local accumulation of vapors in case of a leakage or during maintenance work. It must be noted that using fresh air for ventilation could cause freezing problems during the cold season. It is suggested that adequate air change rates be ensured. Nevertheless for special work e.g. maintenance it is recommended local exhaust systems be considered to supplement the general exhaust system. All indoor

bulk storage tanks should have their emergency vent system outside of the building and the regular venting should be connected to an off-gas treatment system.

When Acrylic Acid is handled indoors, e.g. drumming, fumes should be withdrawn by suction from the workplace.

### 6.2.8 Engineering Features for Environmental Protection

Spill containment helps to protect public waterways and ground water. Dikes around storage tanks are used to contain spills. The size of the diked area should hold the volume of the largest tank. Concrete is typically used as construction material. Make sure that the material used for containment is compatible with Acrylic Acid. Spill containment for bulk unloading areas will reduce environmental risks. Concrete containment is suggested for bulk unloading areas.

Instrumentation to monitor the liquid level in bulk storage tanks should be installed to prevent spills (see [subsection 6.2.12, page 30](#)). It is good practice to have both a level switch and a continuous level measurement device installed. High level alarms and interlocks should be implemented.

Vapor return lines are suggested for bulk unloading facilities to reduce emissions (see [subsection 6.2.5, page 27](#)).

### 6.2.9 Engineering Considerations for Fire Control

It is highly recommended that engineering safeguards be provided for reducing the risk of an exothermal polymerization inside of a bulk storage tank during a fire.

An uncontrolled heat source, such as a pool fire, can cause a violent polymerization and subsequently serious damage.

A foam system with injection nozzles can be used to extinguish an Acrylic Acid fire.

The installation of a sprinkler system may be required by local regulations.

Stationary water monitors are suggested to keep Acrylic Acid fires under control and to cool Acrylic Acid tanks. Separation with diked walls is useful to protect Acrylic Acid tanks from pool fires caused by other chemicals or adjacent tank fires.

The tank insulation should be specified as fire resistant to provide better thermal protection during a pool fire.

A restabilization (shortstopping) system can be installed to allow the quick addition of phenothiazine (PTZ) in the event of a fire. Acrylic Acid containing PTZ is much less likely to polymerize violently during a fire (see [section 9.3, page 55](#)).

### 6.2.10 Materials for Construction in Acrylic Acid Service

Proper choice of materials of construction is important for safety, health, and protection of the environment. Some specific guidance for Acrylic Acid service is given below. Contact your supplier for further information.

- Material of construction usually is stainless steel (i.e. DIN 1.4571 or 316 L). Avoid contamination with alloys containing copper or silver such as brass. These metals may affect stability and may produce a color in the final product.
- Preferred gaskets are made of tanged steel enforced Graphite, PTFE, cross-linked EPDM or Kalrez®.

### 6.2.11 Engineering Considerations for Thawing Frozen Acrylic Acid

For the hazards associated with overheating of Acrylic Acid see [subsection 4.1.1, page 10](#) as well as [subsection 7.4.2, page 37](#).

#### Attention

**Improper Thawing of frozen Acrylic Acid can be very hazardous!**

The heat transfer medium for thawing frozen Acrylic Acid is preferred not to exceed 35 °C. Vessels should be equipped with external heat exchangers, internal coils or an external jacket. Tempered water which does not exceed 35 °C is preferably used for thawing frozen piping, valves, fittings and pumps.

Mobile electric heaters should not be used on drums, trucks, piping systems (including pumps, valves and filters) or vessels in Acrylic Acid service unless it can be ensured that the resulting recommended temperature of 35 °C during heating/thawing is not exceeded. Self-limiting or constant-wattage **electrical heat tracing** limited and instrumented to control at  $\leq 35$  °C is acceptable for this service because of their additional safety features. An independent high temperature shutdown at  $\leq 35$  °C may also be included as an additional safety feature to guard against failure of the heating system.

Thawed material should be circulated to redistribute the inhibitor and replenish dissolved oxygen.

#### Attention

**Do not remove liquid material from still partly frozen Acrylic Acid! Never use steam, steam condensate or other high temperature heat sources directly for thawing(See [section 4.2, page 13](#)) .**

### 6.2.12 Emergency Venting of Bulk Storage Tanks

It is common practice to design the capacity of a tank emergency vent system based on the vapors generated by a pool fire. Relief valves, weighted pallets, quick release man way covers and rupture disks can all be used to vent vapors generated by a pool fire. If used, an open vent can be sized for the pool fire case. Emergency vent devices should be inspected at least once a year to ensure functionality. Potential polymer build-up must be removed.

Emergency vents from indoor storage tanks should be routed to the outside. Contact your supplier for additional guidance.



 **Please note**

There is no known method for reliably relieving pressure from a run-away polymerization of Acrylic Acid in a tank.

It is suggested to use weak seam roofs in order to provide maximum venting in case of an inadvertent, strongly exothermal polymerization. Roof guide cables should be considered to control the trajectory of such a roof.

For more information please refer to [section 4.1, Polymerization, page 9](#) and [subsection 9.1.2, Restabilization \(Shortstopping\), page 52](#).

### 6.2.13 Engineering Controls for Contamination Protection

Best practices preventing back-flow of liquids have to be followed, e.g. check valves in the filling line, automated devices to prevent siphoning from other equipment back into the storage tank.

The venting system should be designed such that backflow of gases from other tanks vent is avoided, e.g. PC-valves.

### 6.2.14 Commissioning and Decommissioning of Tanks

If information is needed, contact your suppliers.





## 7 TRANSPORT & LOADING/UPLOADING

### 7.1 Personal protective equipment for loading and handling

The following protective clothing is recommended: a chemical resistant splash suit or apron, gloves, safety boots and eye protection. Splash goggles should be worn for eye protection. In addition a face shield could be worn for facial skin protection. Clothing made of supported neoprene or other suitable material (e.g. multi-layer laminate single-use suits or aprons) should be worn to protect the body against accidental Acrylic Acid splashes (See [section 5.5, page 19](#) for further information).

### 7.2 General considerations

The following, general considerations apply to all modes of transportation for Acrylic Acid (See [chapter 4, Instability and Reactivity Hazards, page 9](#)).

- Acrylic Acid must be transported and handled under an atmosphere containing at least 5% oxygen. The MeHQ stabilizer is not effective in the absence of oxygen (See [subsection 4.1.5, page 12](#)).
- Do not use pure nitrogen or other inert gases for unloading, blowing lines, or blanketing.

Pure nitrogen or other oxygen-free gases will reduce the amount of dissolved oxygen. The effectiveness of the inhibitor/stabilizer might be significantly reduced, resulting in a hazardous situation.

Cleanliness and good housekeeping is essential. All containers must be free of contamination. A cleaning certificate by an SQAS or EFTCO certified cleaning station is not sufficient proof that the transport vessel is free of contamination. The previous cargo of the transport vessel should also be considered. The incompatible materials list ([Appendix 11.1, page 69](#)) should be followed.

- The transport vessel has to be made of stainless steel (see [Chap. Materials for Construction in Acrylic Acid Service, page 29](#)) and insulated in order to maintain the product temperature between 15 °C and 25 °C.

- Steam or steam condensate must not be used for heating or thawing Acrylic Acid. A proper fail-safe tempered water system or a warm room (35 °C maximum) should be used for these purposes. An independent high temperature shutdown at  $\leq 30$  °C must also be included as an additional safety feature to guard against failure of the heating system. Electrical heating must not be used unless it can be ensured that the resulting maximum product temperature cannot exceed 30 °C during heating or thawing.
- In transit heating is forbidden.
- Acrylic Acid, stabilized (UN 2218) is classified as defined in regulation (EC) 1272/2008:
  - Acute Toxicity (oral and inhalation): GHS07: exclamation mark
  - Skin Corrosion/Irritation: GHS05: corrosion
  - Flammability: GHS02: flame
  - Hazardous to the Aquatic Environment: GHS09: environment

As such, Acrylic Acid must be packed in specific containers when shipped (see [section 2.2, page 4](#)).

- The vessel should have a local temperature indicator with a range of 0 to 100 °C maximum. Check the temperature for plausibility, for example by comparing the product temperature at the loading area.

Loading temperature of Acrylic Acid is 15 °C to 25 °C. Please keep in mind that temperatures during transportation should be always 15 °C to 25 °C.



#### **Please note**

Any temperature increase during transportation, excluding sun radiation in summer, could be an indication of a potentially critical situation.



#### **Attention**

Product temperatures above 30 °C should be reported to the supplier for further investigation and support.

