POTASSIUM HYDROXIDE

PRODUCT STEWARDSHIP MANUAL

Table of Contents

Introduction

Olin is the second-largest producer of Potassium Hydroxide Solutions in North America. Our state-of-the-art production facility and strategically located distribution terminal system further augment our ability to provide rapid, reliable product delivery across North America.

This Olin Product Stewardship Manual contains information on the safe handling and storage of Potassium Hydroxide, also called Caustic Potash, and offered by Olin as a service to its customers and others who handle, use, store, ship, or dispose of potassium hydroxide.

This manual contains information on the physical and chemical properties of potassium hydroxide, health hazards, precautions for handling, first aid, personal protection, containment and cleanup of spills and leaks, disposal, procedures and equipment for safe handling and storage of bulk shipments.

Contact your Olin representative with questions.

At Olin, safety and quality are integral to everything we do. Our goal is zero when it comes to safety, with a focus on preventing accidents, injuries, and chemical incidents not only within Olin, but also as part of Olin's Chlor Alkali Products & Vinyls stewardship program. Olin has internal processes to foster continuous improvement in the areas of product quality, environmental protection, safety, and product stewardship.

Product Stewardship

At Olin, our Product Stewardship program is guided by our core values – Act with Integrity, Drive Innovation and Improvement, and Lift Olin People. We are committed to the safe handling and use of our products – and enabling all our collaborators throughout the value chain to do the same. As a responsible corporate citizen we assess our products' safety, health, and environmental information and take appropriate steps to protect employees, public health, and the environment.

Ultimately, our product stewardship program's success rests with everyone involved with Olin products – from the initial concept and research to the manufacture, sale, distribution, use, disposal, and recycling of each product.

At Olin, we understand that integrating sustainability into everything we do is paramount in our privilege to operate. Olin's stewardship not only extends to care of people and the environment, but also incorporates embodying sustainable practices in our entire value chain.

Manufacturing Location

Olin manufactures Potassium Hydroxide at the Charleston, TN, plant. Through our network of manufacturing facilities, terminals, and shipping equipment, we can ship potassium hydroxide just about anywhere within the United States and North America. For more information about your specific needs, contact an Olin Sales representative.

Manufacturing Process

In the chlor alkali process, a saturated potassium chloride solution (brine) is electrolyzed in an electrolytic cell using membrane technology to produce a dilute potassium hydroxide solution. Olin then concentrates and purifies the potassium hydroxide solution to meet industry demand.

Olin manufactures two strengths of potassium hydroxide solutions: 45% and 50% by weight.

Physical & Chemical Properties

Potassium hydroxide solutions are clear and colorless in appearance and are odor-free. Solid potassium hydroxide is an opaque-to-slightly white, crystalline material that can sometimes be observed on equipment such as delivery hose connections once the solution has dried. Other physical properties such as density, freeze point data, thermal properties and viscosity information can be found in the Technical Data section of this manual.

Potassium hydroxide is corrosive to a variety of surfaces including skin, eyes, some metals, and leather. Appropriate care must be taken when handling potassium hydroxide to prevent injury to personnel and/or damage to equipment and the environment. This manual contains information on how to safely handle potassium hydroxide solutions.

Potassium hydroxide is a very strong base. A 50% solution has a pH of 14. In fact, potassium hydroxide is such a strong base that it would have to be diluted to 5.5% potassium hydroxide concentration to detect a pH below 14. Even at concentrations of less than 0.2%, potassium hydroxide still has a pH greater than 11. In many situations, particularly in the case of environmental impact, a pH greater than 11 is still considered very basic and it may warrant further processing and/or special handling. It is important to keep potassium hydroxide solutions separate from strong acids as the reaction can be violent.

In addition to acids, other compounds including oxidizing agents, phosphorous, certain metals, acetaldehyde, acrolein and acrylonitrile, can react (sometimes violently) with potassium hydroxide. Exposure to metals such as aluminum, brass, bronze, tin, zinc, and their alloys can generate hydrogen gas. Care must be taken during storage and handling to prevent accidental mixing of potassium hydroxide with any of these compounds. See the most current Safety Data Sheet (SDS) for additional information on compatible/incompatible chemicals.

Table 1 – General Physical Data for Potassium Hydroxide Solutions

General physical data for Potassium Hydroxide				
Concentration of KOH (% w/w)	45%		50%	
Specific Gravity at 20°C (68°F)	1.4512		1.5089	
Weight of 1 U.S. Gallon at 20°C (68°F)	12.11 lbs.		12.59 lbs.	
Weight of 1 m^3 at 20°C (68°F)	1451 kg		1509 kg	
Freezing Point (approximate)	- 30°C	- 22°F	- 4°C	39°F
Viscosity at 20°C (68°F)	6.2 cps		8.7 cps	

Figure 1a – 45% Potassium Hydroxide Solution

Figure 1b – Potassium Hydroxide Flakes

Regulatory and Certifications

Olin's potassium hydroxide solutions are well-suited for use in a variety of applications. We offer product certification upon request for various industry and regulatory standards. Contact your Olin Sales representative to discuss specifications, certifications, and product grades (food grade and food chemicals codex (FCC)) available in your particular market.

- American Water Works Association (AWWA B511)
- NSF/ANSI/CAN 60 (Standard 60): Certification by National Sanitation Foundation (NSF) (current locations and grade availability can be found at www.nsf.org)
- Kosher: Certification by Star-K (current locations and grade availability can be found at www.star-k.org)

For further regulatory information, contact your Olin sales representative.

Regulatory commitments apply to the product as shipped from an Olin location and delivered in the Olin-arranged original shipping container, or to product as picked up by the customer from an Olin location. Assurances that the product has not been altered or otherwise changed after being removed from the Olin-arranged original shipping container or after transfer into the customer shipping container, such that it no longer meets the above criteria, will have to be obtained from those companies responsible for the subsequent storage, handling, or repackaging of the product.

Safety & Handling

Safety Data Sheet (SDS)

The following health and safety information is intended to provide general guidelines only. Potassium hydroxide solutions are highly corrosive and very reactive. To prevent personnel injuries and environmental exposure, this product stewardship manual and the most current SDS should be reviewed and understood. Never handle any potassium hydroxide solution before you have read and understood the relevant SDS. The SDS may also provide additional information that is not contained in this manual.

The SDS must be readily accessible to all persons where the product is being used. It is your responsibility to ensure that the most up to date SDS, provided by the supplier, is available to and understood by all employees who work with potassium hydroxide solutions. To obtain an SDS, visit Olin's website at www.olinchloralkali.com or call Olin's Division Headquarters at (423) 336-4850.

This manual should also be reviewed and understood by personnel prior to working with potassium hydroxide. All employees should be instructed and trained in the properties of potassium hydroxide solutions and safe operating procedures and practices including:

- Toxicological Properties
- Personal Protection
- Safe Handling
- First Aid Procedures
- Safety Shower & Eyewash

Always review the Safety Data Sheet (SDS) before handling Potassium Hydroxide solutions.

Toxicological Properties

Danger: Potassium hydroxide is a strong alkali or base which will present a serious health hazard if improperly handled. It is corrosive to the skin, eyes, mucous membranes, and the respiratory tract. Accidental skin or eye contact with this material can cause pain, severe burns, permanent tissue, or eye damage. Mists (from KOH solutions) and dust (dried KOH) represent a hazard to the respiratory tract.

If inhaled, exposure may cause irritation, burns, or permanent damage of the lungs and the respiratory system. Ingestion may cause damage to the gastrointestinal tract with the potential to cause ulceration or perforation. See the SDS for additional information on potential exposure hazards.

Personal Protective Equipment (PPE)

A PPE hazard assessment can help a facility determine what PPE will protect individual(s) performing work for process operations. Consult **The Chlorine Institute** *Pamphlet 65, Personal Protective Equipment for Chlor Alkali Chemicals* and a qualified safety or industrial hygiene professional before conducting a job hazard assessment.

Hazard assessments should be performed for each job task. The results of the hazard assessment can be used to select the level of PPE to protect individual(s) against the hazards of the task. Hazard assessments should be reviewed on a periodic basis and whenever operating practices, procedures or conditions change. The PPE recommendations for several common potassium hydroxide handling tasks below are based on The Chlorine Institute Pamphlet 65 guidance.

Figure 2 – Example of Personal Protective Equipment

- Basic PPE required for routine work duties – such as monitoring the process operations and sampling – should include a hard hat, safety glasses, and the availability of safety goggles and face shield. It is especially important that the face and eye protection match the potential hazards. Because of people's natural tendency to turn their head when solution is sprayed in their direction, both goggles and face shield should be worn for better eye and facial protection. This is especially important when performing line-breaking work.
- When work duties include performing line breaking such as disconnecting unloading hoses or maintenance activities, full PPE should be used, rubber (Neoprene or equivalent) jacket and pants, hard hat, rubber (Neoprene or equivalent) gloves and boots. Consult the most current SDS for additional guidance.
- Additional PPE may be required when containing or cleaning up spilled chemical, especially if the potassium hydroxide solution has dried. If there is potential for KOH dust or mist in the area, an OSHA/ NIOSH respirator approved for this situation should be used.
- In addition to each person's individual PPE, every potassium hydroxide handling area should be equipped with the appropriate emergency PPE including full-face respirators for potential misting situations, chemical resistant suits for emergency response personnel, and safety shower and eyewash stations. This equipment should be kept clean and in good working order and be easily accessible. The storage area for safety equipment should be labeled with a complete listing of its contents.

Safe Handling

- Know the location of the nearest safety shower and eyewash fountain and confirm it is functioning before performing any work in that area.
- Always handle potassium hydroxide solutions in a way that prevents spillage. Potassium hydroxide solutions can make floors slippery. Serious falls and injuries, complicated by potassium hydroxide burns, may result if potassium hydroxide is not immediately cleaned from floors, stairs, or other walkways.
- Avoid bodily contact with any form of potassium hydroxide and immediately flush exposed areas with copious amounts of water.
- Do not use mild acidic materials to neutralize potassium hydroxide on skin and in the eyes. Doing so may significantly increase the severity of chemical burns. See First Aid section.
- Do not mix potassium hydroxide with water or acids except under the direction of trained personnel. This should only be performed in equipment or facilities that have been designed to handle these types of reactions. Because of the large heat of dilution, spattering may occur.
- The neutralization of potassium hydroxide liberates significant heat and can be a violent reaction. This reaction becomes more pronounced as the potassium hydroxide concentration increases. Application of a water spray to the spill before neutralization occurs is recommended to reduce the vigor of the neutralization reaction and the generation of heat. Consult government regulations for proper disposal of neutralized residues.
- Make sure that potassium hydroxide spills, residues, or products of neutralization are not discharged directly into sewers or streams in violation of federal, province, state, and local requirements.
- Mists given off by potassium hydroxide solutions are suffocating and irritating when inhaled. They are also corrosive to most metals and other materials of construction. Therefore, it is important to maintain adequate ventilation at all locations where potassium hydroxide is handled. The choice of appropriate respiratory protection will vary depending upon the expected vapor concentrations in air.
- Carbon monoxide can form from the reaction of potassium hydroxide and carbohydrates, like those found in foods and beverages. Use particular caution by following appropriate vessel entry procedures before entering tanks and equipment used in this service.

Safety Showers & Eyewash Stations

According to OSHA regulations, safety showers and eyewash units need to be located in areas that have the potential for exposure, such as unloading stations, process pumps, control valves and spill containment areas. OSHA refers companies to the ANSI Standard Z358.1 which further defines issues such as accessibility and visibility.

According to ANSI, these safety appliances should be located on the same level as the hazard, without access impediments such as steps, curbs or doors and be located within 10 seconds of reach. They should also be visible even when someone's vision is impaired. Color-coding, reflective tape or some similar method should be used to distinguish them from surrounding equipment, handrails, or walls, so that everyone working in the area will know their location. For more information, consult the most current edition of American National Standards Institute/International Safety Equipment Association ANSI/ISEA Z358.1.

Figure 3 – Safety Shower & Eyewash Station

General First Aid

Prompt response to bodily exposures is critical to minimize potential injurious consequences. Ensure that medical personnel are aware of the chemical(s) involved if exposure or injury occurs.

Always review the most current Safety Data Sheet (SDS) and provide it to medical personnel administering care to injured persons. To obtain an SDS, visit Olin's website URL (www.olinchloralkali.com) or call Olin's Division Headquarters at (423) 336-4850.

First Aid Procedures

Eye Contact: Immediately flush with water for a minimum of 15 minutes, holding eyelids open and occasionally lifting the upper and lower eyelids to ensure water reaches the affected areas. Remove contact lenses if present and can be easily removed.

Washing with water is the only acceptable method of removing potassium hydroxide from the eyes and skin. Do not use soap. A sensation of heat indicates the water is effectively diluting the potassium hydroxide – continue rinsing despite the temporary discomfort.

Do not transport the victim unless the recommended flushing period is completed or if flushing can be continued during transport. Seek medical attention immediately.

Skin Contact: Immediately flush with large quantities of clean water for at least 30 minutes. If there is potassium hydroxide on the head and face, do not remove goggles until after this area has been thoroughly flushed with water. Remove contaminated clothing and jewelry.

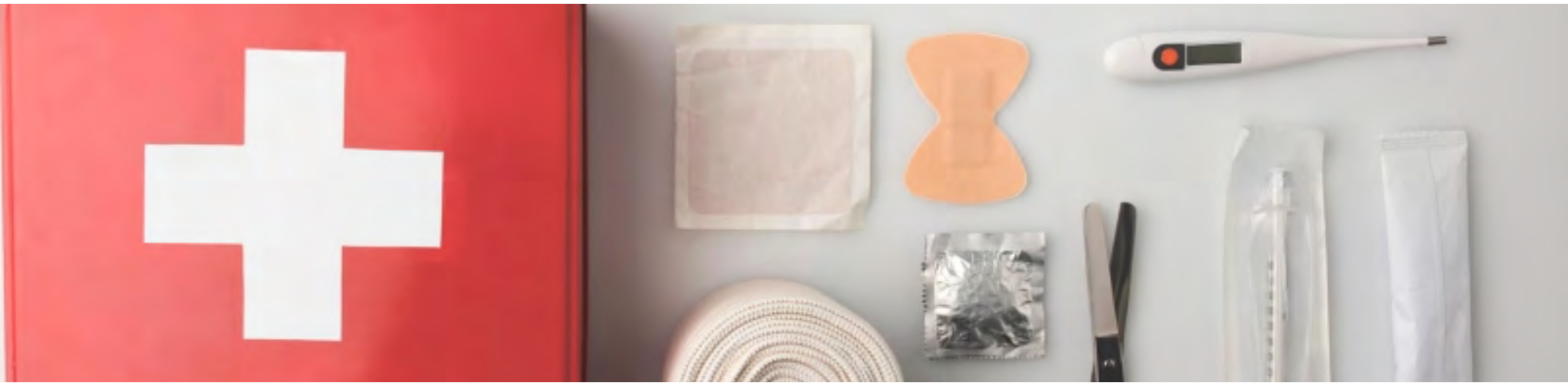
Clothing that has come in contact with potassium hydroxide should not be worn until it has been washed thoroughly. Discard contaminated shoes. Seek medical attention immediately.

Ingestion: **DO NOT** induce vomiting. Immediately drink large quantities of water or milk (at least 8 ounces or 240 mL).
DO NOT give anything by mouth if the person is unconscious or having convulsions. Seek medical attention immediately.

Inhalation: Move person to fresh air immediately. If breathing is difficult, give oxygen. If breathing stops, provide artificial respiration. Induce artificial respiration with the aid of a pocket mask equipped with a one-way valve. Seek medical attention immediately.

Before work continues, adequately ventilate the work area and equip personnel with proper respiratory protection.

Emergency Response Plan & Contacts



Each facility should maintain current procedures for handling emergencies occurring both on-shift and after hours. If your facility meets the requirements of 29 CFR 1910.38 and **external personnel** will be expected to resolve the emergency, then you must have an Emergency Action Plan (EAP) that describes how employees will respond to different emergencies.

Sites with ten or more employees must maintain a written EAP, although a written EAP is desirable for sites of any size. Periodic drills should be conducted to verify employees know the EAP and can carry out the duties identified in the EAP.

Including local emergency response agencies in facility drills can also enhance the effectiveness of drills and communication activities with the community.

Emergency Action Plan

In general, an EAP should address:

- Means of reporting fires and other emergencies.
- Evacuation procedures and emergency escape route identification.
- Procedures for operating critical controls prior to evacuation.
- Accounting of all employees.
- Rescue and medical duty assignments.
- Names/job titles to contact in emergencies.

Emergency Response Plan

An Emergency Response Plan (ERP) is to be maintained for sites that meet the requirements of 29 CFR 1920.38 and 29 CFR 1910.120, where site employees will also act in a First Responder role.

The ERP has additional detailed procedures that specifically address First Responder roles such as training, emergency recognition and prevention, PPE and emergency equipment, decontamination procedures and establishing incident command, to name several components.

The ERP should be periodically revised with your Local Emergency Planning Committee (LEPC) to ensure compliance with local, province, state, and federal requirements.

Like EAPs, it is important to conduct frequent Plan drills. Including your LEPC or outside responder in facility drills can provide important insight into Plan strengths and weaknesses and can also strengthen relationships with the community.