### **7.2.1 Specific Issue associated with Multi-Compartment Shipments**

In addition to the above recommendations for unloading, less than full load shipments must meet all applicable codes and regulations, especially with respect to fill volumes. A risk analysis should be performed by the supplier before the use of multi-compartmented or combination-load trucks or barges due to the potential hazards associated with such vessels. Issues inherent with multi-compartment shipments include, but are not limited to:

- Product contamination due to improper loading, unloading, or vessel internal damage;
- Incompatible storage temperature requirements; and

- Inability to clean compartments with hot water/steam with other compartments full.

Due to the large number of incompatible materials associated with Acrylic Acid (see Appendix 11.1, page 69), and the high probability of a polymerization initiated by an incompatible material, it is recommended that only Acrylic Acid be loaded in the compartments of the vessel.

In case of combination load deliveries, the compartments next to the one containing Acrylic Acid should remain empty and sealed.

Definitely, only compatible materials should be included in the combination load.

It is also recommended that the contents of all compartments be continuously controlled by the shipping and receiving location. Examples of this control include:

Filling and unloading of all compartments at single locations.

Physically sealing any compartment not in use to avoid re-use or cleaning until all monomer is unloaded.

Proper training for carriers with respect to prohibition of steam/hot water, and cleaning of empty compartments with monomer in an adjacent compartment.

Enquire with your supplier about more details with respect to less than full load shipments.

### 7.3 Transportation Incidents – Immediate Actions

If emergency action needs to be taken by drivers when leaks, spills or fire occur during transport, then the “Instructions in Writing According to ADR” (see Appendix 11.2, page 70) must be followed.

See also detailed recommendations on transportation from the following Cefic brochures:

- Recommendations on Safety, Health and Environmental Management Practices for Logistics Service Providers (Cefic, ECTA, EPCA, April 2002)
- Industry Guidelines for the Security of the Transport of Dangerous Goods by Road (April 2005)

Follow precautions stipulated in the supplier’s eSDS for Acrylic Acid. See chapter 9, *Emergency Response in Case of Polymerisation and Fire*, page 51 for additional information.

#### Please note

**For further technical assistance consult the supplier immediately by calling the following emergency response telephone numbers**

Arkema France	+33 03 87 93 8500
BASF SE	+49 180 2273 112
Dow Europe GmbH	+31 11 5694982
Evonik Industries AG	+49 2365 49 22 32
MOMENTIVE Specialty Chemicals a.s.	+420 352 614222
SASOL Chemie GmbH & Co KG	+44 208 762 8322

These suppliers are cooperating on emergency response under the umbrella of the Cefic-ICE scheme.

## 7.4 Bulk Transport by Road and Rail

The bulk transport of Acrylic Acid, either by tank truck, rail car or iso container is authorized by ADR/RID and IMDG.

Please consult these and / or local regulations for complete, up to date, specifications and requirements. For labeling, refer to (EC) 1272 / 2008, so-called GHS legislation.

The transport vessel has to be made of stainless steel (see also Chap. [subsection 6.2.9, page 29](#)) and insulated in order to maintain the product temperature between 15 °C and 25 °C.

### 7.4.1 Information for the Haulier

The temperature of the empty vessel should be less than 35 °C before loading with Acrylic Acid. The temperature of the Acrylic Acid after loading should be checked to be between 15 °C and 25 °C. Acrylic Acid freezes at 13 °C.

**Temperatures >30 °C can be hazardous. Investigation should start immediately!**

Drivers should be thoroughly trained. To ensure reliable operation, the temperatures of product should be monitored. In transit, the driver should log the temperature of the Acrylic Acid once every 8 hours until the delivery is made. Product should not be offered for delivery if the temperature is less than 15 °C without approval of the supplier.

#### Attention

If at any time the temperature reaches 30 °C and higher, immediately contact the supplier (see [section 7.3, page 35](#)).

Such high temperatures may be an indication of polymerization and must be (investigated) taken seriously.

#### Please note

The temperature indicated on the gauge of the tank should be cross-checked, only if there is no indication of any danger, by cautiously inserting a temperature probe via the vapor return connection. If the temperature cannot be confirmed the temperature gauge needs to be repaired. If the temperature is confirmed to exceed 30 °C the vessel should be isolated.

Preventive maintenance or regular instrumentation checks are strongly recommended to make sure the temperature gauge is working properly. If analog temperature indicators are used a temperature range of 0 °C to 100 °C on the gauge is preferred.

Also see [chapter 9, page 51](#) on emergency response for more details.

If no dedicated transport vessels are used, a cleaning certificate according to EFTCO standards indicating the previous cargo must be presented before starting the loading operation (see [section 8.4, page 49](#) and [Appendix 11.1, page 69](#)).



Even if dedicated transport vessels are used, cleaning may be necessary due to polymer formation over time. Polymer may plug the pressure relief valve and may cause the bottom valve to leak.

## 7.4.2 Heating and Thawing of Acrylic Acid

### Please note

**Heating or thawing during transportation is not allowed.**  
**Never use steam or steam condensate for heating or thawing Acrylic Acid.**

Incorrect thawing of frozen Acrylic Acid can be extremely hazardous. Acrylic Acid can be safely thawed by circulation of tempered water through heating coils. The temperature of the water is preferably limited to be below 35 °C (see [subsection 4.1.1, page 10](#)). Thawing should be performed at service providers qualified by the supplier.

Use only automatic temperature controlled, “Fail Safe” alarmed, tempered water systems. Never use steam-water mixing nozzles directly in heating coils, jackets, etc., for thawing. An increase in steam pressure or loss of water supply would create immediate high temperature conditions resulting in a polymerization. Indirect heat exchangers are preferred.

The temperature of both the circulating water and the thawed portion of the monomer should be closely monitored and at least one interlock should be installed in order to prevent overheating of the monomer. If possible, the monomer should be well mixed to ensure that dissolved oxygen and the inhibitor is well distributed during thawing as well as to enhance heat transfer. Mixing could be done by re-circulation, agitation, or by means of an eductor. Always continue thawing process until the entire Acrylic Acid is thawed.

As soon as the Acrylic Acid is thawed, maintain the temperature of the thawed Acrylic Acid at 15 °C-25 °C.

If accidentally a small residue of frozen Acrylic Acid remains in a vessel after emptying, return warm Acrylic Acid to the vessel to provide inhibitor and a heat transfer source for thawing.

### Attention

**Never remove liquid material from a partially frozen or thawed vessel.**

Such material may be uninhibited or contain most of the inhibitor required for the entire contents of the tank truck. The Acrylic Acid should be mixed thoroughly during and after thawing to assure uniform mixing of the inhibitor and dissolved oxygen before any liquid is withdrawn. During thawing, proper venting (such as open manway hatch with a vapor recovery bonnet or a connection to an emission control device via the vapor return line) should be provided. As soon as the material is thawed, the temperature should be maintained between 15 °C and 25 °C.

During cold weather conditions it can happen that Acrylic Acid freezes and causes blocking of the outlet spout during unloading (e.g. when the bottom valve is dripping). Best Practice:

- Unscrew the outlet cap.

- Connect the unloading hose.
- Open the outlet valve (leave the bottom valve closed).
- Start warming up the outlet spout with max. 35 °C water.

### 7.4.3 Unloading

The following procedures are suggested to reduce the risks during the unloading of Acrylic Acid. The contents of the vessel must be **positively identified** before they are transferred. Sampling and analysis are considered as appropriate measures for product identification. Continuous monitoring of the unloading process is recommended.

Acrylic Acid is a corrosive liquid and should be handled accordingly. An emergency shower and eye wash station (for outdoor installations they may require freeze protection) should be directly accessible from the unloading spot. The emergency shower and eye wash station should be tested periodically to ensure that they function properly. Personal protective equipment should be worn while sampling or making any connections.

Proper equipment should be used to protect against spills. The unloading line should be cleared of Acrylic Acid after unloading is completed or arranged so the Acrylic Acid will drain toward the storage tank when transfer is stopped. Where necessary, a check valve should be provided on the unloading hose to ensure that total tank contents will not spill in the event of a hose break. Dedicated hoses at the unloading site should be used to avoid contamination. These hoses usually are better maintained and thereby minimize also the risk of spills. The pump glands, flanged fittings and valve stems should be provided with splash collars in cases where personnel could be exposed to major Acrylic Acid leaks or sprays.

Acrylic Acid should be unloaded using a vapor return line in order to limit emissions to the environment. The vapor return line is recommended to be a standard connector.

Dry disconnect couplings are recommended to be used for the liquid phase at unloading stations of Acrylic Acid. These couplings are considered to be good risk management measures in order to minimize workers exposure and emissions to the environment.

#### Unloading Trucks and Isocontainers

The suggested unloading procedure is by pumping with a closed loop (vapor balance) system in which the vapors are returned to the vessel, or sending the vapors to a scrubber or incinerator.

1. Spot the transport unit and set wheel chocks. Stop the engine and apply the emergency breaks during unloading.
2. Positively identify Acrylic Acid. Before unloading, inspect the vessel to ensure that it is not damaged or leaking. Compare the labels and the vessel identification number to ensure that they are identical to the transport documents.



3. The transport unit must be properly grounded before proceeding with any other operation.
4. Check that the vessel inventory is between 15 °C and 25 °C before unloading. **If the temperature of the Acrylic Acid is above 30 °C immediately contact your supplier.**
5. Verify that the receiving vessel or tank will hold the entire contents of the tank truck or iso container.
6. Connect the vapor hose and open the valves to equalize pressure.
7. Remove the protection cap of the coupling. Be aware: in case of dripping bottom and outlet valves Acrylic Acid contact is possible when removing the protection cap!
8. Ensure that the unloading liquid line is connected to the Acrylic Acid storage.
9. Connect the liquid line and open the external valve.
10. Open the internal valve.
11. Start the pump. Once the flow has started, continue to monitor the vapor return line pressure gauge to confirm the flow and to avoid pulling a vacuum that may implode the vessel.
12. The unloading operation should be monitored closely by plant operators all the time.
13. When the vessel is empty, shut off the pump and close all liquid and vapor valves.
14. Drain and disconnect the hoses and fix the caps.
15. Leave the labels in place (according to the ADR/RID or IMDG guidelines).
16. Disconnect the earthing cables and remove the wheel chocks.
17. Verify that the vessel is empty.
18. The unloading hose should be emptied. If water is used for cleaning the unloading hose and pipeline system it is essential to make sure that a sufficient amount of water is being used. Please refer to [section 4.3, page 13](#) concerning the instability of aqueous Acrylic Acid.

If the vessel cannot be emptied for whatever reason, contact your supplier immediately.

### Unloading Rail Cars (RTCs)

The suggested unloading procedure is by pumping with a closed loop (vapor balance) system in which the vapors are returned to the vessel, or sending the vapors to a scrubber or incinerator. Railcars should preferably be equipped with an auto vent valve system that opens the vapor return valve prior to the bottom valve. This prevents implosion of the RTC in case that the vapor return line is blocked (polymer, frozen material etc.). Please refer to the Cefic/ECTA/EPCA publication "Standard Rail Tank Cars for the carriage of liquid chemicals in bulk: Requirements for design, construction and testing".

1. Spot the rail car and set wheel chocks.
2. Positively identify Acrylic Acid. Before unloading, inspect the rail car to ensure that it is not damaged or leaking. Compare the labels and the rail car identification number to ensure that they are identical to the transport documents.
3. The rail car must be properly grounded before proceeding with any other operation.
4. Check that the rail car inventory is between 15 °C and 25 °C before unloading.
5. If the temperature of the Acrylic Acid is above 30 °C immediately contact your supplier.
6. Verify that the receiving vessel will hold the entire contents of the rail car.
7. Connect the vapor hose and open the valves to equalize pressure (not for auto vent valves).
8. Remove the protection cap of the coupling.
9. Ensure that the unloading liquid line is connected to the Acrylic Acid storage.
10. Connect the liquid line and open the external valve (for auto vent valve systems please follow the instructions on the RTC).
11. Open the internal valve.
12. Start the pump. Once the flow has started, continue to monitor the vapor return line pressure gauge to confirm the flow and to avoid pulling a vacuum that may implode the rail car (not required for auto vent valve systems).
13. When the rail car is empty, shut off the pump and close all liquid and vapor valves.
14. Drain and disconnect the hoses and fix the caps.
15. Leave the labels in place (according to the ADR/RID guidelines).

16. Disconnect the earthing cables and remove the wheel chocks.
17. Verify that the rail car is empty.

If the vessel cannot be emptied for whatever reason, contact your supplier immediately.

### **Unloading Vessels with Pressure**

Vessels must not be unloaded by nitrogen pressure. It is not recommended to unload vessels by using gas pressure due to the risk of spills that cannot be contained.

## 7.5 Drums and Intermediate Bulk Containers

The use of drums or intermediate bulk containers (IBCs) for the transport of Acrylic monomers is authorized by the ADR/RID/IMDG regulations. The use of electrostatically safe drums and IBCs for loading and unloading is required by the UN Transport of Dangerous Goods "Orange Book" for substances with a flash point below 60°C (Volume II, Sec. 4.1.2 of the "Orange Book"). CENELEC report, R044-001, dated February 1999, provides guidance and recommendations for the avoidance of hazards due to static electricity.

Even though there is a range of allowable options in IBC selection, the following factors are important in drum and IBC selection: corrosivity, flammability, UV exposure, temperature exposure, mechanical strength vs. temperature, impact resistance, proximity of use to other containers containing materials of different flashpoints, and odor control. There is a variety of ways to manage these factors by container selection and by organizational means.

From a technical perspective:

- Insulated stainless steel IBCs are the most suitable for Acrylic Acid,
- Drums made of self-supporting high-density polyethylene are recommended.

However, steel drums with polyethylene insert can also be used. Polyethylene in-liner or inserts must be undamaged to prevent corrosion (See [subsection 4.1.4, page 11](#)).

Drums and IBCs should be labeled properly (See [section 2.2, Classification and Labelling according to Regulation \(EC\) No 1272/2008 \[CLP\], page 4](#)).

### 7.5.1 Information for the Haulier

Avoid sources of heat, sparks, or flame. Acrylic Acid should be shipped between 15 °C and 25 °C. Acrylic Acid freezes at 13 °C. Do not load or transport bulging or distorted drums. Bulging drums may indicate polymerization.

#### Please note

| If polymerization is suspected, immediately contact your supplier.

Also see [chapter 4, Instability and Reactivity Hazards, page 9](#) and [chapter 9, Emergency Response in Case of Polymerisation and Fire, page 51](#) for more details.

When a load of drums/IBCs is received, open the doors of the truck carefully before entering. If a strong odor is present, indicating a leaking container, immediately call the supplier.

### 7.5.2 Storage of Drums and Intermediate Bulk Containers

Acrylic Acid monomer is normally inhibited with 200 ppm of MeHQ to prevent polymerization. **Avoid freezing!** The inhibitor separates and preferentially concentrates in the remaining liquid.

 **Please note**

The three most important considerations in shipping and handling Acrylic Acid are:

- to avoid exposure to elevated temperatures,
- to avoid contamination,
- to use an oxygen containing blanket gas.

Ideally, Acrylic Acid should be kept between 15 °C and 25 °C. Do not store in direct sunlight. Indoor storage is recommended. Warehouses must be well ventilated. Keep drums and IBC closed.

The drums should be stored not more than 2 high.

A path of 1,5 meters should be kept free around each block of drums/IBCs, to provide ventilation and both normal and emergency response access.

Contamination can cause an uncontrolled polymerization which may result in violent rupture of the container, fire, serious damage to the surroundings and significant environmental impact.

The presence of oxygen is required for the inhibitor (MeHQ) to be effective. Lack of oxygen can cause an uncontrolled polymerization.

If drums/IBCs freeze, follow thawing procedures described in the following section.

Reuse of Polyethylene drums or IBCs is recommended only for dedicated service. Steel drums with liners are not recommended to be reused. Steel drums with liners should be inspected periodically. Migration or penetration of Acrylic Acid vapors through the liner may cause corrosion of the steel shell and leakage can occur.

Please refer to [chapter 4, page 9](#) for additional information on **Instability and Reactivity Hazards**.

### 7.5.3 Thawing of Drums and IBCs

In the case that drums or IBCs contain partially or totally frozen Acrylic Acid never use steam, hot condensate or electrical heating in direct contact with them. Do not put them close to a heat source. This can result in uncontrolled polymerization.

 **Attention**

**Never withdraw liquid material from a partially thawed drum or IBC. The liquid will contain most of the inhibitor with the remaining solid being not sufficiently stabilized.**

Thawing of frozen Acrylic Acid can be extremely hazardous if proper procedures are not followed. When freezing occurs in drums or IBCs, the first crystals, low in inhibitor, will form along the outer wall of the container.

Preferably, drums and IBCs should be thawed in a heated room at a temperature between 20 °C and 35 °C. This will allow the Acid to thaw gradually over a 48 hour period. Each container should be agitated periodically to mix the inhibitor and dissolved oxygen during thawing (i.e. drum roller, pallet shaker).

Tempered water between 20 °C and 35 °C can also be used.