General Spills

In general, when encountering a leak or spill, the primary focus should be to always maintain your personal safety as well as those around you.

Consult your EAP or ERP regarding specific actions to take when encountering a spill event and you will be seeking assistance from external personnel.

It is important to prevent potassium hydroxide solutions from spilling onto soil, storm sewers or into waterways. Since it is a strong base with a high pH, potassium hydroxide can threaten the survival of most wildlife, especially in aquatic environments.

Potassium hydroxide solutions are corrosive with steel and will react with wood and many organic materials. Potassium hydroxide will readily react with aluminum, zinc, tin, brass, and other nonferrous metals. The reaction will generate flammable hydrogen. Care must be taken to avoid contact with critical structural elements to prevent building and infrastructure damage. If potassium hydroxide was in contact with a building or infrastructure element, the affected area must be thoroughly rinsed and inspected for potential repairs.

Figure 4 – Containing a Minor Spill

How to Respond to Spill Events

Step 1 – Evacuate and Activate

- Evacuate all personnel from the area and restrict access.
- Maintain safe refuge away from and upwind of the spill area.
- Activate the site's Emergency Plan.
- If external personnel will perform Response duties, activate the **Emergency Action Plan.**
- If facility persons will perform Response duties, activate the **Emergency Response Plan.**

Step 2 – Suit up and Remediate

Only trained facility personnel or trained external personnel should perform these functions.

- Suit up with appropriate PPE per SDS and never respond alone.
- Isolate and contain the spill with use of inert materials (ex: sand, dirt, etc.).
- Recover as much chemical as possible for re-use.
- For unusable material, transfer liquids and residues to an approved Hazardous Waste container for proper disposal.
- Manifest and dispose of unusable materials, residues, and their containers consistent with all local, province, state, and federal regulations.
- Neutralize affected area with weak, buffered acids.
- Decontaminate all equipment, PPE, and materials.
- Launder any clothing or jewelry prior to re-use.

Step 3 – Report

- Immediately report spills in accordance with local, province, state, and federal regulations.

Consult the SDS to determine the Reportable Quantity (RQ) threshold for this material. U.S. Federal law requires that if the spill is greater than the RQ it must be immediately reported to the National Response Center (NRC) at 800-424-8802.

Consult local, province, state, and federal regulatory agencies for specific requirements unique to your location. Additional regulatory reporting requirements may vary by jurisdiction.

Storage Tanks, Piping Systems & Other Equipment

Potassium hydroxide users are responsible for building and maintaining a properly designed, safe, and easy to maintain storage and handling system. A properly designed and installed system that meets the objectives of safety and maintenance is generally most economical in the long term.

The following items are important considerations when installing a new storage and handling facility or upgrading existing site equipment. Key factors must be kept in mind when handling potassium hydroxide solutions:

- Potassium hydroxide is highly corrosive and can be hazardous to personnel.
- The viscosity of 45% and 50% potassium hydroxide solutions increases rapidly when temperature falls below 68°F (20°C).
- The weight of undiluted potassium hydroxide solutions is 1.5 times that of water.
- Solution temperature and strength will affect corrosion rates with various materials.

Storage tanks should be located to minimize piping runs, especially exterior pipes in which potassium hydroxide solutions can freeze if a heating system malfunction occurs. It is equally important to locate storage and piping in low traffic areas to minimize potential exposure to personnel.

The following mechanical features are required for potassium hydroxide storage tanks:

- Filling inlet at the top of the tank
- Outlet to the process
- Vent directed away from workplace
- Outlet for overfill protection
- Manway or inspection port
- Level indicator fitting

Labeling

Tanks, piping systems, and other handling systems should be clearly labeled to identify chemical contents. Labels or stencils noting the entire, formal product name, e.g., “Potassium Hydroxide” is preferred and especially beneficial to contractors and others not intimately familiar with the tank farm.

Labels should comply with OSHA’s HAZCOM Standard (CFR1910.1200) and with Canada’s WHMIS (Workplace Hazardous Materials Information System) for Canadian sites. A preferred practice is to also post the Class 8 – Corrosive placard with the UN number (UN 1814) on the storage tank and the unloading connection point.

POTASSIUM HYDROXIDE

Labeling of pipelines provides critical information regarding the intended contents and associated product hazards. General pipeline labeling indicating the product and flow direction can be especially helpful when performing line-tracing activities.

The labeling of receiving pipelines, near the delivery connection point, is particularly important because it can provide an additional layer of protection against accidental delivery of the wrong chemical by providing a visual reference of intended contents for delivery and unloading personnel.

The ASME / ANSI A13.1 standard for pipe marking, requires an employer to use labels that state what a pipe contains and what possible hazards are related to that substance. Always review all federal, province, state, county, city/municipality labeling requirements.

Storage Tank Sizing

The receiving vessel should be part of the bulk storage system strategy. The receiving tank should be large enough to easily accommodate a full inbound bulk shipping container, compensate for likely transit times and tank heels.

The consumption rate and the mode of deliveries are the determining factors in deciding the size of the storage tank.

A general rule of thumb is to size the storage tank at least 1.5 times larger than the full bulk shipping container to maximize freight savings and have ample room to avoid tank overflow during product unloading. Also, the tank capacity should allow for at least two weeks of product consumption, whichever is larger. This means the storage tank should have a capacity of at least 9,200 US Gals (35,000 Liters) in the case of tank truck deliveries and at least 24,000 US Gals (90,000 Liters) in the case of tank car deliveries.

Materials of Construction

Butt-welded stainless steel is the preferred material of construction for storing and handling potassium hydroxide solutions, especially for applications where minor amounts of iron (Fe) pickup are of concern. Tanks should be constructed to American Petroleum Institute (API) 12F, 620 or 650 standards depending on the design parameters chosen. Weld annealing should be performed, especially for tanks subjected to temperatures above 120°F (50°C). A vertical tank design is generally favored over horizontal installations. The rate of level change for a vertical tank's inventory remains constant throughout the fill process and in some applications a lesser tendency for accidental tank overflows can be realized. Tanks should be installed above grade.

Grades 304 and 316 of stainless steel are often selected for potassium hydroxide service where product temperatures do not exceed 170°F (77°C). Stress crack corrosion becomes more prevalent above this temperature. For applications not sensitive to iron pickup during transfer and storage, carbon steel may be utilized. In iron-sensitive end-use applications where carbon steel is utilized, a suitable potassium hydroxide-resistant coating or lining should be applied to the storage vessel. Liner choice will be influenced by factors such as the expected temperature target for product storage. Use of an experienced, reputable coatings company can help ensure the correct coating is selected and that it is applied under optimal conditions for maximum performance.

Nickel and nickel alloys such as Monel® and Inconel® are preferred for high-temperature applications above 170°F (77°C). These materials and nickel-cladded steel are also frequently utilized in select areas of vessels such as the attachment nozzle for steam coils, which will be subject to localized high temperatures during operation.

Fiberglass Reinforced Plastic (FRP) and High-Density Polyethylene (HDPE) materials can be used for potassium hydroxide storage but are typically limited to applications involving smaller product volumes due to the high specific gravity of potassium hydroxide. A compatible surface veil, corrosion barrier and curing procedure are critical design elements to review with your tank fabricator. Components made of aluminum, zinc (example: galvanized pipe), tin, copper and brass will be readily attacked when exposed to potassium hydroxide and should be avoided. Exposure to these types of metals may result in generation of hydrogen gas.

Fabricator Evaluation

The tank fabrication and lining processes are critical to long-term success when storing potassium hydroxide. Industry experience has shown merely utilizing chemically compatible material alone is not a guarantee for lengthy tank service lifetimes. The corrosiveness of potassium hydroxide solutions dictates that special evaluations of the fabricator and the material of construction should be performed, regardless of the type of construction chosen. In addition to fabricator expertise, always consult with your tank manufacturer to ensure the tank is of adequate design to handle the corrosivity and density associated with this product.

Fabricators should be selected based on:

1. Their experience in fabricating tanks intended for this product
2. The performance record of their tanks with potassium hydroxide service
3. The fabrication process used

Once a fabricator is determined, it is important that the manufacturers' recommendations on installation and preventative maintenance are strictly followed.

Venting

Adequate venting is critical for ensuring the tank is not subjected to excessive pressure or vacuum conditions. When unloading shipping containers by compressed air padding, the tank will be subjected to a nearly immediate, large volume of compressed air at the end of the shipping container unloading process, and when transfer lines are cleared.

All tanks, regardless of material of construction, should have vents sized to allow a complete and rapid depressurization of the shipping container into the storage tank. Vents should be opened to atmosphere at all times and never have valves installed. Tank vent diameters should be at least twice (2X) the size of the largest inlet piping diameter and installed on the roof of the vessel, as a general guide. Factors such as the length of the vent piping and number of turns can impede the release of compressed air pad gas and will require further upsizing of the vent. Consult your tank fabricator for specific guidance.

FAILURE TO ADEQUATELY SIZE THE TANK VENT CAN RESULT IN TANK STRESSES AND POSSIBLE CATASTROPHIC VESSEL RUPTURE.

Overflows

Tanks without overflow devices can spray chemical out of the vent or opened manway during an overfill event. Overflow systems can safely channel these liquids into the containment system instead. Overflow nozzles should be installed:

- On the upper side wall of the tank
- Below the roof line
- Away from the fill inlet nozzle

Piping should be attached to the overflow nozzle to direct liquid flow into containment and away from personnel work areas. Nozzles and piping from overflow devices are generally sized at least 1.5 times larger than the largest inlet pipe to ensure adequate capacity but should be reviewed by your tank fabricator during the design phase of construction or when system modifications are made.

Receiving Pipeline & Inlet/Outlet Nozzles

Pipe diameter guidance will vary depending on site layout and mode of delivery. Two-inch piping is typical for most tank truck serviced locations, while larger diameter piping is common for other delivery modes (tank car or barge) to facilitate rapid product transfer.

- Top filling is generally preferred for potassium hydroxide tanks. Top-fill nozzles are typically installed on the roof of the tank. Bottom-filled tanks should employ a double-block valve arrangement to provide redundant backflow protection.
- Tanks should be designed to address normal product supply and periodic maintenance activities. Most outlet nozzles are located as near the bottom as practical. Where outlet nozzles are not located at tank floor level, a low point drain should be installed to remove product heels for maintenance activities.
- A side or roof-mounted manway, typically 18- or 24-inches diameter, should be incorporated into the design to facilitate future maintenance needs.
- The receiving pipeline should be equipped with a drain valve (where practical) near the delivery hose attachment point routed to containment. This valve can be used to collect delivery samples or relieve hose and pipeline pressure after unloading is completed.

Level Measurement

A level measurement system is important for maintaining process operations and for avoiding a possible overflow condition during inbound chemical delivery. External "sight glass" gauging devices are not recommended due to their potential for leakage and product freezing.

Electronic gauging devices utilizing pressure differential, ultrasound or radar are frequently utilized for tank inventory measurement. Level indicators that are not immersed in the product typically perform best, but all electronic level transmitters should be assigned a scheduled, periodic recalibration cycle to ensure accurate readings over the long term.

Equipping the indicator to activate an alarm or automatic shut-off at preset inventory levels can provide an important additional layer of protection against accidental tank overflow conditions. Use of a second high-level device, independent of the regular level transmitter, is desirable.

Posting the maximum allowable storage tank volume in a location clearly visible to unloading personnel will facilitate calculation of available volume for incoming chemical. This, coupled with a local level readout in clear view at/from the unloading station, will allow the unloading staff (and delivery driver for tank truck shipments) to monitor tank levels more effectively during filling.

Heating

Solution strength and expected ambient temperature conditions are important factors when evaluating the need for heating the handling system, including pipelines, pumps, and tanks. The higher freeze point of 50% potassium hydroxide (39°F or 3.9°C) typically dictates the need for heating provisions. For storage of 45% potassium hydroxide, heating considerations become more critical as ambient temperatures approach its freeze point of -22°F or -30°C. Temperatures in the 80-100°F range are often chosen when viscosities, pumping rates, potential product solidification and metallic corrosion factors are considered for either product grade strength.

Insulation can significantly influence heating system efficiencies and costs. Heating costs and ambient temperature extremes should be considered when selecting the efficiency rating (R-factor) of the insulation. Insulation should be well-protected with jacketing to keep it dry and minimize external corrosion of the metallic surface. Jacketing materials made of aluminum and tin can be easily damaged from potential potassium hydroxide exposure and should be avoided.

Heating can be accomplished with steam or electric heat sources. For bayonet style heating systems, a nickel or nickel alloy heating element should be considered. The heater should be attached to a nickel or nickel alloy flange on the tank nozzle to accommodate the localized high temperature associated with steam heating systems. Carbon and stainless-steel heat exchangers and coils are not recommended due to the accelerated rate of corrosion expected during operation. Horizontal bayonet coils should be properly positioned inside the tank to maximize heating efficiency and protect the tank surfaces from overheating. Horizontal heating coils should be properly supported, typically at least 8 inches above the tank floor and extend across the center of the tank to about one foot of the opposite tank wall. A thermal agitation pattern will form in the tank, resulting in uniform contents heating as the potassium hydroxide solution is warmed around the coils.

Steam should be regulated to a maximum of 15 psig (103 kPa gauge) when heating potassium hydroxide.

A preferred steam heating system involves the use of an external heat exchanger that is supplied potassium hydroxide solution from the storage tank. External heat exchangers offer greater convenience when performing maintenance work, as the tank does not have to be drained for repairs or inspections. The potential for tank wall “hot spots” associated with internal-mounted steam heating systems is also eliminated. Shell and tube or plate and frame design configurations are frequently used. A recirculation pump is required to supply the heat exchanger.

Tank temperature management by use of a temperature controller is preferred as it eliminates the need to manually monitor and operate the heating system. The controller should include a high-temperature alarm and thermocouple at the same liquid level as the steam coils. This guards against the thermocouple erroneously reading the air temperature if the tank is nearly empty, which can cause coils and product heels to be super-heated. Installation of a second thermocouple at eye level provides a conveniently located, redundant temperature readout.

The storage tank can be heated using an electrical, horizontal bayonet type heat exchanger similar to the steam-heated system described above if a source of steam is not available. Electric heat trace cabling or pads applied to the tank exterior offer another heating option. Insulation and protective sheathing should be used to minimize ongoing heat loss, especially when heat trace cabling or pads are the only heat source.

Tie-Downs

Tanks should be adequately secured using tie-downs installed from the factory to prevent tank movement from high winds or seismic activity.

Tank Cleaning, Inspection, and Preparation

Tank cleaning and inspection should be part of a scheduled, periodic maintenance program for potassium hydroxide storage equipment. Tank cleaning frequencies will be influenced by factors such as the amount of product throughput and vessel inspection activities. Tank cleaning residues are hazardous and should be disposed of in accordance with local, province, state, and federal regulations.

Tanks should undergo scheduled visual and mechanical inspections by qualified, trained personnel. Inspectors should adhere to the American Petroleum Institute (API) 653 standard or equivalent for inspecting and repairing steel tanks. Keep detailed inspection records, both from visual inspections and the non-destructive testing (NDT) data obtained during mechanical inspections, for future reference.

New or repaired piping and tank systems should be water tested under use conditions before being placed in potassium hydroxide service.

Unlike stainless steels, carbon steel requires special preparation before storing potassium hydroxide solutions. New, unlined carbon steel tanks and piping or those that have undergone significant repair will develop a fragile layer of ferric oxide surface scale when exposed to air. This scale will be readily dissolved upon the initial tank fill and will discolor clear potassium hydroxide. Colors ranging from reddish-brown to dark grey or black are common. The tank and piping should undergo passivation before the initial product filling process begins for applications sensitive to iron or visual appearance.

Passivation is most effective when the tank walls can be continuously exposed to heated potassium hydroxide for a minimum length of time, drained and then immediately filled to reduce exposure to the atmosphere. The use of a rotating sprayer head inserted via a roof-top opening is often preferred for larger tanks, whereas filling the tank to its maximum fill level may be an option for small volume vessels. Solution strengths of 10-20% potassium hydroxide maintained at a temperature of 100-120°F (38-49°C) for at least 2-4 hours have been found to be successful. Use of stronger and/or warmer potassium hydroxide solutions can reduce passivation times.

The amount of external heating can be minimized by diluting 50% potassium hydroxide in the storage tank and relying on the heat of dilution to provide much of the heat source. After passivation, remove the product heel to minimize contamination of future inbound deliveries and immediately refill.

Containment Systems

Tanks should be installed on an appropriate foundation capable of supporting the weight load of a full tank, taking into consideration soil and sub-soil attributes. Reinforced concrete foundation pads with an impervious material inside the wall are preferred. The tank pad or foundation should be designed to minimize moisture exposure and entrapment to the tank bottom. Elevating pads above the containment system floor is a preferred design concept to achieve this goal.

A well-designed handling system should incorporate effective secondary containment to collect potential drips or spills in product storage and unloading areas. Secondary containment regulations often vary by location, so it will be important to review local codes/city ordinances, as well as province, state and federal requirements in the design phase. In general, containment systems should be capable of holding at least 110 % of the largest tank capacity found in the contained area. For outdoor tanks in high rainfall locations, additional capacity should be considered.

Incompatible chemicals should be separated by walls within the overall containment area. Containment system drain piping should be dedicated to potassium hydroxide or strong alkali effluents.

Concrete is typically the preferred choice for bulk storage containment systems. A well-designed system will have reinforced floors and walls. The concrete should be sealed with an industrial coating to extend containment lifetime and to limit the potential of chemical migration through cracks or open expansion joints. The effectiveness of industrial coatings will be largely influenced by the overall condition of the concrete, amount of surface preparation before application and the type of coating applied. Two-part epoxy coatings intended for strong alkalis are preferred. The use of cinder blocks for containment walls is not preferred because of their porous nature and relatively weak strength.

Maintenance and housekeeping practices wherein systems are kept in good repair and any leakage is promptly cleaned up can greatly extend containment system integrity. Maintenance becomes critical as minor imperfections that allow chemical to contact the concrete structure may not be adequately rinsed away from rainfall or housekeeping events.

Containment systems may vary by design and material of construction for non-metallic tanks or small volume storage applications such as “day” tanks. Double-walled tanks are often considered for vessels if there is limited room for the tank and containment system. Use of a liquid-detection monitor in the open space between the tank walls can provide notification of internal vessel failure. The double-walled feature does, however, impede the ability to perform important visual inspections of the tank wall (refer to tank manufacturers’ guidance).

Shipping container unloading stations should also incorporate secondary containment to collect leaks, spills, or wash-down water. Reinforced concrete is generally the preferred material for tank truck unloading station containment systems because most unloading areas must be able to accommodate delivery equipment weight loads.

The presence of railroad ties and the occasional need for track maintenance make removable containment pans preferable to concrete sumps or pits for tank car unloading. Polyethylene or fiberglass reinforced plastic (FRP) containment pans are available from many containment system vendors for liquids collection between track rails. They offer the benefit of being removable for future track maintenance purposes. **Routing of the containment system drains should avoid exposure to incompatible chemicals.**

Piping

Structural strength, chemical resistance and operational conditions are important factors to consider when selecting piping materials of construction. Adequate pipeline support is important regardless of material of construction.

Schedule 40 or greater seamless stainless steel (grades 304 or 316) piping is suitable for most potassium hydroxide applications. Flanged or welded piping is preferred, especially for 2-inch and larger diameters. The threads of threaded pipe tend to act as conduits for potassium hydroxide to weep/leak from the threaded area due to potassium hydroxide's low surface tension. The act of thread cutting also reduces pipe wall thickness and can facilitate pipe failure in these areas if significant corrosion occurs. Use of threaded piping is generally discouraged for these reasons.

Piping should be heat-traced and insulated if ambient temperatures are anticipated to approach the freeze point of potassium hydroxide, even for short periods of time. General temperature guidelines can be found in the Storage Tank Heating section of this manual. Self-regulating heat tracing cabling is preferred for most applications. Heated pipelines should be insulated to minimize heat loss. Insulation should be enclosed in sheathing to maintain integrity and minimize external corrosion of the metal surface that can occur via repeated exposure to rainwater. Sheathing should be chemically compatible with potassium hydroxide to protect against chemical exposure from a mechanical failure.

Steam tracing is generally not recommended for intermittent flow piping as the temperature of potassium hydroxide can quickly exceed recommended maximum temperatures for carbon or stainless steels under static conditions. Excessive temperatures, especially for static product, will result in accelerated corrosion rates. When using steam in continuous flow pipe applications, step-offs or insulators should separate the steam coil from direct pipe contact to avoid localized corrosion. Low-pressure steam, regulated to 15 psig or less should be utilized.

The piping system should be sloped/free draining to facilitate maintenance and avoid low spots and collection of potassium hydroxide, which can make freeze protection more difficult. Low point drains, if utilized, should be directed to containment. Likewise, pipe routing should be selected to minimize potential exposures to personnel or the environment if failure were to occur.

Above grade piping is generally preferred. Flange guards prevent exposure to product sprays and drips that may occur at flanged connections when gaskets fail. Flange guards are particularly desirable in overhead pipe runs or high pedestrian and vehicular traffic areas.

Underground piping is not desirable, but where it cannot be avoided, the pipe should be placed in an impermeable trench with adequate drainage and protected by a removable cover to allow for convenient inspection of piping. Provisions to retard corrosion such as cathodic protection should be utilized for buried pipe runs.

For end-use applications such as dosing meters, small-diameter PVC/CPVC tubing is often used. As with larger diameter piping, proper support is required. A protective enclosure such as a conduit or equivalent device should be used where foot or vehicular traffic is likely.

Pumps and Meters

Potassium hydroxide is a hazardous material; therefore, pumps should be selected carefully. The expected service conditions must first be thoroughly reviewed before a safe and reliable design can be engineered. Material selection must be based on expected service temperatures, pressures, concentrations, and impurities. Once an application has been determined, a pump manufacturer should be consulted for design use and final pump selection.

Magnetic, centrifugal, or positive displacement pumps are frequently utilized in potassium hydroxide service. Stainless steel is preferred for product temperatures maintained below 120°F (50°C) although carbon steel may be considered in some applications for pump internals. Nickel or nickel alloys are typical materials of construction for temperatures exceeding 170°F (77°C). Mag drive pumps are typically plastic lined.

Pumps should be equipped with a power monitor to protect against "run-dry" or "dead-head" conditions. This protective feature is especially important for magnetically driven pumps. Sealed pumps should be protected by a shroud to prevent chemical leaking from the seal to be slung onto personnel and equipment in the area.

Provisions for heating pump casings during cold ambient temperatures should be considered. Variable speed start/stop capabilities are preferred for limiting flow surges and are especially desirable in repackaging operations.

Metering of potassium hydroxide is often achieved using rotameters, magnetic or Coriolis-style flow meters. Internal components should utilize stainless steel, nickel, or nickel alloys. Rotameters should avoid the use of glass, which is prone to chemical attack from potassium hydroxide.

Valves

A number of different valve designs can be used with potassium hydroxide solutions and are generally chosen based on intended service and maintenance experience. Globe, ball, plug, diaphragm, and gate valves could be considered where positive shut-off is required.

Note - Check and butterfly valves are not recommended for positive shut-off applications.

Globe, gate, and diaphragm valves offer the benefit of not trapping liquid inside the valve cavity, which can minimize potential for valve freezing in cold climates. Metal-to-metal and fluoropolymer seat designs are prevalent.

Shipping Potassium Hydroxide Solution

Hazardous Materials Transportation System

The safe transport of hazardous materials such as potassium hydroxide solutions involves several different organizations:

- Regulatory Agencies (U.S. Department of Transportation, Transport Canada, U.S. Coast Guard, others)
- Chemical Manufacturer (Olin)
- Carriers (Railroads & Trucking)
- Tank Car / Tank Truck / Equipment Owners (various)
- Receiving Customer

Each of these organizations plays an important role in the safe shipment of hazardous materials.

Table 2 – North American Agencies per Shipping Modes

Shipping Mode	Regulation/Enforcement Agency
Rail	(USDOT) Federal Railroad Administration (FRA) Transport Canada
Roadway	USDOT – Federal Motor Carrier Safety Administration Transport Canada
Waterway	U.S. Coast Guard Transport Canada
Pipeline	USDOT – Pipeline & Hazardous Materials Safety Administration (PHMSA) Transport Canada

Regulatory Agencies are the governing bodies in the transportation arena that oversee the safe movement of all hazardous materials whether by land, air, or water. They define and enforce the rules covering the safe handling and transport of hazardous materials.

Each regulatory agency has an enforcement arm to assure compliance with record-keeping and equipment regulations. Penalties, including fines and potential jail terms for corporations and individuals, can be imposed for violations of regulatory requirements.

While the U.S. Department of Transportation (and Transport Canada for Canadian shipments) regulates the movement of hazardous materials by rail, road and pipeline, enforcement of these regulations in the U.S. is carried out by different agencies depending on the mode of shipment.

Olin's responsibility in the hazardous material transportation system includes the safe operation of its loading facilities as well as maintaining and delivering the transportation equipment in good working order for shipment whether owned, leased or contracted by Olin. A variety of inspection and maintenance procedures are carried out before the shipping container is offered for shipment after loading.

Olin's goal is to ensure the safety of our personnel and, to the extent possible, all those who come in contact with a shipment of potassium hydroxide, while effectively using our fleet and complying with all applicable laws.

The **carrier**'s (railroads, trucking & marine towing companies) responsibility in the hazardous transportation system is to safely move the potassium hydroxide shipping containers from the shipper to the customer. The carriers must comply with a variety of regulations governing the movement of hazardous materials from agencies, including the Department of Transportation, Transport Canada, the Association of American Railroads, and individual state regulatory agencies.

It is important to note that in the case of tank cars and barges (empty after use), the customers or end-users become the shipper of record when they release the potassium hydroxide container for shipment back to Olin.

Carriers (rail and truck) rely on the shipper (Olin and/or the customer) to provide them with clean, safe, and secure potassium hydroxide shipping equipment.

The potassium hydroxide **customer's** responsibilities in the hazardous materials shipping process are similar to Olin's. Customers must follow the appropriate regulations in the handling and unloading of potassium hydroxide containers and in the case of tank cars and barges, prepare them for shipment back to Olin.

A customer's goal is to safely handle and unload potassium hydroxide containers, comply with all regulatory requirements and where applicable, prepare the container for safe shipment back to Olin.

As the legal "shipper of record," customers assume full responsibility for proper inspection, preparation and securement of tank cars released to the carrier. Failure to adequately prepare containers for reverse movement may result in regulatory fines or citations.

Potassium Hydroxide Shipping Containers

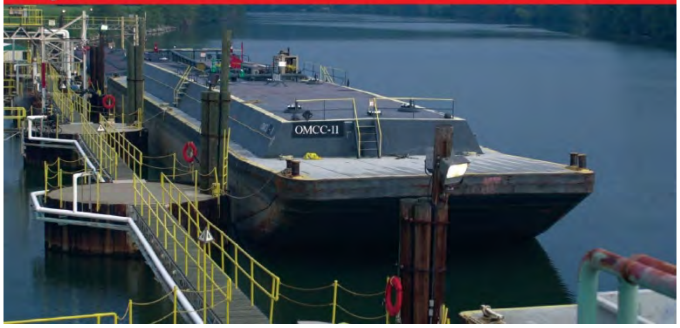
Olin ships potassium hydroxide solutions in bulk containers (tank cars, tank trailers, barges, ships and by pipeline). Each delivery mode has unique advantages. Olin representatives can help you determine which type of delivery method best suits your needs.

Barges

Olin operates a fleet of barges for transporting liquid potassium hydroxide. Capacities range from 600 to 1,000 tons (dry basis). These barges are double skinned, contain 2 to 4 internal storage tanks and have a diesel driven or electrically powered unloading pump on deck. The arrangement of the unloading lines, product valves, piping and unloading pumps will vary between barges. Contact your Olin representative for additional information.

Customers are responsible for barge unloading. The specific unloading system used will depend on the needs and conditions of the receiving site. Very large potassium hydroxide customers located on navigable waterways may save substantial freight costs by taking advantage of barge delivery.

Barges



Ocean Vessels

Olin also has the ability to service the industry worldwide with ocean vessels. Contact an Olin representative for more information.

Ocean Vessels

Tank Cars

Olin owns and/or leases a large fleet of tank cars for shipping potassium hydroxide. Tank cars are built to DOT specification 111S100W1 or 111A100W1. Each car transports 16,000 gallons (52 tons dry basis) of potassium hydroxide. These cars are lined with an alkali-resistant material to prevent iron contamination of the potassium hydroxide. The insulation system has been designed to keep the car contents from freezing in cold weather over normal shipping times and consists of a 4-inch layer of insulation covered by an 11-gauge steel jacket. Some Olin potassium hydroxide cars have a steam jacket for heating the bottom outlet valve area and most are equipped with external steam jackets for heating the entire tank.

Tank Cars

Numerous important regulatory, environmental, safety and health informational items are available on each tank car. Tags and stenciling display required regulatory, car maintenance and operating information as well as safety, spill mitigation and first-aid information along with emergency response contacts.

Customers are responsible for unloading tank cars. Most cars are equipped for both top and bottom unloading (see Unloading section). The specific unloading method utilized will depend on available equipment at the unloading site.

Tank Trucks

Olin may transport potassium hydroxide solutions via contract carriers. Customers may also have their own trucks or may prefer to use a contract carrier of their choice.

Tank trucks used in potassium hydroxide service must be authorized by the regulatory agencies (U.S. DOT, Transport Canada) and include equipment that conforms to the MC-307, DOT-407, MC-312 and DOT-412 designations. While tank trailer capacities vary from approximately 3,500 to 7,000 gallons, they usually contain no more than 12 tons of KOH (dry basis) because of the over-the-road weight limitations.

Tank Trailers

The tank is usually stainless steel and can be insulated or uninsulated. The typically short transit time of a tank trailer makes steam coils or other auxiliary heating of the potassium hydroxide solution unnecessary.

Potassium hydroxide trailers incorporate a double valve arrangement on the unloading line. The internal valve is hydraulically or pneumatically operated and can be closed remotely in the case of an emergency. The unloading connections can be located in the middle or at the rear of the trailer. A data plate specifying tank fabrication, inspection, and other regulatory information is located on the driver's side of the trailer frame near the front.

The DOT requires that tank trailers be inspected periodically (includes internal and external visual inspections as well as leak, thickness, and pressure testing) and that these dates be stenciled on the front head of the trailer. An Olin tag, located on the outlet valve, also provides environmental, safety and health information.

Tank trailers can be unloaded by the driver or by properly trained and certified employees at the receiving site. If the driver unloads the tank trailer, clearly defined procedures should be followed to ensure communication and coordination between the driver and the appropriate plant representatives. See the Unloading section for additional information.

Tank trucks can be unloaded by pad air or pump. Compressed air is applied up to a maximum of 25 psig to displace the potassium hydroxide out of the tank truck through the outlet piping and valve. Trailers are equipped with a rupture disk set at *approximately* 30 psig to protect the tank truck from over pressurization. As a rule of thumb, one pound of air pressure will provide a static lift of approximately 19 inches (48 cm) for 50% potassium hydroxide. *In applications where more than 25 psig of compressed air pad is required, customers should consider use of a fixed pump for tank truck unloading.*

Pipelines

For large users of potassium hydroxide solutions, pipeline supply from Olin's production or terminal locations may be an important consideration during site selection. In such cases, it may be possible for the customer to take potassium hydroxide by pipeline. Olin can offer substantial help in planning for pipeline delivery.

Pipelines

Unloading Potassium Hydroxide Solutions

Unloading Procedures & HazMat Training

Establishment of robust unloading procedures should occur before product is received and then reviewed on a periodic basis or revised when operational practices dictate. Unloading procedures will be unique to each facility, receiving area and delivery mode. However, well-written unloading procedures include several common attributes and components.

Although the primary focus of the unloading procedure is to ensure the correct product is safely delivered into the storage facility, it should also be written to address unexpected events such as spills or other incidents. All procedures should be documented, with periodic training provided, to ensure personnel understand the procedure requirements. *Verbal procedures for unloading should be avoided as they can foster inconsistency between staff members and an ever-changing standard.*

Use of pre- and post-unloading checklists offers the advantage of physically carrying the key elements of the unloading procedure to the work area for review/completion. Errors that can potentially occur from relying upon recollection of the formal unloading procedures can be avoided. Checklists help ensure all key unloading items are reviewed/inspected and encourage consistency between different staff members. Typical components include:

- Review of paperwork (bill-of-lading/shipping papers and certificate of quality) to verify they match the shipping container placard and receiving pipeline label
- Delivery address and purchase order numbers are verified
- Ensure adequate tank space exists to safely receive the entire shipping container contents, regardless of delivery mode
- Safety shower and eyewash units have been located and verified operational
- PPE has been inspected and donned
- Mechanical inspection of the shipping container and transfer hoses has been completed

Because potassium hydroxide is a hazardous material (Hazmat), all personnel handling potassium hydroxide must be properly trained or “qualified” on the topics of General Awareness, Function Specific, Safety and Security as required by 49CFR 172.704 (U.S. DOT) and Transport Canada’s Transport of Dangerous Goods Act S.C. 1992, c.34 (Canada) before handling this product. Regulations require Hazmat personnel to undergo this training at least once every three years.

General Unloading System Requirements

Customers should carefully consider the way that potassium hydroxide solutions will be received and handled at their facilities. Each receiving location needs adequate equipment, facilities, personal protective equipment, and procedures to safely unload this chemical. Personnel should be prepared to deal with both normal and abnormal situations. Unloading system features to consider include:

1. Potassium hydroxide unloading operations must only be performed by properly trained personnel who understand the hazardous materials they are handling.
2. All workers must wear proper protective equipment and clothing per the function specific task being conducted. They also must strictly observe all prescribed safe-handling procedures and practices. Contact with potassium hydroxide solutions can cause severe burns to skin and eyes. If inhaled, it may cause mild irritation to severe burns of the lungs and respiratory tract.