When the material has thawed, the temperature of the drum or IBC should be maintained between 15 °C and 25 °C.

#### 7.5.4 Emptying of Drums and Intermediate Bulk Containers (IBC)

Acrylic Acid is a corrosive liquid and should be handled accordingly. The contents of the drums and IBC should be *positively identified before* they are transferred and used.

To empty a drum/IBC in an area where flammable atmosphere may occur (e.g. Zone 2 rating) the following procedures must be followed:

- Before drums/IBCs are opened, they should be supported and grounded/earthed. Polyethylene drums have to be placed into an earthed housing (designed according to CENELEC guidelines) prior to starting the decanting operation.
- Drums/IBCs and fittings should never be struck with tools or other objects that may cause sparking or puncture.

Drum contents may be under pressure or vacuum. When removing plugs (bungs) from a drum of Acrylic Acid (or opening an IBC), the operator should wear PPE recommended in [section 5.5, page 19](#) and locate the nearest emergency safety shower and eye wash station.

He should use a plug (bung) wrench. The operator should place the drum plug (bung) up, and loosen the plug (bung). After the plug (bung) starts to loosen, it should be given not more than one full turn. If internal pressure exists, it should be allowed to escape to the atmosphere. Only then should the operator loosen the plug (bung) further and remove it.

The preferable safe method for emptying drums/IBC is by pump or by gravity:

- Note that electric pumps must comply with the area electrical classification. A static free dip pipe or flexible stainless steel hose should be used to empty the drum/IBC.
- When emptying by gravity, use self-closing valves.
- Vent drum/IBC while emptying, thereby preventing collapse of the drums or IBCs during emptying.
- Do not use pressure to empty drums.

Do not cut, drill, grind, or weld on or near drums/IBC. The heat from such work could ignite residual material in the drum/IBC. Residual vapors may explode on ignition.

Improper disposal or reuse of containers may be dangerous and / or illegal. Empty drums/IBC can be hazardous due to residual liquid and vapor. Before a drum/IBC is disposed of, it should be repeatedly washed with water to remove traces of Acrylic Acid. Dispose of rinse water properly (see [section 8.1, page 47](#)). The drum should be rendered unusable for further use.

## 7.6 Transportation via Marine Shipment

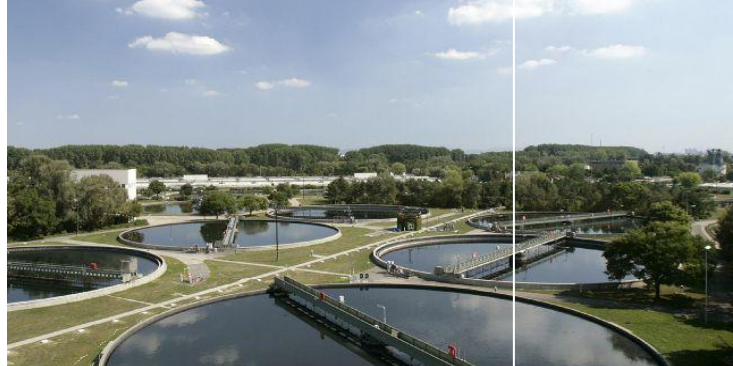
It is a recommendation not to transport Acrylic Acid via deep tank shipment as long as no Phenothiazine stabilizer has been added to the Acrylic Acid.

Transport of standard inhibited/stabilized (200 ppm MeHQ) Acrylic Acid by isocontainer is the suggested mode of transportation.

Additional stabilization and extended transportation time can influence the polymerization and has to be taken into consideration.







## 8 Environmental Considerations

### 8.1 Waste Disposal

State laws and local regulations governing waste disposal make it essential for producers, suppliers, hauliers and users of Acrylic Acid to be fully aware of viable options for the ultimate disposal of materials containing Acrylic Acid. Materials to be disposed of may be residues from production or cleaning operations as well as waste material from spills.

Acrylic Acid has been described in [chapter 5, page 15](#) as a material causing severe skin burns and eye damage. Accordingly it should always be handled with all appropriate safety equipment.

Wastes of the monomer may be diluted and washed into a biological waste water treatment plant after notification of the person in charge. The biodegradability of the material in diluted form is good (90 - 100% DOC reduction (9 d) (OECD 301 A (new version)) (aerobic, activated sludge, domestic, non-adapted)). However, Acrylic Acid may be toxic to the system if the bacteria have not been conditioned properly to this material. Accordingly, the initial feed rate should be low with a stepwise increase if a significant amount is to be fed into the biological treatment purification. It should be kept in mind, however, that larger quantities may affect the optimal Acidity of the milieu and therefore have to be balanced by simultaneous addition of sodium hydroxide.

#### Please note

As Acrylic Acid is toxic to algae, biological treatment is necessary and spillages into surface waters and public sewers must be avoided.

Solid materials containing Acrylic Acid, such as absorbents or polymeric material can be disposed of by incineration. Disposal in landfills must be thoroughly checked with the authorities and should be practised only as a last choice.

For disposing of waste materials originating from laboratory or retain samples, great care must be exercised to keep the monomer separated from incompatible materials (see [Appendix 11.1, page 69](#)), e.g. peroxides which may initiate polymerization.

### 8.2 Spill and Leak Control

Emphasis should be placed on the prevention of leaks and spills through careful design and good operating procedures. Written spill and leak response procedures are recommended and may be required by law. Acrylic Acid is readily

biodegradable by wastewater treatment plants with adapted sludge. Acrylic Acid is highly toxic to algae.

Therefore do not allow spills to enter drains, sewers or watercourses. Notify your appropriate regulatory body if spills or uncontrolled discharges enter watercourses.

Acrylic Acid should only be handled in diked areas.

In the event of accidental spillage of Acrylic Acid to surface water or to a municipal sewer system, the pollution control agencies must be promptly notified.

### 8.3 Air Emissions

Discharges of Acrylic Acid vapors into the atmosphere are subject to restrictions in Europe, and must therefore be disposed of in conformity with air pollution control regulations.

The most appropriate way is to avoid emissions resulting from displaced gases, if possible. In most cases this can be accomplished by back venting through a vapor return line. It should be considered good practice in all storage facilities and (un-)loading installations. The use of venting pipes, however, must effectively exclude contamination of the Acrylic Acid. Vapor return lines must be heat traced to avoid condensation of Acrylic Acid vapors which do not contain any stabilizer.

Exhaust gases loaded with Acrylic Acid originating from production should be cleaned prior to being emitted into the atmosphere. The exhaust gas can be treated via:

- Thermal Combustion Unit, e.g. a flare.
- Catalytic Conversion Unit.
- Caustic scrubber.

A low cost option is a purification tower operated with water (scrubber) . Acrylic Acid can readily be washed out from gases with water and be drained into a biological treatment plant. The dimensional design for an appropriate tower depends on the flow rate of the gas. An approved design example with a corresponding drawing is suggested in [section 10.1, page 59](#).

Where waste water treatment is not available, off gas purification may also be affected with caustic solution. Spent caustic solutions should be withdrawn and replenished periodically.

 **Please note**

The use of an activated carbon system is not recommended, since:

- Depending on the concentration of Acrylic Acid in the waste gas, adsorption on the carbon surface can be accompanied by release of a large amount of heat that may cause hot spots in the carbon bed and subsequent polymerization or even ignition.
- If flammable vapors are present, the heat released may pose a fire hazard (e.g., a fire may start if the temperature reaches the auto-ignition temperature of the vapor and oxygen is present to support ignition).

## 8.4 Cleaning of Transport Vessels (Road Tankers/RTCs/IBCs)

Dedicated Acrylic Acid transport vessels may over a certain period of time develop a gradual growth of polymer on the walls and armatures. If polymer has formed, it may possibly act as a seed for further polymerization. Moreover, polymer particles may adversely affect the quality.

It is therefore recommended to periodically clean containers thoroughly.

If the previous cargo is an incompatible (see Appendix 11.1, page 69) then this vessel is not acceptable even after cleaning.

Cleaning of Road Tankers and RTCs has to be carried out in cleaning stations recommended by the European Federation of Tank Cleaning Organizations (EFTCO). A European Cleaning Certificate will be issued at these cleaning stations.





## 9 Emergency Response in Case of Polymerisation

Signs that indicate an emergency:

- increased temperatures of the Acrylic Acid (due to external heating or an exothermal polymerization).
- venting of the container.
- container deformation.

If there is an emergency during transport or in a user's tank call immediately your supplier (see [section 7.3, page 35](#)) and facilitate the establishment of communications between the personnel at the emergency site and the supplier's emergency response team.