3. Safety showers/eyewash stations and other personal protection equipment should be located in close proximity to the unloading connections. *However, the safety device should be located so that it will not be affected by an accidental release event if that were to occur.* This critical equipment must be easily and quickly accessible by those who need it. For example, someone with potassium hydroxide in their eyes will have impaired vision making it difficult to locate the eyewash unless it stands out very clearly from the surrounding equipment. They would also have difficulty with stairs, curbs, narrow walkways, turns or other obstacles on the way to the safety shower/eye wash. By ANSI Z358.1 Standard, these safety appliances should be located on the same level as the hazard, free of access impediments such as steps, curbs, doors and be located within 10 seconds of reach or approximately within 55 ft.

4. Safe, unobstructed access to and from work areas around unloading connections is required for both routine operation and emergency situations.

5. Leak containment systems (catch pans under tank cars, paved pads under tank trucks) should be provided for those places where spillage may occur. This includes the transfer hose connection drain valves, pump seals and valves. These systems should provide positive control for leaks or spills that might occur during the handling of potassium hydroxide. It is important to make sure the materials of construction for the containment equipment are compatible with all potassium hydroxide concentrations that might be handled in the system. The containment system should be designed and operated such that accidental mixing with other chemicals does not occur. Containment liquids should be verified or tested prior to reuse, recycle or disposal.

6. Adequate lighting is available in all work areas, especially at the unloading connections.

7. Adequate supplies of water (equipment rinsing and spill cleanup) or other utilities should be readily available.

8. Flexible unloading hoses should:
   - Be made of alkali resistant material with a spiral wire wound structure
   - Have stainless steel connections
   - Have a suitable pressure rating for the service where they are used
   - Only be used to connect the potassium hydroxide transportation equipment to the unloading piping. Generally, only one length of hose should be used to prevent safety and handling problems. If situations require use of multiple sections of hose for unloading, corrective actions should be identified to minimize the length of the unloading hose.

9. The unloading area should be roped off/barricaded and warning signs posted to minimize/prevent pedestrian traffic during active unloading operations.

10. Tank car and tank truck wheels should be chocked to prevent accidental movement during the unloading operation.

11. Level indicating devices and communication procedures should be used to ensure that there is enough space in the receiving tank for the entire product load.

12. If a pad gas unloading system is used, air is the preferred pad gas. A point of use oil/particulate filter should be installed on the source air to prevent carry-over into the potassium hydroxide tank car or tank truck during unloading. The source air line should be equipped with a regulator set to a maximum of 25 psig to prevent over pressurization of the shipping container.

13. If any other compressed gas is used, the customer should exercise due caution and Olin should be notified. Gases other than air can have additional hazards associated with them. For example, inert gases, like nitrogen, can present a potential suffocation hazard to workers who work on the tank car, tank truck or storage facility.

14. The vent system on the receiving tank should be properly sized and discharged to a safe area (see Tank section for details). The discharge location of the vent is particularly important with air pad unloading systems as some potassium hydroxide may be atomized in the air when the shipping container's pressure is relieved. If the mist is discharged from the vent, it could pose a hazard to nearby persons.

15. In the case of tank car unloading systems, access by roadway to the unloading station should be considered as a backup in case truck shipment becomes necessary.

Other sections of this product stewardship manual contain additional information on the design and operation of potassium hydroxide solution handling facilities. Additional industry specific information can also be found in the following pamphlets issued by **The Chlorine Institute** at www.chlorineinstitute.org**:**

- *Pamphlet 80: Recommended Practices for Handling Sodium Hydroxide and Potassium Hydroxide Solution (Caustic) Barges*
- *Pamphlet 87: Recommended Practices for Handling Sodium Hydroxide and Potassium Hydroxide Solution (Caustic) Tank Cars*
- *Pamphlet 88: Recommended Practices for Handling Sodium Hydroxide and Potassium Hydroxide Solution (Caustic) Cargo Tanks (Tank Trucks)*

If you have any questions or need additional assistance, contact your Olin representative.

Tank Car Unloading

Tank car unloading must be conducted by qualified personnel according to Transport Canada – Transportation of Dangerous Goods (TDG) and US Department of Transportation (US DOT) regulations. Placards on all 4 sides of the tank car, as well as the valve tags should be reviewed and compared against the Bill of Lading and Certificate of Quality prior to unloading to confirm the product ordered is the product delivered.

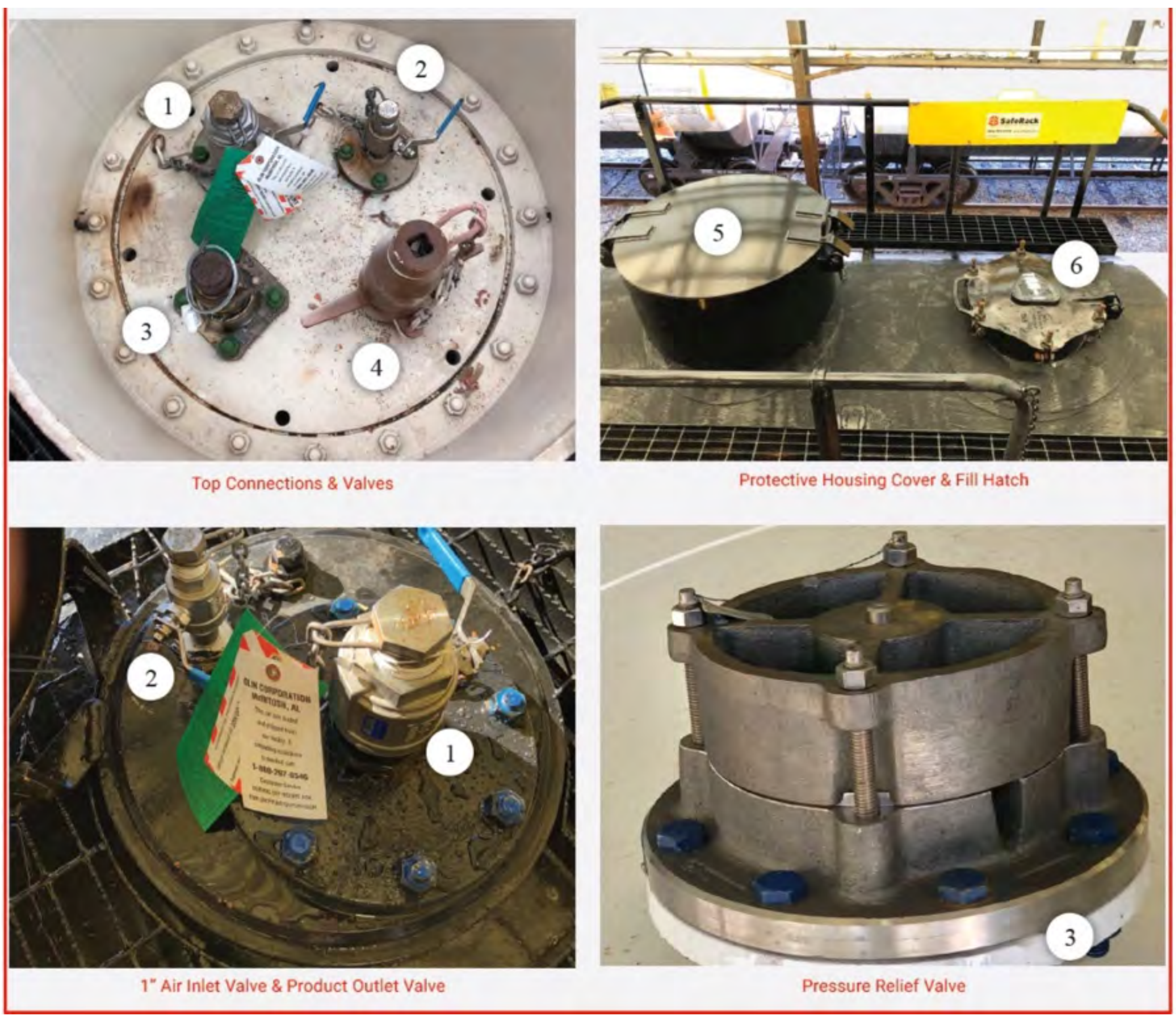
Adequate personal protective equipment should be worn during the unloading. Ensure that safety showers and eye wash fountains are operational before beginning any active operational tasks that may expose personnel to unexpected drips or residues.

Potassium Hydroxide Tank Cars – Top Connections/Equipment

The following equipment is on the top of every potassium hydroxide tank car:

Figure 5 Typical Top Arrangement, Caustic Potash Car (16,000 gal.)

1. 2" Ball Valve – Unloading Connection with Plug (Connected to the Eduction Pipe)
2. 1" Ball Valve – Air/Vent Connection with Plug
3. Pressure Relief Device (Or Rupture Disc)
4. Top-Operated Bottom Valve Box Cover
5. Protective Housing Cover (Dome Cover)
6. Fill Hatch (Can be Used for Sample Collection)

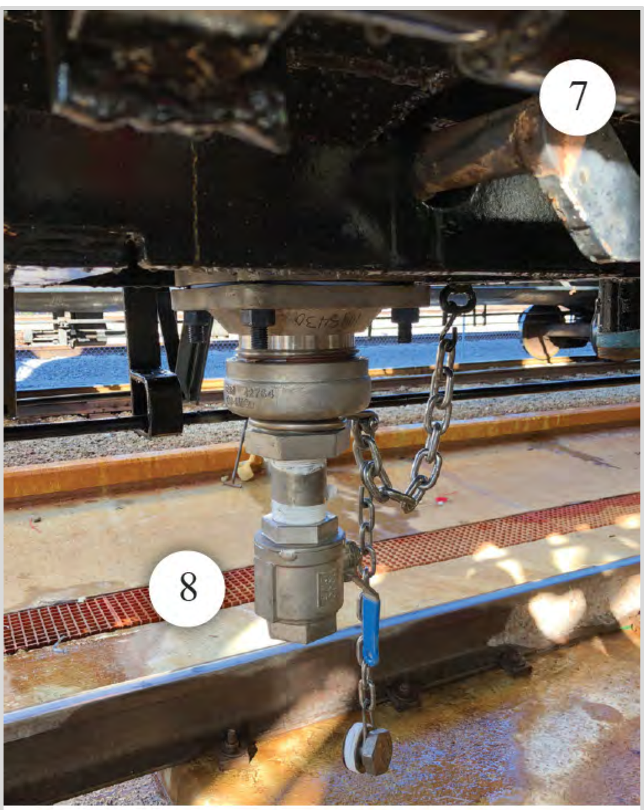


Some cars have all these valves and fittings arranged inside a single protective housing (dome) while other cars have only the 1- and 2-inch valves inside a smaller protective housing. The rest of the equipment on these cars (fill hatch, safety relief, bottom outlet valve wrench handle) is located along the centerline near the protective housing. All valve plugs should have a chain securing them to the tank car. See figures 5, 6, and 7 for typical configurations.

Potassium Hydroxide Tank Cars – Bottom Connections/Equipment

Most tank cars are equipped with an outlet valve for bottom unloading. However, bottom unloading has drawbacks due to safety reasons (see Top or Bottom Unloading section for additional information). On many tank cars, the bottom outlet valve is an internal valve, operated by a connecting or reach rod located near the other fittings on top of the tank car. This reach rod extends from the top of the car to the valve on the bottom of the car. The valve handle forms a protective cover for the reach rod itself. To operate this bottom outlet valve, the reach rod cover (4) is removed, inverted, and connected to the reach rod. Other tank cars have low-profile valves at the bottom of the car. These can be ball valves or wafer-sphere valves.

Figure 6 – Bottom Outlet Valve Arrangement

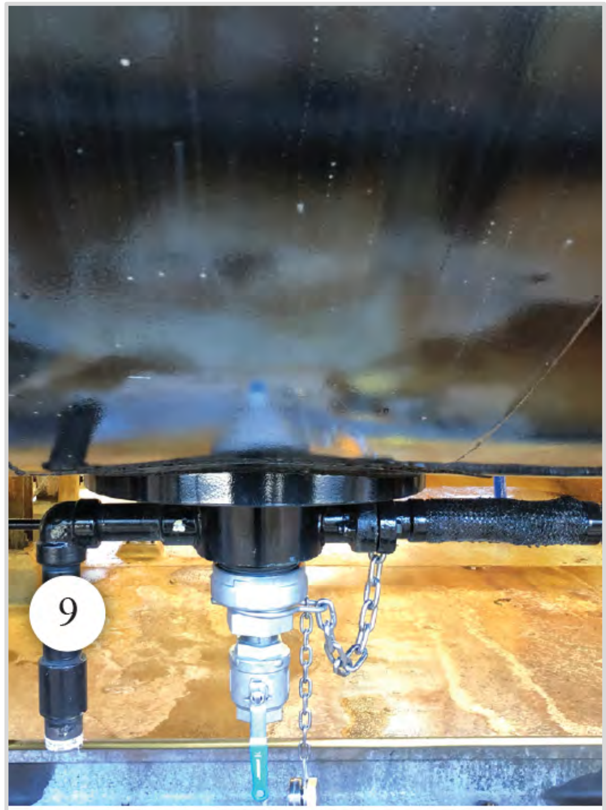


Bottom Outlet Valve & Handle; 2" Auxiliary Valve

Just below the bottom outlet valve (connected to handle (7)), there is an additional 2-inch auxiliary or external ball valve (8) provided for safety and operating ease. For bottom unloading, the operator connects the unloading line to the outlet of the auxiliary valve. Figures 6 and 7 show typical bottom outlet valve configurations.

A steam chamber with individual steam inlet (9) and outlets may enclose the bottom potassium hydroxide outlet in some tank car designs. Either steam connection may be used to attach a steam line when a car is being prepared for unloading. The other connection provides for condensate removal (see Steaming section).

Figure 7 – Steam Coil Inlet Connection



Steam Coil Connection; Top Operated Bottom Outlet Valve and 2" Auxiliary Valve

Potassium Hydroxide Tank Cars – Pressure Relief Devices

Rupture discs or pressure relief valves are installed on all tank cars to prevent over pressurization. The maximum relief pressure depends on the tank car design. If a car is equipped with a rupture disc it will relieve at either 80 or 165 psig (550 kPa or 1140 kPa gauge). Tank cars equipped with a pressure relief valve will relieve at 165 psig (1140 kPa gauge). Details for individual cars are stenciled on the side of the tank.

Some tank cars may arrive with rupture discs that have burst or pressure relief valves that have opened in transit. This is usually due to excessive hydraulic shock when the carriers handle the cars. Efforts have been made to minimize such occurrences (increased rupture disc ratings and internal tank baffles). Contact your Olin representative immediately if tank cars are received with external chemical residue or have blown rupture discs. Failure to install a disc or use of an improper disc can cause an extremely unsafe situation and is in violation of DOT regulations. Additionally, DOT regulations require that persons performing repair/maintenance activities be certified to DOT regulations.

Potassium Hydroxide Tank Cars – Insulation & Steam Coils/Jackets

Olin tank cars have insulation that is at least four inches thick. Because of the effectiveness of this insulation, tank cars with short transit times may require no or minimal steaming during cold ambient temperatures. However, where long hauls or extremely cold weather conditions prevail, tank cars may be equipped with external steam coils or jackets. If the temperature of the potassium hydroxide makes steaming necessary, connection must be made to the steam coil/jacket as well as to the potassium hydroxide outlet chamber.

The steam inlet for the coils/jacket is usually located near the bottom outlet valve. Figure 7 shows a typical configuration for the steam fittings. Unless the connections are otherwise marked, steam may be applied to either end of the steam coil. The other connection serves for condensate removal and should be connected to a steam trap (see Steaming section).

Top or Bottom Unloading – Which Should You Be Using?

Although bottom unloading of tank cars is fairly common, unloading potassium hydroxide solutions from the top has significant benefits to both personnel and the environment. Bottom unloading is generally preferred when tank cars are pump unloaded via gravity or for sites where a compressed air source is not available.

Personnel Protection. Several personnel protection benefits can be realized with a top unloading system. Rapid egress and access from underneath the tank car can be impeded by the undercarriage, grab irons, ladder, and other appliances. The track rails can also contribute to trips or sprains when moving in and out from under the tank car.

All these issues are compounded if a problem, such as a leak, develops while working under the car because any personnel under the tank car are in a potentially awkward position. Anyone hurrying to move away from the bottom outlet runs a greater risk of getting hurt on the various obstructions and obstacles. The typical body positions under the tank car (crouching, sitting and/or laying) can also impede visibility and restrict rapid access in the event of a leak, potentially increasing the risk to the worker.

Almost all these factors are eliminated when unloading from the top of the tank car. Access and egress impediments to the connection points are minimized and there are typically no or only minimal overhead obstructions when working from the tank car platform. In addition, improved body position increases the worker’s ability to be more aware of everything that is going on around them. Use of a top access platform with drop gangway or equivalent maximizes these benefits. Use of a top access platform with fall protection is strongly recommended for both top and bottom unloading to maximize safety and efficiency. References are available for prefabricated platform systems.

Environmental Protection. When it comes to environmental protection, top unloading tank cars have gravity working in their favor. A broken connection or other leak on the unloading hose (or pipe) from the top of the tank car reduces or in the case of pump unloading, eliminates the possibility of spilling the entire tank car contents. If a similar situation occurs in a bottom unloading system, there is a greater possibility that the entire tank car contents will be lost to the ground before the valve could be secured. All of Olin’s potassium hydroxide tank cars are equipped to allow top unloading. If you need additional information or would like assistance in converting from bottom to top unloading, please contact your Olin representative.

Pump Unloading

In a pump unloading system, some air pressure is needed to lift the potassium hydroxide solution up to the top of the eductor or dip tube, at most 12.5 feet and start the liquid flow to “prime” the unloading pump. To lift the potassium hydroxide 12.5 feet requires approximately 10 psig air pressure. Once a pump prime has been established, the unloading will take the same time as if you were unloading from the bottom. It is important to safely depressurize the tank car and leave the fill hatch open when pump unloading to prevent a vacuum from developing in the tank car unless a “dual unloading mode” is utilized.

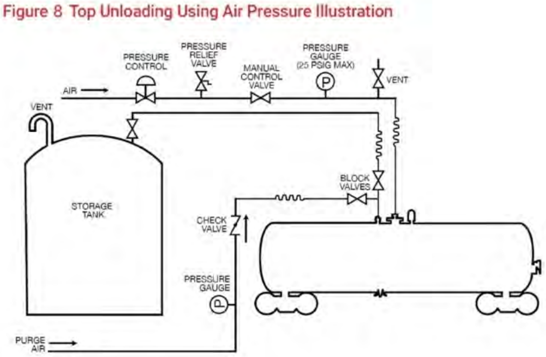
Leaving the fill hatch open is a DOT requirement. Failure to do so could lead to an interruption of the unloading or even damage to the tank car.

The use of self-priming pumps is especially desirable for top-unloading of tank cars. For unloading facilities without self-priming pumps, a “dual mode” unloading process utilizing a transfer pump and a positive compressed air pad application should be considered. The positive pressure pad provides the motive force for pump priming and prevents the tank car from being placed under vacuum conditions. This type of unloading operation would require the tank car to remain sealed during unloading. To prevent accidental vacuum application, a pressure switch or other warning device should be installed to activate pump shutdown if a loss of air pressure occurs.

Top Unloading Potassium Hydroxide Tank Cars

An elevated platform and gangway system should be provided for safe access and egress from the top of the tank car. The platform should incorporate fall protection devices such as protective cages or equivalent fall arrest systems. The pad gas filtration device and hose connection, as well as the receiving pipeline are typically located within arm’s reach of the unloading platform, which limits hose length and associated clutter, while maximizing convenience for component access.

Figure 8 Top Unloading Using Air Pressure Illustration



The preliminary steps of positioning the tank car and installing the necessary safety devices must be carried out in accordance with the instructions outlined in the General Unloading section. The unloading steps should generally follow this sequence:

1. The tank car should be accurately spotted and protected during unloading by warning signs and derails and/or locked switches. The brakes should be set, and the wheels chocked to prevent accidental movement. Warning signs (Blue Flags) meeting DOT/TDG regulations and a closed derail device must be placed at least one tank car length on the open end(s) of the track on which the tank car is being unloaded. These signs must remain in place and the derail set to derail a car as long as the tank car is connected to the unloading system.
2. The dome fittings and safety appliances should be inspected for evidence of leaks or other defects before unloading to prevent possible chemical sprays after the tank is subjected to air pressure.
3. While wearing proper PPE, relieve any tank car pressure or vacuum by opening the 1-inch vent valve making sure that the valve discharge is pointed away from all personnel. Open the fill hatch by first loosening, but not removing, all the nuts. Lift the cover slightly with the opening away from all personnel to ensure there is no pressure, spray, or other problems. Take any necessary samples and confirm that the contents are suitable for unloading.
4. Secure the tank car fill hatch so there are no air leaks. Fill hatch securement bolts should be evenly torqued using a “star” pattern when tightening.
5. If unloading is to be done by air pad, all air line fittings should be inspected before each use for potential leaks and the oil trap should be checked and drained regularly to prevent carryover of oil and other contaminants into the potassium hydroxide. The unloading air system should be designed and operated not to exceed a safe working pressure: 25 psig (172 kPa gauge) is recommended as a maximum and lower pressures are desirable. Contact Olin if pressures above 25 psig are required.
6. Make sure the storage tank is adequately vented to handle the air pressure surge (air pad unloading) that occurs when the tank car is empty.
7. Close the 1-inch ball valve if it was opened in step 2. If the tank car is not opened prior to unloading, remove the 1-inch plug from the air-inlet ball valve and connect the air line. Be sure to install safety pins if quick connect couplings are used.
8. Connect and apply steam to the steam chamber around the bottom tank well/unloading valve if

needed. The bottom well and the top and bottom valves are not insulated and will be the first areas to experience product freezing in colder temperatures. The eductor pipe used during top unloading extends into the bottom well of the car to allow complete unloading of the car contents. Application of steam to the outlet valves and eductor pipe will not thaw chemical inside the tank. Consult the 'Steaming Section' for additional details.

9. Open the 2-inch ball valve on the car and the appropriate valves in the unloading line.

10. Verify the air supply regulator is set to a maximum of 25 psig (172 kPa) before opening the air supply valve. A valve in the potassium hydroxide unloading line can be used to control the flow of the potassium hydroxide. If pump unloading, shut off the air supply when potassium hydroxide flow is established, disconnect the air line and open first the 1-inch vent valve to release all air pressure, then the fill hatch to prevent a vacuum during the unloading process. This vacuum will stop the potassium hydroxide flow at some point during the unloading operation and could cause the tank car to collapse.

    DOT regulations require the fill hatch cover to remain open to provide adequate venting capacity when pump unloading.

11. If air pad unloading, the unloading hose will jump or surge when unloading is completed. Allow the air to blow through the transfer lines to the storage tank for 3 to 4 minutes to clear the lines. Shut off the air to the tank car and allow the pressure to relieve to the storage tank. If pump unloading, shut off the pump when the car is empty (car level is visible through the fill hatch). Note that it is advisable to equip the pump motor with a "low-amp" cut out to avoid/minimize potential damage to the pump sealing mechanism or magnetically driven pump components, if equipped.

12. Close the tank car unloading ball valve and appropriate unloading line valves. Disconnect the unloading line and allow it to drain to an appropriately contained area. When disconnecting the hose, always assume potassium hydroxide is present and under pressure until you are certain this is not the case.

13. Install the plugs on all tank car valves (air inlet and product outlet ball valves), making sure they are wrench tight and that all valves are fully closed. It is a DOT requirement.

14. Wash the tank car and unloading station of any incidental product drippage and collect rinse water in the containment system.

15. Perform a mechanical inspection of the tank car consistent with 49 CFR 173.31 (d).

16. Secure the dome housing with pins and seals.

17. It is important to keep all equipment, tools, and PPE clean. After use wash all valves, hoses, wrenches, PPE, and any other items used during the unloading process to remove oil, dirt, grit and potassium hydroxide residues.

18. **As the legal "shipper of record," you are responsible for ensuring the tank car is prepared for safe return shipment before release to the carrier. Failure to adequately prepare the tank car may result in you accruing regulatory fines or citations.**

Bottom Unloading Potassium Hydroxide Tank Cars

Bottom unloading requires special procedures and PPE be in place to address personnel protection while under the tank car, should a leak or incident occur. A no or low-pressure pad unloading design concept should always be utilized when bottom unloading to further enhance safety. In general, gravity flow of chemical from the tank car to the transfer pump is the preferred method when bottom unloading. For unloading stations that have long transfer distances or do not have a pump, pressure padding or a 'dual motive force' using both a modest air pressure pad and a transfer pump are common options.
Regardless of bottom unloading mode chosen, HIGH PRESSURE (AIR PAD) TRANSFERS FROM THE BOTTOM OF THE TANK CAR ARE NOT RECOMMENDED. The design of the bottom outlet valve assembly dictates only LOW PRESSURE be applied. A pressure pad of ~ 10 psig is adequate for most facility configurations, but in no instance should pad pressures for bottom unloading exceed 25 psig. Figure 9 shows a typical arrangement for bottom unloading potassium hydroxide by pump. The exact configuration will vary by facility design, but unloading steps should follow this general sequence:

1. The tank car should be accurately spotted and protected during unloading by warning signs and derails and/or locked switches. The brakes should be set, and the wheels chocked to prevent accidental movement. Warning signs (Blue Flags) meeting DOT/TDG regulations and a closed derail device must be placed at least one tank car length on the open end(s) of the tank car(s) being unloaded. These signs must remain in place and the derail set to derail a car as long as the tank car(s) is connected to the unloading system.

2. While wearing proper PPE, relieve any tank car pressure or vacuum by opening the 1-inch vent valve, making sure that the valve discharge is pointed away from all personnel. Open the fill hatch by first loosening, but not removing, all the nuts. Lift the cover slightly with the opening away from all

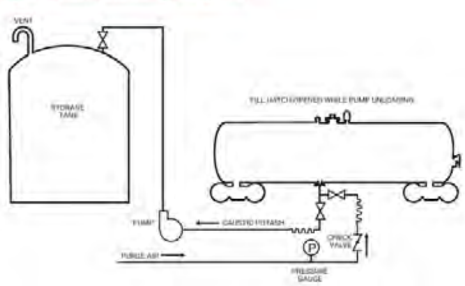
personnel to ensure there is no pressure, spray, or other problems. Take any necessary samples and confirm that the contents are suitable for unloading.

3. For pump or gravity unloading, vent the car by removing the outlet plug from the air inlet ball valve, connecting an appropriate vent line and opening the valve. If air pad unloading, make sure all valves and the fill hatch are closed.

4. Exercise extreme caution when removing the plug from the 2-inch auxiliary bottom outlet valve in case the valves have leaked through for any reason.

5. Open the 2-inch auxiliary valve and any valves in the line to the storage tank. During cold temperatures, apply steam via a steam lance to the exterior of the bottom outlet valve assembly area prior to opening the bottom outlet valve (see Steaming section).

Figure 9 Bottom Unloading Arrangement



6. After connecting and securing the transfer hose to the tank car, open the main outlet valve on the car. **CAUTION: Do not force this valve's movement. Attempting to open/close frozen valves will damage them!**

   Steam should be applied to the outlet chamber until it opens easily (see Steaming section for additional information). Remember that many cars have an internal bottom outlet valve that is operated from the top of the car (see Bottom Connections section).

7. For pump or gravity unloading, it is important to verify the fill hatch is open to prevent buildup of a vacuum during the unloading process. This vacuum will stop the potassium hydroxide flow at some point during the unloading operation and could cause the tank car to collapse.

   DOT regulations require the fill hatch to be opened to provide adequate venting during pump unloading.

   If pump unloading, turn on the pump and potassium hydroxide will flow to storage.

8. Verify the air supply regulator is set to a maximum of 25 psig (172 kPa) before opening the air supply valve. A valve in the potassium hydroxide unloading line can be used to control the flow of the potassium hydroxide. If pump unloading, shut off the air supply when potassium hydroxide flow is established, disconnect the air line and open first the 1-inch vent valve to release all air pressure, then the fill hatch to prevent a vacuum during the unloading process. This vacuum will stop the potassium hydroxide flow at some point during the unloading operation and could cause the tank car to collapse.

   DOT regulations require the fill hatch cover to remain open to provide adequate venting capacity when pump unloading.

9. If air pad unloading, the unloading hose will jump or surge when unloading is completed. Allow the air to blow through the transfer lines to the storage tank for 3 to 4 minutes to clear the lines. Shut off the air to the tank car and allow the pressure to relieve to the storage tank. If pump unloading, shut off the pump when the car is empty (product level is visible through the fill hatch). Note that it is advisable to equip the pump motor with a "low-amp" cut out to avoid/minimize potential damage to the pump sealing mechanism or magnetically driven pump components, if equipped.

10. Close the tank car unloading ball valve and appropriate unloading line valves. Disconnect the unloading line and allow it to drain to an appropriately contained area. When disconnecting the hose, always assume potassium hydroxide is present and under pressure until you are certain this is not the case.

11. Install the plugs on all tank car valves (air inlet and outlet ball valves) making sure they are wrench tight and that all valves are fully closed. It is a DOT requirement.

12. Wash the tank car exterior and unloading station of any incidental product drippage and collect rinse water in the containment system.

13. Perform a mechanical inspection of the tank car consistent with 49 CFR 173.31 (d).

14. Secure the dome housing with pins and seals.

15. It is important to keep all equipment, tools, and PPE clean. After use, wash all valves, hoses, wrenches, PPE, and any other items used during the unloading process to remove oil, dirt, grit, and potassium hydroxide residues.

16. **As the legal "shipper of record," you are responsible for ensuring the tank car is prepared for safe return shipment before release to the carrier. Failure to adequately prepare the tank car may result in you accruing regulatory fines or citations.**

Steaming Procedures

Because of the relatively high freezing point (50% KOH = 39°F or 3.9°C), potassium hydroxide is shipped in heavily insulated tank cars. Tank cars almost always arrive at the user's site with the bulk of the product liquid. However, in cold weather, the outlet valves and the bottom of the eduction pipe are often plugged by a small amount of frozen potassium hydroxide that can be thawed by placement of a steam lance around the outlet valve. Many tank cars are equipped with a steam chamber enveloping the bottom outlet valve assembly which can be heated by applying steam via the coil connectors. A steam lance will be required to thaw top-located outlet valves, if frozen.

Occasionally, the bulk of the potassium hydroxide in the tank car may be frozen on arrival, especially for 50% potassium hydroxide. This condition might be caused by extremely cold weather or very long delays in delivery time. To accommodate these circumstances, Olin has a portion of its fleet equipped with external steam coils to provide a means for thawing the entire contents of a frozen car.

Maximum permissible pressure of the heating steam is stenciled on tank cars. Higher pressure must be avoided. Temperatures from steam at higher pressures may damage linings and result in contamination of the potassium hydroxide.

General Steaming Guidelines

The guidelines below are applicable to steaming either top or bottom unloading of potassium hydroxide cars:

1. Inspect tank cars for evidence of freezing before unloading in cold temperatures. This should be done when the fill hatch is initially opened, and samples are taken. The need for steam application will depend on the solution strength of the tank car and ambient weather conditions. General steaming guidelines can be found on the following page. Be sure to wear the appropriate personal protective equipment when taking the sample from the tank car.

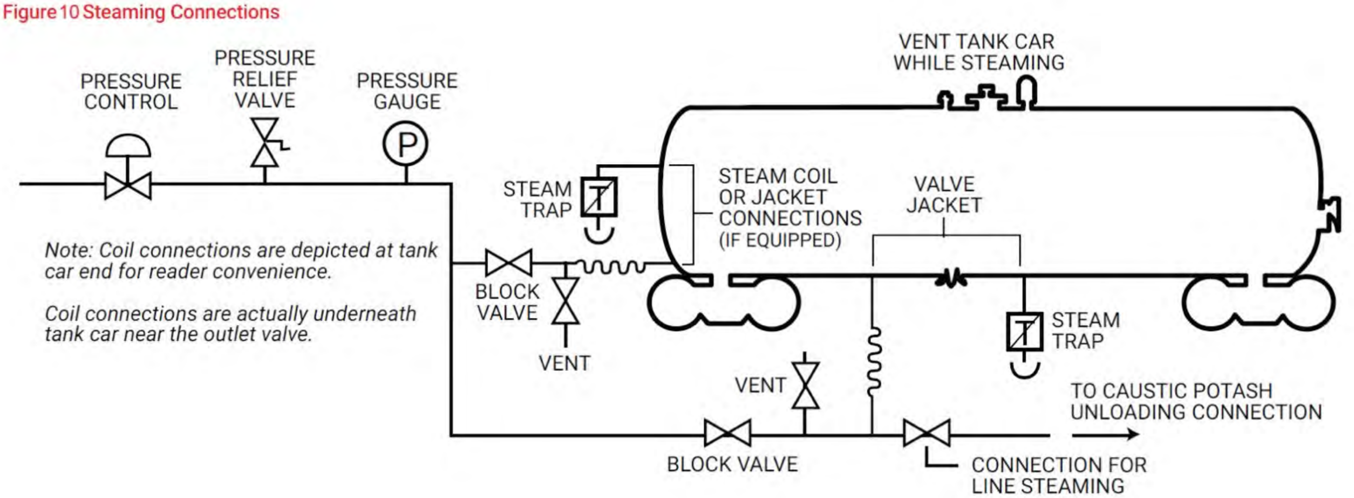
Table 3 – Steaming Guidelines vs Ambient Temperature

Solution Strength	Temperature	Action
50% KOH	Above 80°F (27°C)	No Steam
50% KOH	Below 80°F (27°C)	Apply Steam
45% KOH	Above 60°F (15°C)	No Steam
45% KOH	Below 10°F (-12°C)	Apply Steam

2. In addition to product temperature, the decision when to steam tank car contents should consider factors such as the presence of heated pipelines, pipeline length and desired transfer time. Consult the viscosity data in the Technical Data section of this manual.