Users of Acrylic Acid should develop site- specific written emergency plans for Acrylic Acid spills, fires, exothermal and incipient polymerizations.

These plans should focus on:

- Clearly identifying the features that categorize an event as an emergency.
- What should be done to secure the emergency site and immediate actions to mitigate the danger?
- A very important feature of the plan should be early notification of the incident so that the supplier can quickly provide expertise in helping to manage the incident.

### 9.1 Detection and Response to Incipient Polymerization in a Storage Tank

If a system is installed and operated with all of the prevention measures recommended in this brochure and required by prudent engineering practice, the chances of experiencing an inadvertent polymerization are minimized. However, in the case of unforeseen events which might lead to incipient polymerization in a storage tank, it is necessary to detect such an event in a timely manner to avoid, stop or mitigate polymerization. An option to provide additional protection from these unforeseen events is the use of a restabilization (shortstop) system. This subsection deals with the operation of such an optional restabilization system.

Credible Initiation Scenarios:



- External heating of Acrylic Acid (Please refer to [subsection 4.1.1, Overheating, page 10](#) and [subsection 6.2.1, Detection of Critical Conditions inside Bulk Storage Tanks, page 24](#) and [subsection 6.2.2, Temperature Control of Bulk Storage Tanks and Accessories, page 24](#) and [subsection 6.2.4, Pumps and Protection of Pumps from Overheating, page 26](#) and [section 9.3, Fires, page 55](#)).
- Removal of the dissolved oxygen from the monomer: If the monomer is purged with an inert gas (e.g. nitrogen or carbon dioxide) and the dissolved oxygen is removed, the MeHQ inhibitor becomes ineffective and polymerization will ultimately occur. The length of the induction period until polymerization occurs and the maximum rate of polymerization are unpredictable because they depend on the previous storage history of the Acrylic Acid. If inert purging is known to have occurred, the Acrylic Acid should be sparged with a gas containing 5 to 21 Vol.-% of oxygen as soon as possible. Air is preferred (Please refer to [subsection 4.1.5, page 12](#)).
- Chemical contamination: The scope of a contamination scenario is very difficult to pre-define since the identity and concentration of the contaminant is unpredictable. However, it is recommended that the restabilization (shortstop) system be immediately activated if contamination with a known or potential polymerization initiator has taken place. If such contamination has occurred without the knowledge of responsible personnel, the restabilization (shortstop) system should ultimately be activated in the event of an exothermal polymerization (Please refer to [subsection 4.1.3, page 11](#), ).

### 9.1.1 Polymerization Detection

The most reliable way to detect the approach of a runaway polymerization is by redundant temperature monitoring in SIL 3 quality and recording of the tank contents. This is best done by comparison of the actual temperature to the target storage temperature range, 15 °C to 25 °C. Acrylic Acid polymerization is a highly exothermic reaction (1075 kJ/kg which releases energy that results in heating of the liquid in the storage tank. A temperature monitoring system should be designed as per requirements of [subsection 6.2.1, Detection of Critical Conditions inside Bulk Storage Tanks](#).

Cloudiness or turbidity may be another indication of polymerization.

### 9.1.2 Restabilization (Shortstopping)

Successful restabilization of Acrylic Acid requires a timely response to detection of a significant temperature increase. The lack of a timely response may result in the onset of polymerization leading to accelerated temperature and pressure rises. Therefore the activation criteria given in [section 9.1.2](#) were developed. Concepts how to introduce the restabilization inhibitor into the storage tank in a safe way have been developed (please refer to [section 10.3, page 64](#)). Due to the large number of possible contaminants and concentrations of those contaminants, these criteria may not apply if the cause of the inadvertent polymerization is contamination.

### Restabilization (Shortstop) Inhibitor

Phenothiazine (PTZ) in solution is the preferred shortstop agent. While addition of PTZ has worked in most cases, there is no assurance that it will always be effective. Obvious exceptions are contamination of Acrylic Acid with gross amounts of a polymerization initiator or a delay in activation of the shortstop system.

As PTZ is a solid it should be added as a solution to ensure easier addition and mixing. Commercial solutions are available. Please consult your supplier for details.

PTZ is not soluble in water and only slightly soluble in aqueous Acrylic Acid. Addition of a large amount of de-ionized water to Acrylic Acid undergoing polymerization could moderate the reaction by removing heat. The addition of large amounts of water should therefore only be considered as a last resort after the addition of PTZ. However, the release of large volumes of steam and Acrylic Acid vapor, and the possibility of tank overflow detract from this option.

### Restabilization (Shortstop) Inhibitor Solution

The following criteria are recommended for the selection of a solvent for the PTZ shortstop inhibitor:

- It should be a good solvent for PTZ (preferably at least 6 wt.-% PTZ solubility at the lowest anticipated ambient temperature).
- It should not promote polymerization and should be inert to the system.
- It should not be highly toxic.
- The flash point of the solvent must be higher than the flash point of Acrylic Acid.
- It should not exacerbate any potential fugitive emission problem resulting from the emergency.

Ideally, one would not want to add a new chemical to the potential runaway system, so Acrylic Acid might be considered as a solvent for PTZ. Unfortunately, the solubility of PTZ in Acrylic Acid is only about 2 wt.-% at ambient temperature. The PTZ shortstop solution should be as highly concentrated as possible to minimize its volume so that it can be pumped in as quickly as possible. The final concentration of PTZ in the Acrylic Acid to be shortstopped is suggested to be in the range of 200 to 1000 ppm. However, in the case of contamination, restabilization may not be possible at any concentration of PTZ, depending on the nature and concentration of the contaminant.

PTZ shortstop inhibitor does not abort or oppress dimerization or oligomerization (see [section 4.4, page 14](#)).

### Activation Criteria for Restabilization (Shortstop) Systems

It is recommended to activate the restabilization (shortstop) system immediately if any of the following criteria apply:

### Please note

- A temperature increase of greater than 5 °C/h has been detected without external cause.
- The temperature in the liquid has reached 45 °C.
- There is a fire near an Acrylic Acid tank.
- A known polymerization initiator or incompatible substance has been inadvertently added to the Acrylic Acid. (see Appendix 11.1, page 69)

The above criteria should provide adequate time for adding and dispersing the restabilization solution to tank contents.

Any temperature or temperature rise that exceeds the possible rise from external heat sources (ambient, sun, pumps, temperature control systems, receipt of warmer product, etc.), may indicate an ongoing polymerization. The lowest practical temperature or temperature rise should be used as a call for investigation. Manual activation of the shortstop system is preferred for sites with continuous manning; otherwise automatic activation of shortstop system should be used. In any case, the shortstop system should be activated if the criteria specified above are met. Methods how to do that safely have been developed (please refer to [section 10.3, page 64](#)).

Restabilization will not prevent dimerization taking place (Please refer to [section 4.4, page 14](#)). The heat release by dimerization may cause polymerization to be triggered.

### Attention

Do not approach a tank whose contents have reached or exceeded 50 °C.

### Mixing of Restabilization (Shortstop) Inhibitor

It is possible to quickly bring the concentration of the shortstop inhibitor to effective levels by circulating the tank contents with a pump and / or by gas induced mixing. If a pump is used to mix shortstop solution, the interlock instrumentation must be designed to allow for this emergency procedure to be executed. The use of eductor tubes on the tank inlet(s) or a gas lift can reduce the time required to mix the shortstop solution with the tank contents.

The design and installation of the shortstop inhibitor system should be specific to the tank farm layout. Methods how to do that safely have been developed (please refer to [section 10.3, page 64](#)). Please clarify the above mentioned issues by consulting your supplier.

### Restabilization (Shortstop) of Road Tankers

Road Tankers arriving at the unloading site with elevated Acrylic Acid temperatures (higher than max. storage temperature of 25 °C) may require restabilization. The first step is to verify the temperature as indicated in [autorefsec:cleaning, Cleaning of Transport Vessels \(Road Tankers/RTCs/IBCs\), page 49](#). If the temperature reading is confirmed to be high, Phenothiazine or phenothiazine solution should be added to the tank either via the vapor return, the manway or the



bottom outlet. The tank content can be mixed by shortly driving and stopping the vehicle.

### Attention

Do not approach a tank whose contents have reached or exceeded 50 °C.

## 9.2 Spills

Containment is the most important technique for handling spills. Numerous techniques can be used in containing spills (see also [chapter 8, page 47](#)):

- Acrylic Acid on the ground: diking, diverting and absorption;
- Acrylic Acid still leaking from a container: plugging, patching, repairing, and tightening of container fittings or secondary containment (drums).

If there is a facility capable of treating Acrylic Acid, small spills may be washed to the chemical waste treatment sewer with large amounts of water. Small spills of up to 5 liters can be absorbed using sand or infusorial earth.

Large spills should be contained, if possible, within a diked area. A temporary dike can be arranged by stacking sand bags or similar devices. Avoid run-off into storm sewers routed to public waters.

Wherever possible, the material should be recovered in appropriate containers for reuse or disposal. The Acrylic Acid is likely to be contaminated and therefore Phenothiazine should be added as a stabilizer (0,1 wt.-% is the minimum recommended amount).

However, if a waste water sewer is available, the remainders can also be sparingly washed down after dilution and neutralization prior to being discharged to a waste water treatment plant.

### Attention

PPE must be worn when fighting larger spills

(see also [section 5.5, page 19](#)).

A chemical suit, rubber boots and respiratory protection (self-contained or air-supplied) must be worn.

More information on environmental considerations with regard to spill prevention is given in [section 8.2, Spill and Leak Control, page 47](#).

## 9.3 Fires

Acrylic Acid is a flammable liquid with a flash point of 48,5 °C. Under normal recommended storage conditions (15 °C to 25 °C) Acrylic Acid is not a significant fire risk because the liquid's temperature is well below its flash point and adequate risk management measures are in place.

Potentially explosive mists may be generated in case of spray or high velocity liquid jets discharged from a nozzle or pipeline.

Flow or discharge velocities of more than 4 m/s from a line might generate static electricity. Ensure that there is proper grounding and electrical connectivity when transferring from one container to another. Fine mesh filters should be

avoided or provisions should be taken to allow for relaxation of electrostatic charges generated. Splashing into a tank can be avoided by using a dip tube. Heat input from sun radiation may result in temperature layers. The temperature of the top liquid layer might be above the flash point for storage tanks or vessels where there is insufficient insulation or circulation. A spark discharge from static electricity or any other common ignition source may cause ignition. Further information on how to avoid issues with static electricity can be retrieved from CENELEC.

### 9.3.1 Burning Acrylic Acid

Water can be used to fight a fire, since Acrylic Acid and water are miscible in any proportion.

Small fires can be fought with carbon dioxide or dry chemical extinguishers. For larger fires, foam can be used.

In the event that the content of an Acrylic Acid tank has caught fire, a restabilization agent should be added as quickly as possible as a first step. This will help to prevent a runaway polymerization, assuming that this was not the cause of the fire. Please refer to [section 9.1.2, Activation Criteria for Restabilization \(Shortstop\) Systems](#), page 53 on the maximum temperature when to approach the storage tank.

Addition of water into a tank of burning Acrylic Acid could result in a pressure build-up if the temperature of the Acrylic Acid is above 100 °C. In addition the sequence must always be first to add the restabilization agent and - only if this is not effective - to add water (see [section 4.3, page 13](#)). This is because the water could be rapidly vaporized, causing a significant pressure surge and massive venting of a mixture of steam containing Acrylic Acid vapor.

#### Please note

| Always add restabilization agent as first step.

### 9.3.2 Fire adjacent to an Acrylic Acid Storage

Acrylic Acid is a reactive substance which can polymerize if exposed to high temperatures (see [chapter 4, Instability and Reactivity Hazards, page 9](#)).

Therefore it is essential that an emergency plan is developed which contains measures to closely monitor and record the temperature of Acrylic Acid storage tanks.

In case of a fire in the vicinity of an Acrylic Acid tank or tank farm, the Acrylic Acid containing tank(s), pipes should be cooled by water spray. Local overheating could result in an inadvertent, violent and exothermal polymerization evolving considerable heat and pressure and ejecting hot vapor and polymer.

A water spray or fog of 7 l/(min, m<sup>2</sup>) to tank or pipeline surfaces is usually sufficient to absorb heat and maintain a lower temperature.

Tank cooling and circulation by means of the external cooling system should be initiated to reduce the risk of local overheating of the tank contents.

Incident commanders, fire fighters, and emergency response personnel must be trained on the polymerization hazards of Acrylic Acid in order to determine the

proper response in case of an emergency (Please refer to [subsection 9.1.2, page 52](#) for further advice on restabilization).

In the event of a fire affecting Acrylic Acid, it is necessary to evacuate all non-essential personnel when the liquid temperature reaches 45 °C, due to the risk of a runaway polymerization.

At 45 °C latest a restabilization agent should be added to the monomer to limit the risk of an inadvertent polymerization.

 **Attention**

| **At 60 °C all personnel should be evacuated.**

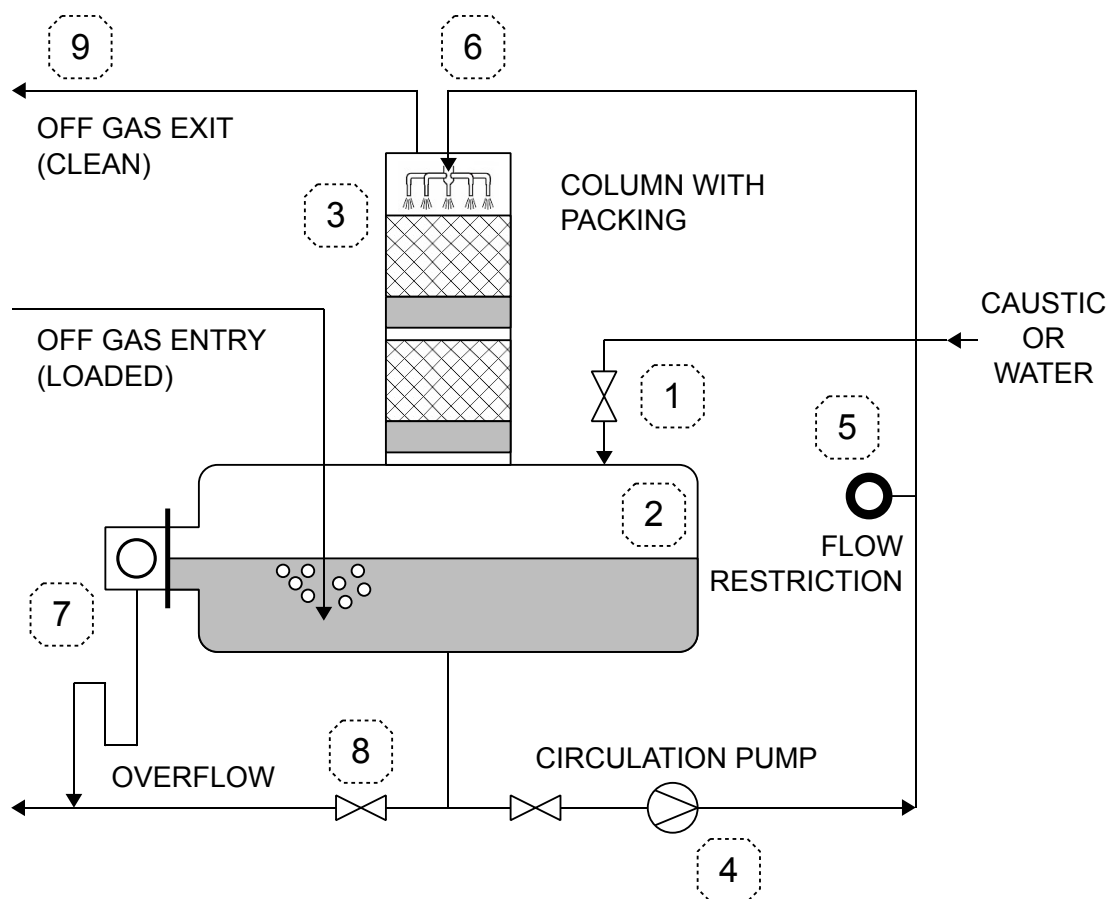
After the fire, continue to monitor the temperature of the storage tank for at least 48 hours to verify that the temperature is not rising and the tank is stabilized.



## 10 Design of Equipment for Acrylic Acid Service

### 10.1 Design Suggestions for an Off-Gas Purification Unit

#### Simplified scheme for a scrubber as Off-Gas Purification Unit



#### Description of suggested Off-Gas Purification design

1. The inlet valve can be designed for manual operation or as a flow control valve. If water is used as an absorbent a continuous flow should be maintained. The overflow is disposed of into a sewer routed to a biological wastewater treatment. If this is not available diluted sodium hydroxide should be used as absorbent.