3. Tank car valves and their attachment points are not insulated and therefore will typically be the first points to freeze, if any potassium hydroxide residue is inside the valve cavity. Despite confirming product inside the tank car is adequately warm, an application of low pressure (15 psig max.) steam to the external body of the valve(s) may need to be provided whenever ambient temperatures approach the freeze points of either 50% or 45% KOH, respectively. For tank cars without a steam chamber enveloping the bottom outlet valve assembly, heat can be provided via a steam lance (typically made of

Figure 10 Steaming Connections



an L-shaped piece of metallic tubing) connected to low pressure steam and applied to the exterior of the 2-inch auxiliary valve for about 30 minutes to melt any frozen product. Once thawed, it may be necessary to insert the steam lance up through the opened 2-inch auxiliary outlet valve to adequately thaw the internal valve. Never attempt to open the internal valve while applying steam to this valve. Confirm the tank car is connected to the unloading system before opening the internal valve. Apply steam to the internal valve for at least 30 minutes. Steaming work should be performed over catch pans or containment for environmental protection. Always use low pressure (15 psig max.) steam. Never use gas fired cutting or blow torches to heat tank car valves.

4. If the weather is very cold or the car has been in transit for an extended period, it may require significantly longer steaming to liquefy the contents of the car. If the car is equipped with an external heating coil/jacket, steam pressure should be limited to a maximum pressure of 15 psig (103 kPa gauge). Contact your Olin representative for additional information.
5. Never steam partially full tank cars. Steaming application to less-than-full tank cars may result in damage of the protective tank liner.
6. To avoid pressure buildup during steaming, the tank car must be vented by opening the vent valve or fill hatch.
7. Never inject steam or water directly into the tank car through the fill hatch.
8. Electrical tracing used on potassium hydroxide piping and equipment must be thermally rated to withstand a 300 °F (149 °C) pipe wall temperature to allow steaming without damaging the tracing (see Equipment section).
9. On most tank cars, either of the steam fittings can be used as inlet or outlet. Cars with other requirements will be marked to show limitations. A pressure control valve and a pressure relief valve (15 psig [103kPa] maximum) should be installed in the steam line that supplies steam to the heating coils.
10. Use of a steam trap on the discharge of the steam heating connections helps melt solidified potassium hydroxide and is more effective than a throttling valve or any other device on the condensate discharge. Also, using a steam trap saves labor since it requires little attention from operating personnel. Discontinue steaming as soon as product is melted and ready to be unloaded. Adequate steaming is achieved when the product has reached a temperature corresponding to the General Steaming Guidelines. Potassium hydroxide solutions should not be heated any higher than 120°F (49°C) in the tank car. Avoid excessive steaming of tank cars and never steam partially empty tank cars. Steaming partially empty tank cars can damage the protective interior lining very rapidly. Excessively hot potassium hydroxide can also cause rapid corrosion of carbon steel and even stainless steel piping systems (potassium hydroxide temperatures >170°F or 77°C).
11. Remove the steam trap when steaming is completed. In cold weather, condensate should be blown out of the coils with air to prevent damage from freezing. Caps should be left off the steam fittings to allow drainage in transit.

Additional information on steaming potassium hydroxide tank cars can be found in **The Chlorine Institute** *Pamphlet 87, Recommended Practices for Handling Sodium Hydroxide Solution and Potassium Hydroxide Solution (Caustic) Tank Cars* at www.chlorineinstitute.org.

Tank Trailer (Truck) Unloading

Unloading Facilities

Tank trailer unloading stations should be laid out to provide easy access to the receiving pipeline connection. Wherever possible, drive-through unloading stations are preferred over backing of the tank truck into the unloading station. In-plant street access should be designed to accommodate tractor/trailer combinations and incorporate wide intersections.

Reinforced concrete unloading pads sloped to a containment device such as a dedicated sump or French drain provide a hard surface for trailer parking. This unloading pad concept can also collect potential drips and leaks that may occur during the delivery process. Where multiple chemicals are received in the same area as potassium hydroxide, engineering and/or procedural provisions should be incorporated to avoid mixing of incompatible materials.

Rapid delivery typically makes steaming of the trailer unnecessary. However, steam should be available at the unloading site to thaw the trailer's valve, which may have frozen product in cold climates. Additional utilities such as water to rinse unloading equipment and containment, as well as lighting for night-time unloading should also be provided.

The user should provide an appropriate pipeline for product receiving that includes:

1. A 2-inch male quick connect hose connector of stainless steel construction. Connectors located at approximately thigh-to-hip height are preferred for ergonomic reasons.
2. A block valve installed directly behind the hose connector to prevent loss of contents from pipeline backflow.
3. A drain valve located near the transfer hose connection point and directed to containment to relieve hose pressure or collect pre-unloading samples.
4. A clearly identified delivery hose connection point using text such as "45% Potassium Hydroxide" or "Potassium Hydroxide UN 1814" to avoid wrong tank – wrong product events.

Trailers can be provided with air compressors for unloading if the facility does not have a compressed air source. Most carriers do not offer unloading pumps. Check availability with Olin before scheduling your delivery. Customer-supplied compressed air must be regulated to a maximum of 25 psig and include an oil and particulate filter to eliminate introduction of the contaminants into the shipping container and product being received. A Chicago-style connector is standard for attaching the air supply line to the tank trailer.

Figure 11 Typical Tank Trailer Connections

The receiver of the inbound delivery is responsible for checking and accepting the potassium hydroxide before unloading. Procedures should be established and followed to be certain the product is acceptable before unloading.

Typical Tank Trailer Connections

All tank trailers are equipped with an internal foot valve (1), an auxiliary product valve (2), a two- or three-inch quick-connect fitting for unloading hose attachment (3) and a rear emergency shut-off device (4) as depicted in figure 11. Each tank trailer is also equipped with a one-inch Chicago style connector (not shown) for pneumatic product transfer.

Figure12 Typical Emergency Shut-Off Device

Unloading Procedures

Detailed information on tank trailer unloading facilities and procedures is available from **The Chlorine Institute,** *Pamphlet 88, Recommended Practices for Handling Sodium Hydroxide Solution and Potassium Hydroxide Solution (Caustic) Cargo Tanks* at www.chlorineinstitute.org.

The delivery driver normally unloads tank trailers. They are responsible for following the proper safety rules and operating procedures as prescribed by the recipient, Olin, and government regulations. If the truck driver is performing the unloading, it remains the customer's responsibility to verify the driver has attached the unloading hose to the proper tank connection and that the tank has enough available capacity to receive the full load.

A plant representative should accompany the driver during the high-risk part of the unloading activities, such as when the tank trailer is being connected and when the connections are broken after unloading has been completed. The DOT requires that the entire truck unloading operation be attended by a competent unloader who is alert, located within 25-feet of the trailer and has an unobstructed view of the unloading hoses. If the plant representative is in close proximity to the potassium hydroxide hose connection points, they should also wear all applicable personal protective equipment. In addition to being trained in the use of proper protective equipment and specific unloading procedures and equipment, site personnel assisting the delivery driver should be trained in the location and activation of the emergency shut-off device. All tank trailers are equipped with an emergency shut-off device located at the driver's side front and rear of the tank trailer. See figures 11 and 12.

The recipient is responsible for providing competent and knowledgeable supervision, safety equipment special to the site and a properly designed and maintained unloading area. The exact steps of the unloading operation will depend on each site's unique configuration. The steps used in unloading should follow this general sequence:

1. Spot the tank trailer. Set the brakes and chock the wheels to prevent accidental movement. Place warning signs and/or barricades around the unloading area. Locate and inspect PPE and any portable containment devices which may be used. Locate and check the eyewash and safety showers to be certain they are operating properly.
2. Unless the truck's compressor is being used for unloading, turn off the engine and remove the keys to ensure the truck will not be moved prematurely.
3. While wearing full PPE and using fall protection, relieve any pressure or vacuum in the tank trailer by opening the air vent valve, making sure that the valve discharge is pointed away from all personnel.
4. If a sample is required prior to unloading product, open the fill hatch cover by first loosening, but not removing, all the bolts. Lift the cover slightly with the opening away from all personnel to ensure there is no pressure, spray, or other problems. Take any necessary samples and confirm that the contents are suitable for unloading.
5. Secure the fill hatch to prevent any air leaks if air pad unloading or open the fill hatch as a vent for pump or gravity unloading. Fill hatch securement bolts should be evenly torqued using a star pattern when tightening.
6. Make sure the storage tank is adequately vented to handle the air pressure surge (air pad unloading) that occurs when the tank trailer is empty and depressurized.
7. Verify the internal foot valve and auxiliary valve are closed and that the bonnet on the auxiliary valve is tight *before* removing the valve cap. The unloader should position his/her body and open the cap as if there were potassium hydroxide solution in the unloading line just in case some material may have leaked through the valve(s) during transit.

8. During cool ambient temperatures, it may be necessary to thaw frozen chemical residue inside the valve cavity before unloading begins. Tank trailer outlet valves are not insulated and are often the first areas to exhibit frozen chemical during cold weather events. Application of low pressure steam (15 psig or less) to the exterior of the outlet valve for a few minutes is generally effective at thawing frozen valves. See general steaming guidance in the Tank Car General Steaming Guidelines section of this manual.

9. Attach the transfer hose to the tank trailer and to the facility's receiving pipeline connector. Lock or strap the "ears" on all quick connect fittings to ensure that they do not accidentally open during the unloading operation. **If pump unloading, make sure the fill hatch is open to vent the tank trailer and prevent damage and possible collapse.** If air pad unloading, connect the air lines and be sure to use safety pins on all quick couple fittings.

10. Open the valves on the unloading lines. Open the auxiliary, then internal valves, on the tank trailer. Start the unloading pump or open the compressed air line depending on the unloading system. Monitor the tank pressure in the air pad unloading system, keeping it below 25 psig.

11. When the potassium hydroxide transfer is complete, shut off the pump or air pad. The level in the tank trailer can be seen through the open fill hatch with pump unloading. If air pad unloading, the hose will jump or surge when the tank trailer is empty. Continue unloading for 3 to 4 minutes after this starts to ensure the hose and piping are empty. Shut off the air flow source and allow the tank trailer pressure to bleed down through the potassium hydroxide unloading hose; disconnect the air hose.

11. Once the unloading hose and piping are empty, close the internal valve on the potassium hydroxide tank trailer, the auxiliary valve and finally the valve on the receiving piping. Make sure any pressure in the hose is bled off, using the drain valve located on the receiving pipeline prior to closing pipeline valves. Disconnect the hose first at the unloading line and then from the tank trailer. Drain any potassium hydroxide residue into an appropriate containment area.

12. Wash down the trailer, hose, other equipment, and the containment area to remove any potassium hydroxide residue or other materials. Make sure all wash water and any spilled material is collected and handled appropriately. Verify all tank trailer valves are closed. Close and secure the fill hatch lid if it was opened. Properly stow unloading hoses. Verify the pipe cap or plug is secured in place on the tank trailer outlet valve and receiving pipeline.

Barge Unloading

While there are many similarities between barge unloading and tank car unloading, barge operations involve different regulatory agencies and potential hazards associated with the waterways. Detailed information on potassium hydroxide barges, barge handling facilities and procedures and the regulatory agencies involved is available from **The Chlorine Institute** *Pamphlet 80, Recommended Practices for Handling Sodium Hydroxide and Potassium Hydroxide Solution (Caustic) Barges* at www.chlorineinstitute.org.

General Information

Receipt of potassium hydroxide by barge requires careful coordination between supplier, user and various authorities having jurisdiction over the facilities. In the U.S., the Army Corps of Engineers has responsibility for maintaining navigation channels while the Coast Guard enforces the DOT regulations governing vessels, waterfront facilities (up to the first valve within containment) and unloading personnel. Other authorities may also be involved. Canadian barge customers should seek guidance from Transport Canada for applicable regulations.

The U.S. Coast Guard requires that a designated Person-In-Charge of the facilities (PIC-facilities) and a Person-In-Charge of the vessel (PIC-vessel) be assigned and present during the entire unloading operation. There are specific requirements that must be met to qualify as the Person-In-Charge. Contact the Coast Guard or your federal regulatory agency or Transport Canada for Canadian facilities if there are any questions about these qualifications.

Prior to unloading, various items should be checked including:

- Documentation, labels, and markings.
- Barge equipment including pumps, piping, connections, mooring lines, transfer hoses.
- Barge void spaces for the presence of water.
- Emergency equipment, navigation aids and containment devices.
- Testing and certification information. The Coast Guard requires that the hose and lines up to the first valve within the containment be tested regularly and that the pressure indicator be calibrated at least yearly.
- Certifications for all Persons-in-Charge are current.

Unloading Facilities

Special care must be given to the design of barge unloading facilities. In particular, it is essential to prevent the accidental discharge of potassium hydroxide solutions into the waterways. This especially applies to the contents of transfer lines at the end of the unloading procedure.

Unloading Procedures

Personnel safety and protection of the environment is of utmost importance when unloading potassium hydroxide barges. The following items should be included in all barge unloading procedures:

- Use all applicable personal protective equipment (see Personal Protection Equipment section).
- The emergency shutdown system is tested and in good working order before unloading starts.
- Cargo line connections are secured with the correct bolts and properly sized drip pans placed under each connection.
- After a joint inspection, the PICs complete a Declaration of Inspection.
- The unloading operation is monitored at all times for leaks and is carried out to ensure that the vessel does not list (tilt) excessively in the water. Listing can lead to broken mooring ropes, stopping the unloading flow before the barge is empty (starving the pump suction) and in extreme cases, submerging of deck areas.
- Secure the piping and cargo tanks after the barge is unloaded. It is particularly important to make sure any product residues are properly cleaned from the barge and that barge manifold piping is drained to prevent any potassium hydroxide from freezing in the lines.
- A final inspection of barge and unloading facilities is required before the barge is released. A written format is advisable for follow up and record keeping.

  As the legal "shipper of record," you are responsible for ensuring the barge is prepared for safe return shipment before release to the carrier. Failure to adequately prepare the barge may result in you accruing regulatory fines determined by the U.S. Coast Guard or Transport Canada.

Pad Air Quality - Point of Use

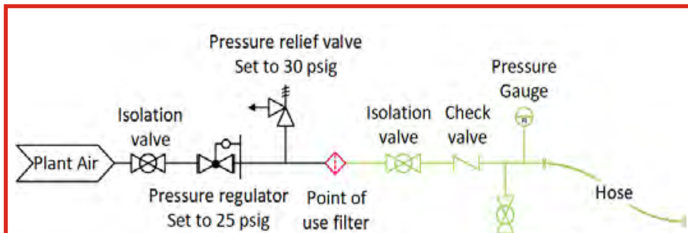
As a customer receiving chlor alkali chemicals such as potassium hydroxide, it is important to understand and implement a proper air padding system for unloading any of the chlor alkali corrosive liquids. Air padding systems can be a significant source of product contamination and require on-going inspection and maintenance to prevent failure. An additional engineering control "point-of-use filter" is recommended for the pad air system at the point of use or connection point to the shipping container.

This filter will help ensure pad air quality while eliminating contaminants such as oil and or solid particulates from being introduced into the shipping container and product from the pad air system. This recommended engineering control requires the following components to be appropriately designed and installed, along with good operating practices.

Note: The following diagram (Figure 13) shows the components of a properly designed pad air system. Proper installation and maintenance of pad air systems can significantly minimize contaminants from entering the shipping container during unloading.

- Safety features including isolation valves, pressure regulator, pressure relief valve, point of use filter, check valve, pressure gauge and purge/vent valve for safe line evacuation prior to disconnection
- Piping (in green) that is used downstream of the point-of-use filter must be made of product-compatible material to protect against chemical vapor introduction and corrosion
- Pad air connector and hose must be made of product-compatible material
- Effective pad air system maintenance program

Figure 13 – Typical Pad Air Supply System



*All components shown in **green** must be compatible with the corrosive liquid being transferred.*

Suggested Filter Arrangement

The point-of-use filter should meet these requirements:

- *Be located close to or at the shipping container* — all 'downstream' components must be chemically compatible.
- Be a high-efficiency filter with a rating of 1.0 micron or less.
- Have a pressure drop indicator and auto-drainer.

Safety Features: Pressure Regulator, Pressure Gauge and Pressure Relief Valve

The use of high pressure on the pad air systems has the potential to overpressure the shipping container, resulting in the *activation* of the safety relief valve on shipping containers and the potential of a chemical leak.

It is often misunderstood that unloading rates are directly related to pad pressures. As a general guide, the volume of compressed air and piping diameter, not the pressure of pad air, have the greatest influence on unloading rates.

In most applications, it is important for the pad air delivery to be regulated so that it does not exceed 25 psig using a pressure regulator. A pressure gauge equipped with a diaphragm made of compatible material of construction such as Teflon™ (PFA, FEP, PTFE) should be installed to allow the control of the pressure during the unloading process.

A good safety practice includes the installation of a pressure relief device set to a maximum operating pressure of 30 psig immediately downstream of the pressure regulator. The pressure relief device provides redundant protection against possible shipping container over-pressurization if the pressure regulator fails.

- Typical safety relief valve settings: approx. 32-35 psig tank trucks, approx. 165 psig tank cars.

Isolation Valve

As shown in figure 13, it is imperative that the isolation valve nearest to the shipping container be in the closed position any time it is not actively being used to apply air, including when the unloading process is stopped. This isolation valve helps ensure corrosive vapors do not back flow into the air system.

Pad Air Piping Material of Construction

Experience has clearly shown that when dealing with corrosive liquids, a careful selection of the pad air system's material of construction at point of use is critical to provide adequate structural strength, chemical resistance and prevent product contamination.

When exposed to these chemical vapors, the resulting corrosion and rust produced will enter the pad air and contaminate the product, as well as the shipping container.

At the point of use or where sections of piping may be exposed to chemical vapors (green section shown in figure 13), chemical-resistant piping is recommended. For a lined piping system, the liner offers the chemical resistance needed, while the metallic piping offers structural strength.

Note: Although solid PVC or CPVC piping offers an adequate product corrosion barrier to chlor alkali products, it is not suitable for use in compressed air service primarily because of the safety risk from shattering and injury to personnel. These materials do not provide the structural strength of lined metallic piping.

Pad Air System Maintenance

A timely and effective maintenance program is critical for ensuring delivery of clean, water droplet-free, oil-free and particulate-free pad air to the shipping container. Despite the implementation of scheduled preventative maintenance programs and well-trained personnel, failures can occur and go unnoticed, regardless of equipment design or configuration.

A white rag test should be performed at least once monthly to provide a redundant verification of proper operation. To be effective, the white rag test should be performed at the shipping container end of the pad air hose by introducing compressed pad air into a clean white rag at regular full flow rates, not throttled, for one to two minutes.

Performance of the white rag test should incorporate safety provisions such as hearing and eye protection, avoidance of line-of-fire body positioning, use of the buddy system, hand protection and a means to mechanically secure the rag to the end of the discharge system.

Any particulate matter, moisture or discoloration observed indicates a failure in one of the system's upstream components and should prompt further investigation.

System maintenance practices will vary by the age of the system, equipment design, manufacturer and operating environment or conditions, but several general guidelines are applicable in all situations.

An inspection checklist should be used to confirm that all components of the system have been inspected or serviced and that any noted deficiencies are corrected.

Maintenance guidelines issued from the compressor manufacturer should be consulted and typically represent the minimum frequency at which maintenance should be performed.

General inspection guidelines for delivering high-quality padding air are shown in Table 4.

Distribution hoses should be visually inspected for evidence of damage such as bulges, cracks or cuts to the exterior sheathing, connector wear or evidence of moisture, residue, or corrosion on the connector.

Table 4 – Pad Air Supply Inspection Guidelines

Hose & Connector	Before each use Daily Visual inspection for evidence of fatigue, wear or damage
White rag test at point of use	At least monthly
Trap & filter inspection/service	At least monthly
Pressure drop indicators	Daily inspection / during use
Filter replacement	Per manufacturer guidelines, white rag test or pressure drop
Regulator or check valves	Annual preventative maintenance
Note: *The information above is given merely as an example. Actual operating conditions, age of system, system design and frequency of use should be considered when developing inspection and maintenance frequencies. Over time, experience and inspection data records may indicate need for further adjustment of maintenance cycles.*	

Unloading by Pump

Where unloading with "pad air pressure only" is not possible, the tank car or tank truck may be unloaded using a pump. Pump unloading is favored by customers desiring to minimize/control fume generation in the receiving storage tank/fume scrubber.

A self-priming, seal-less, centrifugal pump is preferred as the design eliminates packing leaks which may occur with pumps equipped with packing or mechanical seals. Seal-less pumps should be equipped with low amperage flow safety switches to ensure the pump is not operated in a dry or deadheaded state to prevent catastrophic pump damage. The pump manufacturer should be consulted before selecting a pump to review the expected operating conditions, such as the required vertical lift distance from the shipping container to the storage tank or process, type of service (continuous or intermittent) and desired flow rate to determine the best pump for your particular application.

The pump should be located at ground level for ease of maintenance service. The pump should be located within a containment area to collect or contain any leak or dripping from the hose and/or sampling. The pump inlet and discharge should be equipped with drain valves to remove any alkali in the unloading hose or transfer piping when hoses are disconnected or when pump maintenance is required. Customers may utilize the drain valves located on the pipeline or pump for product sampling activities as well.

The procedures and equipment necessary for pump unloading will be determined by the type of pump selected. Additional details may be obtained by contacting Olin's Technical Service Group.

Analytical Guidelines

The accurate determination of potassium hydroxide assay is influenced by many factors including sample point selection, sample technique, sample handling, analytical methodology and analytical equipment and technique.

Prior to sampling at a particular site, a hazard review covering the site-specific functions should be performed to identify the best procedures and personal protective equipment (PPE) for the health and safety of site personnel and the environment. Refer to the Safety Data Sheet (SDS) for potassium hydroxide solutions for additional information on appropriate PPE.

Sampling

Careful sampling is essential for accurate analysis of potassium hydroxide solutions. Exposure of samples to air must be minimized since potassium hydroxide rapidly absorbs water and carbon dioxide.

When shipping container samples are required, top sampling of tank trailers and tank cars is preferred and should incorporate the use of an elevated platform with fall protection provisions. Sample collection and testing should be performed while wearing proper PPE as determined by a qualified safety or industrial hygiene professional. To ensure the most representative sample, the shipping container should be profiled using a sample thief, which will allow all levels of the vessel to be evaluated.

If shipping containers must be sampled from the bottom, the first material withdrawn should be discarded. Minor amounts of scale and other foreign material may be present in the shipping container piping but will not be representative of delivery. Since frozen potassium hydroxide will have different product and impurity concentrations, it should be thoroughly thawed before sampling.

Potassium hydroxide samples should be transferred to clean, dry polyethylene sample bottles. Glass containers should not be used, as potassium hydroxide will tend to etch the glass. Whenever possible, the sample should be collected from a properly designed/engineered sample point installed directly on the unloading piping where there is flow through the sample point.

Procedures should be in place to ensure the sample point is purged sufficiently to provide a representative sample of the shipping container. Consult the SDS for appropriate PPE to be worn during sample collection activities.

All wetted surfaces of sample collection equipment (thief, bottles and bottle cap inserts) should be nonmetallic. Sample bottles should be cleaned and flushed with the sample media.

Fill the bottle to the desired amount but no more than two-thirds of its capacity to avoid over-pressurization, leakage or bottle bulging which may occur as the product warms in storage.

Analytical Methods

Olin recommends the ASTM methods of analysis for potassium hydroxide solutions. These are published as E 291 (Vol. 22) “Chemical Analysis of Caustic Soda and Caustic Potash (Sodium Hydroxide and Potassium Hydroxide)”.

E 291 gives methods for Total Alkalinity, Carbonate, Chloride, Iron and Sulfate. The methods are such that almost any well-equipped laboratory can perform these analyses. These methods are adequate and suitable for most quality control and process purposes. If other methods are required, contact your Olin representative.

Technical Data

The following pages present technical data for potassium hydroxide solutions. If the technical information you need is not included in this manual, please contact your Olin representative.

Table 5 – Physical Constants for Pure Potassium Hydroxide

Physical Constants for Pure (KOH)	
Molecular Weight g/mol	56.106
Boiling Point (1 atm) K °C «F	 1,600 1,327 2,421
Melting Point K °C °F	 633 360 680
Latent Heat of Fusion cal/mol	2,000
Heat of Formation kcal/mol	– 102
Heat of Vaporization cal/mol	30,850
Specific Gravity (@ 25 °C)	2.04

Chart 1 – Specific Gravity for Potassium Hydroxide Solutions at Various Temperatures

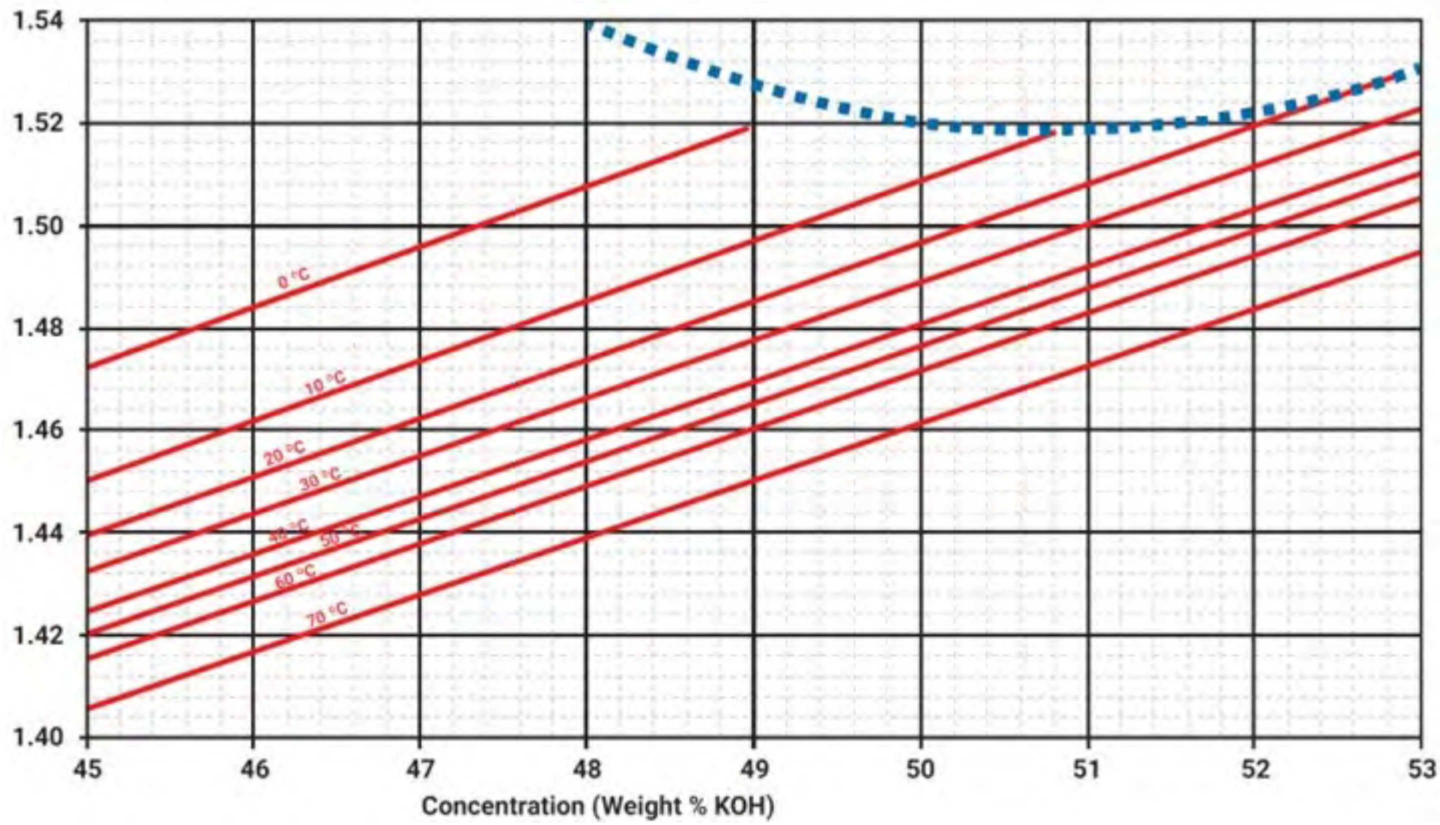


Table 6 – Specific Gravity vs. Potassium Hydroxide Concentration and Temperature Chart (SI units)

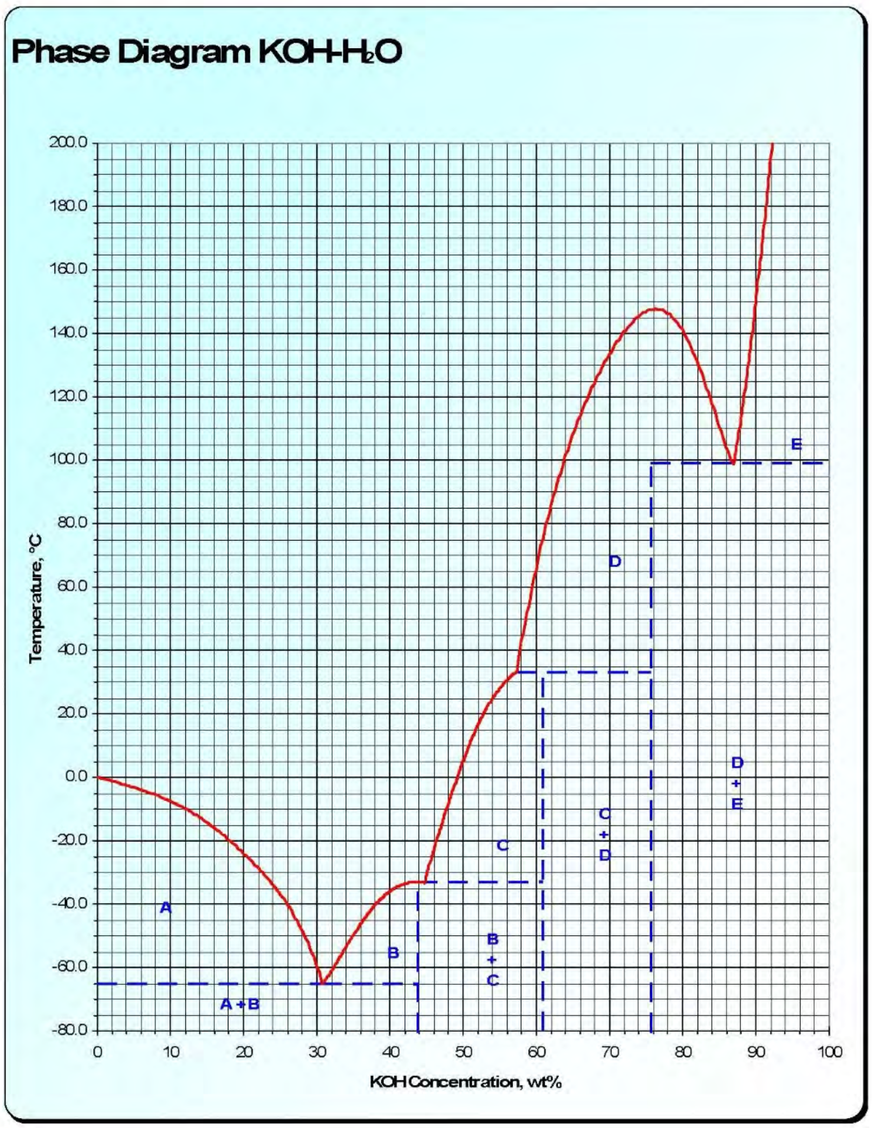
wt% KOH	0 °C	10 °C	20 °C	30 °C	40 °C	50 °C	60 °C	70 °C
44.0	1.4603	1.4505	1.4398	1.4327	1.4249	1.4207	1.4159	1.4060
44.2	1.4626	1.4528	1.4421	1.4349	1.4271	1.4229	1.4181	1.4082
44.4	1.4650	1.4551	1.4443	1.4372	1.4293	1.4251	1.4203	1.4104
44.6	1.4673	1.4574	1.4466	1.4394	1.4316	1.4274	1.4226	1.4126
44.8	1.4697	1.4597	1.4489	1.4417	1.4338	1.4296	1.4248	1.4148
45.0	1.4721	1.4621	1.4512	1.4440	1.4361	1.4319	1.4271	1.4171
45.2	1.4744	1.4644	1.4534	1.4462	1.4383	1.4341	1.4293	1.4193
45.4	1.4768	1.4667	1.4557	1.4485	1.4405	1.4363	1.4315	1.4215
45.6	1.4791	1.4690	1.4580	1.4507	1.4428	1.4386	1.4338	1.4237
45.8	1.4815	1.4714	1.4603	1.4530	1.4450	1.4408	1.4360	1.4260
46.0	1.4839	1.4737	1.4626	1.4553	1.4473	1.4431	1.4383	1.4282
46.2	1.4863	1.4760	1.4649	1.4576	1.4495	1.4453	1.4405	1.4304
46.4	1.4886	1.4784	1.4672	1.4598	1.4518	1.4476	1.4428	1.4327
46.6	1.4910	1.4807	1.4695	1.4621	1.4541	1.4499	1.4451	1.4349
46.8	1.4934	1.4830	1.4718	1.4644	1.4563	1.4521	1.4473	1.4371
47.0	1.4958	1.4854	1.4741	1.4667	1.4586	1.4544	1.4496	1.4394
47.2	1.4982	1.4877	1.4764	1.4690	1.4608	1.4566	1.4518	1.4416
47.4	1.5006	1.4901	1.4787	1.4713	1.4631	1.4589	1.4541	1.4439
47.6	1.5029	1.4924	1.4810	1.4735	1.4654	1.4612	1.4564	1.4461
47.8	1.5053	1.4948	1.4833	1.4758	1.4677	1.4635	1.4587	1.4484
48.0	1.5077	1.4971	1.4856	1.4781	1.4699	1.4657	1.4609	1.4506
48.2	1.5101	1.4995	1.4879	1.4804	1.4722	1.4680	1.4632	1.4529
48.4	1.5125	1.5018	1.4903	1.4827	1.4745	1.4703	1.4655	1.4551
48.6	1.5149	1.5042	1.4926	1.4850	1.4768	1.4726	1.4678	1.4574
48.8	1.5173	1.5066	1.4949	1.4873	1.4790	1.4748	1.4700	1.4597
49.0	1.5197	1.5089	1.4972	1.4896	1.4813	1.4771	1.4723	1.4619
49.2	1.5221	1.5113	1.4996	1.4919	1.4836	1.4794	1.4746	1.4642
49.4	–	1.5137	1.5019	1.4943	1.4859	1.4817	1.4769	1.4665
49.6	–	1.5161	1.5042	1.4966	1.4882	1.4840	1.4792	1.4688
49.8	–	1.5184	1.5066	1.4989	1.4905	1.4863	1.4815	1.4710
50.0	–	1.5208	1.5089	1.5012	1.4928	1.4886	1.4838	1.4733
50.2	–	1.5232	1.5112	1.5035	1.4951	1.4909	1.4861	1.4756
50.4	–	1.5255	1.5136	1.5059	1.4974	1.4932	1.4884	1.4779
50.6	–	1.5279	1.5159	1.5082	1.4997	1.4955	1.4907	1.4802
50.8	–	–	1.5183	1.5105	1.5020	1.4978	1.4930	1.4824
51.0	–	–	1.5206	1.5128	1.5043	1.5001	1.4953	1.4847
51.2	–	–	1.5230	1.5152	1.5066	1.5024	1.4976	1.4870
51.4	–	–	1.5253	1.5175	1.5090	1.5048	1.5000	1.4893
51.6	–	–	1.5277	1.5198	1.5113	1.5071	1.5023	1.4916
51.8	–	–	1.5301	1.5222	1.5136	1.5094	1.5046	1.4939
52.0	–	–	1.5324	1.5245	1.5159	1.5117	1.5069	1.4962