2. Suitable material for the container and the column is stainless steel or glass fiber reinforced resin.
3. For the random packing, Raschig rings or any other packing material may be used. The insertion of 2 distributor trays is recommendable. The packing may be stainless steel or plastic material. For stability reasons, trays should be made from stainless steel.
4. Recirculation pump according to design data.
5. Flow restriction for the absorbent in the bypass. If too much absorbent is fed into the column, the free gas flow is suppressed and pressure will build up.  
With insufficient feed of fluid the washing efficiency is unsatisfactory.
6. A conical nozzle uniformly distributes the absorbent on the packing.  
If packing of the column is not uniform the gas escapes through a coherent channel and no washing is achieved.
7. Overflow into the sewer (only if routed into treatment plant).
8. Valve for complete drainage of the container.
9. Outlet for the purified exhaust gas.

**The following layout data are suggested:**

<b>Volume flow</b> in [m <sup>3</sup> /h] of absorbent in recirculation:	2-4% of gas volume flow V in [m <sup>3</sup> /h]
<b>Diameter D</b> [mm] of column:	15 to 25 times the square root of the gas volume flow V in [m <sup>3</sup> /h], corresponding to a gas velocity of approximately of 0,5 to 1,5 [m/sec].
<b>Length L</b> [mm] of column:	Approximately 10 to 20 times the diameter D [mm]



2. Cooling and heating media return.
3. Level indication with low/high alarm and low/high interlock and recording. Interlock high should shut down the unloading pump to avoid overfilling of tank. Interlock low should shut down the pump to avoid spray formation in the tank or dry running.
4. Conservation valve and flame arrestor to protect the tank shell in case pressure design characteristics are exceeded. Flame arrestors must be periodically inspected for free passage (polymer formation!) .
5. Vapor return line with insulation and heat tracing (depending on ambient temperatures). The vapor return line minimizes emissions. For fire protections the line should be equipped with a flame arrestor. The line has an inclination so that any condensed liquid is drained back. The flame arrestor must be inspected for free passage (polymer formation!) prior to using the line.
6. Drain valve and sight glass. Empty out, if condensed material from vapor return line is visible.
7. Product off-take to consumption (application process).
8. Temperature indication with high/ low alarm and reading.
9. Temperature control with high/ low alarm and reading.
10. Sump pit below truck unloading station for collection of spills. This pit should be separated from other pits which may contain incompatible materials.
11. Earthing (grounding) of Isotainer.
12. Drain valves for pump and line system.
13. Earthing (grounding) of tank.
14. Check valve in unloading line to avoid backflow from tank into Isotainer.
15. Insulation of the whole storage tank.
16. Diked area around tank and pumping station to collect spills.
17. Temperature indication with high alarm and interlock at the product pump to protect pump from overheating and to avoid polymerization.
18. Safety and eye showers (not shown).
19. Unloading hose (dedicated).
20. Flow indication with low alarm and interlock at discharge of product pump to protect pump from dry running and deadheading (overheating).
21. Off-gas treatment (see [subsection 6.2.5, page 27](#)).

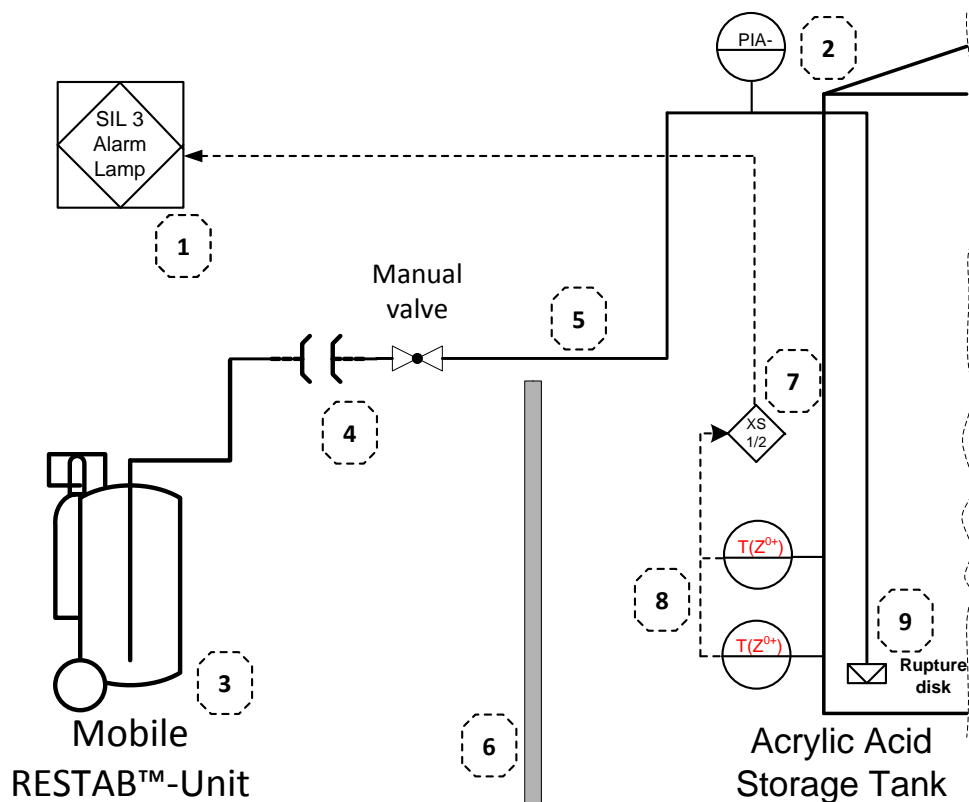


22. Weak-seam roof.
23. Sloped tank floor for complete drainage.
24. Connection of restabilization (see Fig. [section 10.3, page 64](#)).
25. Mixing Nozzle and in case of low level dip tube recirculation.

### 10.3 Design Suggestions for the connection of a restabilization system

The two following diagrams are representing possibilities to inject the shortstop solution into the storage tank in case of emergency. Both systems are either designed or can be designed such that the mixing of the liquid phenothiazine (PTZ) solution is provided even if any other power fails, like e.g. any electrical power supply. However a redundancy in terms of power, local connection to a compressed air network etc. is acceptable to provide for the case of emergency.

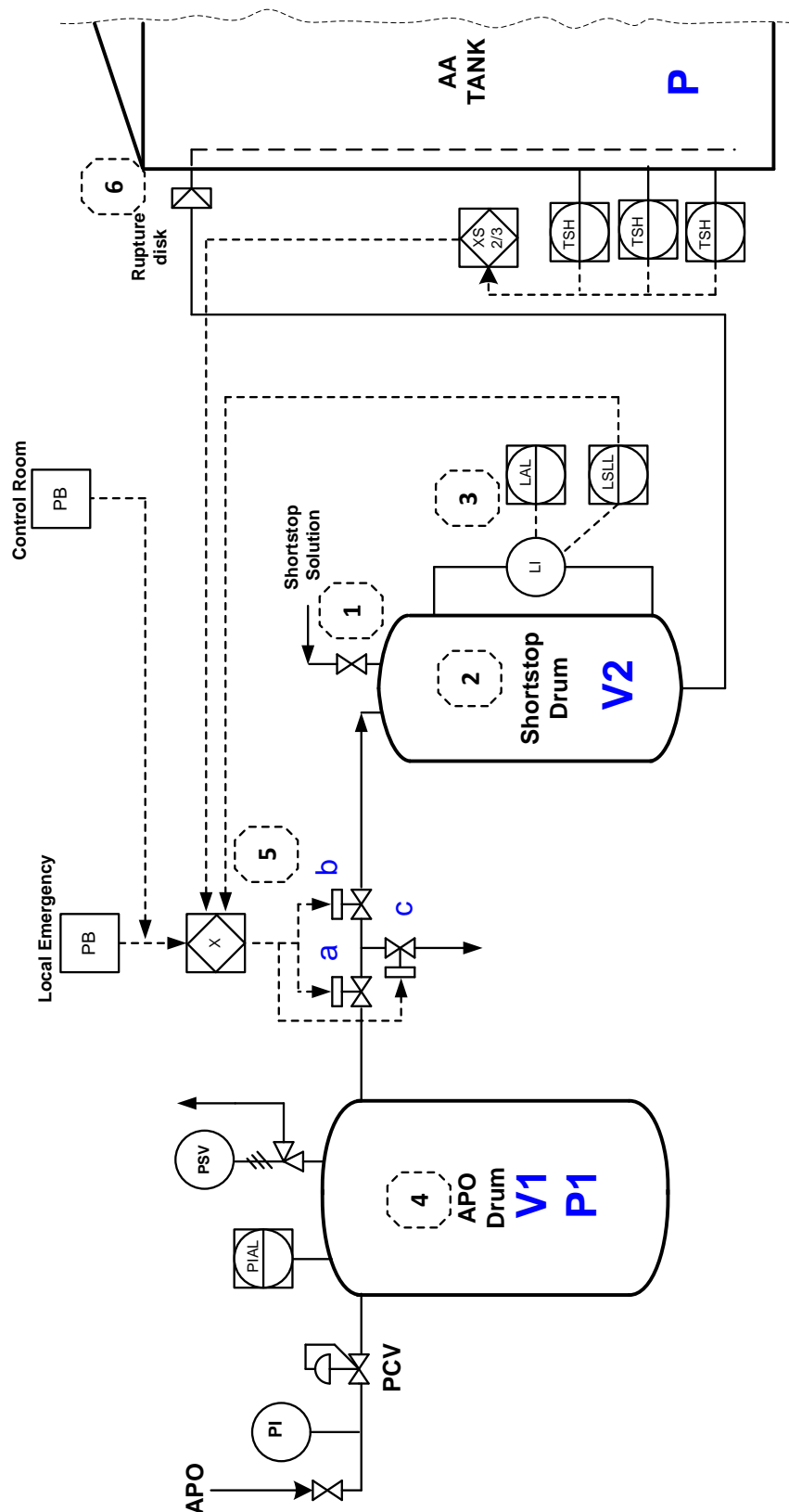
#### 10.3.1 Schematic Design of a tank installation using mobile RESTAB™ units



1. A "SIL 3 level alarm lamp" that cannot simply be muted by a push button. The signal needs to be visible for all operating personnel as long as the alarm condition is in place. The control room has to be 24/7 manned.
2. This pressure alarm is an indication whether the rupture disk is intact. The rupture disk keeps the monomer out of the pipeline to make sure that no polymer is blocking the pipeline.

3. Mobile RESTAB™-Units are commercially available. Please search on the Internet for suppliers. A mobile unit can be used for different tanks. The feed pipeline has to be dedicated.
4. The mobile unit is connected via a dry disconnect coupling. Only after the valves at the RESTAB™-Unit have been opened the manual valve is opened.
5. Dedicated pipeline for the restabilization liquid designed such that the pressurized gas will convey the liquid completely especially through the vertical sections of the pipeline.
6. A Fireproof Wall at banded area or a place distant to it where the connection of the mobile unit can be made safely even if a fire is inside the banded area of the storage tanks.
7. For safety purposes a "1 out 2" selection is used to initiate the alarm. A "1 out n" alarm is suggested in case of a higher number of temperature probes in the storage tank.
8. Two independent temperature probes located such that they are always covered by liquid and as far apart as possible are installed. The thermocouples installed are of "SIL 3" quality being themselves redundant.
9. Zero void volume rupture disk at the end of a dip tube. The construction should be such that the dip tube can be taken out and the rupture disk repaired without having to empty the tank. Alternatively the pipeline can be kept clear using a constant flow of air. In this case a low flow alarm instead of a low pressure alarm should be used.

### 10.3.2 Schematic Design of a fixed installation restablization (shortstop) system



1. Filling or refilling of shortstop solution in the drum
2. Shortstop solution storage, capacity of volume V2, is adapted to the dilution

level and to the AA storage tank size.

3. Level indication with low alarm and with LSSL reported in the control room.
4. Air or lean air pressure tank of volume V1 and pressure P1, used to flush shortstop solution into the AA storage tank of static pressure P.
5. Interlock sequence opening valves a and b, and closing valve c, in order to push shortstop solution. A manual valve can also be used provided it is located in a safe place distant enough from storage tank.
6. Rupture disk bursting under the pressure of shortstop solution going to the AA storage tank.



## 11 Appendix

### 11.1 Incompatible Substances

Almost any contamination can potentially destabilize the monomer and should be avoided. The following is a partial list of chemicals which are considered to be incompatible with Acrylic Acid. In most cases, these contaminants cause polymerization of the monomer.

1. peroxide or peroxy- in name
2. per in name, e.g. t-butylperacetate
3. peresters or peroxyesters
4. percarbonates or peroxyarbonates
5. hydroperoxide or hydroperoxy- in name
6. azo compounds
7. azides
8. ethers (if containing peroxide)
9. amines
10. conjugated polyunsaturated acids and esters
11. aldehydes and some ketones
12. reactive inorganic halides (e.g. thionyl chloride, sulfuryl chloride)
13. caustics (e.g., NaOH, KOH, Ca(OH)<sub>2</sub>)
14. strong mineral acids (e.g., nitric, sulfuric, hydrochloric acids)
15. oxidizing agents (e.g., chromic acid, permanganates, nitric acid)
16. mercaptans
17. carboxylic acid anhydrides (rendering MeHQ inefficient)
18. inert gases (<5% Vol.-% oxygen)
19. certain transition metal ions (iron, ...)

## 11.2 Instructions in Writing According to ADR

Actions in the event of an accident or emergency

In the event of an accident or emergency that may occur or arise during carriage, the members of the vehicle crew should take the following actions where safe and practicable to do so:

- Apply the braking system, stop the engine and isolate the battery by activating the master switch where available;
- Avoid sources of ignition; in particular, do not smoke or switch on any electrical equipment;
- Inform the appropriate emergency services, giving as much information about the incident or accident and substances involved as possible;
- Put on the warning vest and place the self-standing warning signs as appropriate;
- Keep the transport documents readily available for responders on arrival;
- Do not walk into or touch spilled substances and avoid inhalation of fumes, smoke, dusts and vapours by staying up- wind;
- Where appropriate and safe to do so, use the fire extinguishers to put out small/initial fires in tyres, brakes and engine compartments;
- Fires in load compartments should not be tackled by members of the vehicle crew;
- Where appropriate and safe to do so, use on-board equipment to prevent leakages into the aquatic environment or the sewage system and to contain spillages;
- Move away from the vicinity of the accident or emergency, advise other persons to move away and follow the advice of the emergency services;
- Remove any contaminated clothing and used contaminated protective equipment and dispose of it safely.

**For the labelling please refer to ADR as published under:**

[http://www.unece.org/trans/danger/publi/adr/adr\\_linguistic\\_e.htm](http://www.unece.org/trans/danger/publi/adr/adr_linguistic_e.htm)

## 11.3 Index of Abbreviations

ADR	Accord européen relatif au transport des marchandises dangereuses par route. European agreement concerning the international carriage of dangerous goods by road.
BAMM	Basic Acrylic Monomer Manufacturers Inc.
BLEVE	Boiling Liquid Expanding Vapor Explosion



BS	British Standard
CAS	Chemical Abstract System
Cefic	Conseil Européen de L'Industrie Chimique
CENELEC	Comité Européen de Normalisation Electrotechnique
CLP	Regulation on Classification, Labelling and Packaging of substances and mixtures
DIN	German Industry Standard (Deutsche Industrie Norm)
EBAM	European Basic Acrylic Monomer
EC	European Commission
ECHA	European Chemical Agency
ECTA	European Chemical Transport Association
EFTCO	European Federation of Tank Cleaning Organizations
EINECS	European Inventory of Existing Commercial Chemical Substances
EPCA	European Petrochemical Association
EPDM	Ethylene propylene diene monomer
eSDS	extended Safety Data Sheet
EU	European Union
EVOH	Ethylene Vinyl Alcohol Polymer
GHS	Globally Harmonised System
HAZOP	Hazard and Operability
IBC	Intermediate Bulk Container
IBC Code	International code for the construction and equipment of ships carrying dangerous chemicals in bulk
ICE	Intervention in Chemical Transport Emergencies
IEC	International Electrotechnical Commission
IMDG	Code International Maritime(IMO) Dangerous Goods Code
IMO	International Maritime Organization
ISO	International Standard Organization
LEL	Lower Explosion Limit
LC50	Lethal Concentration (50%)
LD50	Lethal Dosis (50%)
LOC	Limiting Oxygen Concentration
MeHQ	Monomethyl ether of hydroquinone
mSv	milli Sievert (unit for radiation)
NEC (US)	National Electrical Code (United States)
OECD	Organization for Economic Corporation and Development
OEL	Occupational Exposure Limit
PC-valve	Pressure control valve
PE	Polyethylene

PPE	Personal Protective Equipment
PTFE	Polytetrafluorethylene
PTZ	Phenothiazine
PVA	Polyvinyl Alcohol
PVC	Polyvinyl Chloride
REACH	Registration Evaluation Authorization of Chemicals (European Chemicals Legislation)
RID	Règlement International concernant le transport de marchandises dangereuses par chemin de fer. Regulations concerning the international carriage of dangerous goods by rail
RTC	Rail Tank Car
SIL	Safety Interlock Level
SQAS	Safety and Quality Assessment System (Cefic )
STOT	Specific Target Organ Toxicity
UN	United Nations
UV	Ultra Violet
UEL	Upper Explosion Limit

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