Table 7 – Density Chart for Potassium Hydroxide Solutions (English units)

wt% KOH	32 °F		50 °F		68 °F		86 °F		104 °F		122 °F		140 °F		158 °F	
	lbs sol./ gal	lbs KOH/ gal	lbs sol./ gal	lbs KOH/ gal	lbs sol./ gal	lbs KOH/ gal	lbs sol./ gal	lbs KOH/ gal	lbs sol./ gal	lbs KOH/ gal	lbs sol./ gal	lbs KOH/ gal	lbs sol./ gal	lbs KOH/ gal	lbs sol./ gal	lbs KOH/ gal
0	8.3	0.00	8.3	0.00	8.3	0.00	8.3	0.00	8.3	0.00	8.2	0.00	8.2	0.00	8.2	0.00
1	8.4	0.08	8.4	0.08	8.4	0.08	8.4	0.08	8.4	0.08	8.3	0.08	8.3	0.08	8.2	0.08
2	8.5	0.17	8.5	0.17	8.5	0.17	8.5	0.17	8.4	0.17	8.4	0.17	8.4	0.17	8.3	0.17
3	8.6	0.26	8.6	0.26	8.6	0.26	8.5	0.26	8.5	0.26	8.5	0.25	8.4	0.25	8.4	0.25
4	8.7	0.35	8.7	0.35	8.6	0.35	8.6	0.34	8.6	0.34	8.5	0.34	8.5	0.34	8.4	0.34
5	8.7	0.44	8.7	0.44	8.7	0.44	8.7	0.43	8.6	0.43	8.6	0.43	8.6	0.43	8.5	0.43
6	8.8	0.53	8.8	0.53	8.8	0.53	8.8	0.53	8.7	0.52	8.7	0.52	8.6	0.52	8.6	0.52
7	8.9	0.62	8.9	0.62	8.9	0.62	8.8	0.62	8.8	0.62	8.8	0.61	8.7	0.61	8.7	0.61
8	9.0	0.72	9.0	0.72	8.9	0.71	8.9	0.71	8.9	0.71	8.8	0.71	8.8	0.70	8.7	0.70
9	9.1	0.82	9.0	0.81	9.0	0.81	9.0	0.81	8.9	0.80	8.9	0.80	8.9	0.80	8.8	0.79
10	9.1	0.91	9.1	0.91	9.1	0.91	9.1	0.91	9.0	0.90	9.0	0.90	8.9	0.89	8.9	0.89
11	9.2	1.01	9.2	1.01	9.2	1.01	9.1	1.00	9.1	1.00	9.1	1.00	9.0	0.99	9.0	0.99
12	9.3	1.12	9.3	1.11	9.2	1.11	9.2	1.11	9.2	1.10	9.1	1.10	9.1	1.09	9.0	1.08
13	9.4	1.22	9.4	1.22	9.3	1.21	9.3	1.21	9.2	1.20	9.2	1.20	9.2	1.19	9.1	1.19
14	9.5	1.33	9.4	1.32	9.4	1.32	9.4	1.31	9.3	1.31	9.3	1.30	9.3	1.30	9.2	1.29
15	9.6	1.43	9.5	1.43	9.5	1.42	9.4	1.42	9.4	1.41	9.4	1.41	9.3	1.40	9.3	1.39
16	9.6	1.54	9.6	1.54	9.6	1.53	9.5	1.52	9.5	1.52	9.4	1.51	9.4	1.51	9.3	1.50
17	9.7	1.65	9.7	1.65	9.6	1.64	9.6	1.63	9.6	1.63	9.5	1.62	9.5	1.61	9.4	1.60
18	9.8	1.77	9.8	1.76	9.7	1.75	9.7	1.74	9.6	1.74	9.6	1.73	9.6	1.72	9.5	1.71
19	9.9	1.88	9.9	1.87	9.8	1.86	9.8	1.86	9.7	1.85	9.7	1.84	9.6	1.83	9.6	1.82
20	10.0	2.00	9.9	1.99	9.9	1.98	9.8	1.97	9.8	1.96	9.8	1.95	9.7	1.95	9.7	1.93
21	10.1	2.11	10.0	2.10	10.0	2.09	9.9	2.09	9.9	2.08	9.9	2.07	9.8	2.06	9.7	2.05
22	10.2	2.23	10.1	2.22	10.1	2.21	10.0	2.20	10.0	2.19	9.9	2.19	9.9	2.18	9.8	2.16
23	10.2	2.36	10.2	2.34	10.1	2.33	10.1	2.32	10.0	2.31	10.0	2.30	10.0	2.29	9.9	2.28
24	10.3	2.48	10.3	2.47	10.2	2.45	10.2	2.44	10.1	2.43	10.1	2.42	10.1	2.41	10.0	2.40
25	10.4	2.60	10.4	2.59	10.3	2.58	10.3	2.57	10.2	2.55	10.2	2.55	10.1	2.53	10.1	2.52
26	10.5	2.73	10.5	2.72	10.4	2.70	10.3	2.69	10.3	2.68	10.3	2.67	10.2	2.66	10.2	2.64
27	10.6	2.86	10.5	2.85	10.5	2.83	10.4	2.82	10.4	2.80	10.3	2.79	10.3	2.78	10.2	2.76
28	10.7	2.99	10.6	2.98	10.6	2.96	10.5	2.95	10.5	2.93	10.4	2.92	10.4	2.91	10.3	2.89
29	10.8	3.12	10.7	3.11	10.7	3.09	10.6	3.08	10.6	3.06	10.5	3.05	10.5	3.04	10.4	3.02
30	10.9	3.26	10.8	3.24	10.7	3.22	10.7	3.21	10.6	3.19	10.6	3.18	10.6	3.17	10.5	3.15
31	11.0	3.40	10.9	3.38	10.8	3.36	10.8	3.34	10.7	3.32	10.7	3.31	10.6	3.30	10.6	3.28
32	11.0	3.53	11.0	3.52	10.9	3.49	10.9	3.48	10.8	3.46	10.8	3.45	10.7	3.44	10.7	3.41
33	11.1	3.68	11.1	3.65	11.0	3.63	11.0	3.62	10.9	3.60	10.9	3.59	10.8	3.57	10.8	3.55
34	11.2	3.82	11.2	3.80	11.1	3.77	11.0	3.75	11.0	3.74	11.0	3.72	10.9	3.71	10.8	3.68
35	11.3	3.96	11.3	3.94	11.2	3.91	11.1	3.90	11.1	3.88	11.0	3.86	11.0	3.85	10.9	3.82
36	11.4	4.11	11.4	4.09	11.3	4.06	11.2	4.04	11.2	4.02	11.1	4.01	11.1	3.99	11.0	3.96
37	11.5	4.26	11.4	4.23	11.4	4.21	11.3	4.19	11.3	4.16	11.2	4.15	11.2	4.14	11.1	4.11
38	11.6	4.41	11.5	4.38	11.5	4.35	11.4	4.33	11.3	4.31	11.3	4.30	11.3	4.28	11.2	4.25
39	11.7	4.56	11.6	4.54	11.5	4.50	11.5	4.48	11.4	4.46	11.4	4.45	11.4	4.43	11.3	4.40
40	11.8	4.72	11.7	4.69	11.6	4.66	11.6	4.63	11.5	4.61	11.5	4.60	11.4	4.58	11.4	4.55
41	11.9	4.88	11.8	4.85	11.7	4.81	11.7	4.79	11.6	4.76	11.6	4.75	11.5	4.73	11.5	4.70
42	12.0	5.04	11.9	5.00	11.8	4.97	11.8	4.94	11.7	4.92	11.7	4.90	11.6	4.89	11.6	4.85
43	12.1	5.20	12.0	5.16	11.9	5.13	11.9	5.10	11.8	5.07	11.8	5.06	11.7	5.04	11.6	5.01
44	12.2	5.36	12.1	5.33	12.0	5.29	12.0	5.26	11.9	5.23	11.9	5.22	11.8	5.20	11.7	5.16
45	12.3	5.53	12.2	5.49	12.1	5.45	12.1	5.42	12.0	5.39	11.9	5.38	11.9	5.36	11.8	5.32
46	12.4	5.70	12.3	5.66	12.2	5.61	12.1	5.59	12.1	5.56	12.0	5.54	12.0	5.52	11.9	5.48
47	12.5	5.87	12.4	5.83	12.3	5.78	12.2	5.75	12.2	5.72	12.1	5.70	12.1	5.69	12.0	5.65
48	12.6	6.04	12.5	6.00	12.4	5.95	12.3	5.92	12.3	5.89	12.2	5.87	12.2	5.85	12.1	5.81
49	12.7	6.21	12.6	6.17	12.5	6.12	12.4	6.09	12.4	6.06	12.3	6.04	12.3	6.02	12.2	5.98
50	–	–	12.7	6.35	12.6	6.30	12.5	6.26	12.5	6.23	12.4	6.21	12.4	6.19	12.3	6.15
51	–	–	–	–	12.7	6.47	12.6	6.44	12.6	6.40	12.5	6.38	12.5	6.36	12.4	6.32
52	–	–	–	–	12.8	6.65	12.7	6.62	12.7	6.58	12.6	6.56	12.6	6.54	12.5	6.49

Chart 2 – Potassium Hydroxide Solutions Phase Diagram

Potassium hydroxide solutions have two eutectic points. These points, sometimes called minimum freezing points, define the potassium hydroxide concentrations that will not undergo partial freezing as they are cooled. Since potassium hydroxide solutions at these concentrations continue to behave as a liquid instead of a slurry at temperatures down to the actual freezing point, they are generally easier to handle. A 34% solution of potassium hydroxide freezes at the lowest temperature, -105 °F (-76 °C). The most prevalent solution strengths have freeze points of negative 22 °F (-30 °C) and 39 °F (4 °C), for 45% and 50% solutions, respectively.



Phase Diagram - Composition of Solids								
		Maximums				Transition Points		
		Concentration	Temperature			Concentration	Temperature	
Compounds		(wt%)	(°C)	(°F)		(wt%)	(°C)	(°F)
A	Ice	0.0	0.0	32.0	**A to B**	30.8*	-65.2	-85.4
B	KOH•4H2O	43.8	-32.9	-27.2	**B to C**	44.8	-33.0	-27.4
C	KOH•2H2O	60.9	75.3	167.5	**C to D**	57.4	33.0	91.4
D	KOH•H2O	75.7	147.2	297.0	**D to E**	87.0*	99.0	210.2
E	KOH	100.0	406.0	762.8				

* - Eutectic Point

Table 8 – Viscosity (centipoise) for Potassium Hydroxide Solutions (wt % KOH) vs. Temperature

Temp °C	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
0 °C	1.9	2.1	2.4	2.7	3.2	4.0	5.3	7.5	11.8	19.9
20	1.1	1.2	1.4	1.6	2.0	2.4	3.1	4.1	6.2	8.7
25	0.98	1.1	1.2	1.5	1.8	2.2	2.7	3.6	5.3	7.3
30	0.89	1.0	1.1	1.3	1.6	2.0	2.5	3.2	4.6	6.3
35	0.81	0.91	1.0	1.2	1.5	1.8	2.2	2.8	4.0	5.5
40	0.73	0.83	0.95	1.1	1.3	1.6	2.0	2.5	3.5	4.8
45	0.67	0.77	0.87	1.0	1.2	1.5	1.8	2.3	3.1	4.2
50	0.62	0.71	0.81	0.94	1.1	1.4	1.7	2.1	2.8	3.8
55	0.57	0.66	0.75	0.88	1.0	1.3	1.5	1.9	2.5	3.4
60	0.53	0.61	0.70	0.82	0.96	1.2	1.4	1.8	2.2	3.1
65	0.50	0.57	0.66	0.76	0.90	1.1	1.3	1.6	2.0	2.8
70	0.47	0.53	0.62	0.72	0.84	1.0	1.2	1.5	1.9	2.5
75	0.44	0.50	0.58	0.67	0.79	0.94	1.1	1.4	1.7	2.3
80	0.41	0.47	0.55	0.63	0.74	0.88	1.1	1.3	1.6	2.2
85	0.39	0.44	0.52	0.60	0.70	0.83	1.0	1.2	1.5	2.0
90	0.36	0.42	0.49	0.57	0.66	0.78	0.94	1.2	1.4	1.9
100	0.33	0.38	0.44	0.51	0.59	0.70	0.84	1.0	1.2	1.6
110	0.30	0.34	0.40	0.46	0.54	0.63	0.76	0.92	1.1	1.4
120	0.27	0.31	0.36	0.42	0.49	0.58	0.69	0.83	1.0	1.3
130	0.25	0.28	0.33	0.38	0.45	0.53	0.63	0.76	0.93	1.2
140	0.23	0.26	0.30	0.35	0.41	0.49	0.58	0.70	0.86	1.0
150	0.21	0.24	0.28	0.33	0.38	0.45	0.54	0.64	0.79	0.95
160	0.20	0.23	0.26	0.31	0.36	0.42	0.50	0.60	0.73	0.88
170	0.19	0.21	0.25	0.29	0.34	0.39	0.47	0.56	0.68	0.81
180	0.18	0.20	0.23	0.27	0.32	0.37	0.44	0.52	0.63	0.76
190	0.17	0.19	0.22	0.25	0.30	0.35	0.41	0.49	0.59	0.71
200	0.16	0.18	0.21	0.24	0.28	0.33	0.39	0.46	0.55	0.67
210	0.15	0.17	0.20	0.23	0.27	0.31	0.37	0.44	0.52	0.63
220	0.14	0.17	0.19	0.22	0.25	0.30	0.35	0.41	0.49	0.60
230	0.14	0.16	0.18	0.21	0.24	0.28	0.33	0.39	0.47	0.57
240	0.13	0.15	0.17	0.20	0.23	0.27	0.32	0.37	0.45	0.54
250	0.12	0.14	0.17	0.19	0.22	0.26	0.30	0.36	0.43	0.51
260	0.12	0.14	0.16	0.18	0.21	0.25	0.29	0.34	0.41	0.47
270	0.11	0.13	0.15	0.17	0.20	0.23	0.27	0.32	0.37	0.44
275	0.11	0.13	0.15	0.17	0.20	0.23	0.27	0.31	0.36	0.42

Tables 9 & 10 – Dilution of Potassium Hydroxide Solutions for 45% KOH and 50% KOH

Desired % wt KOH	To Obtain Desired %, Add:		Diluted Volume (X original volume)
	kg water per kg 45% KOH	vol water per vol 45% KOH	
1	43.91	63.85	64.68
2	21.46	31.20	32.06
3	13.97	20.32	21.19
4	10.23	14.87	15.76
5	7.98	11.61	12.50
6	6.49	9.43	10.33
7	5.42	7.88	8.78
8	4.62	6.71	7.61
9	3.99	5.80	6.71
10	3.49	5.08	5.99
11	3.08	4.49	5.40
12	2.74	3.99	4.91
13	2.46	3.57	4.49
14	2.21	3.21	4.13
15	2.00	2.90	3.83
16	1.81	2.63	3.56
17	1.64	2.39	3.32
18	1.50	2.18	3.11
19	1.37	1.99	2.92
20	1.25	1.81	2.75
21	1.14	1.66	2.60
22	1.04	1.52	2.46
23	0.95	1.39	2.33
24	0.87	1.27	2.22
25	0.80	1.16	2.11
26	0.73	1.06	2.02
27	0.67	0.97	1.92
28	0.61	0.88	1.84
29	0.55	0.80	1.76
30	0.50	0.73	1.69
31	0.45	0.66	1.62
32	0.41	0.59	1.56
33	0.36	0.53	1.50
34	0.32	0.47	1.44
35	0.29	0.41	1.39
36	0.25	0.36	1.34
37	0.22	0.31	1.30
38	0.18	0.27	1.25
39	0.15	0.22	1.21
40	0.12	0.18	1.17
41	0.10	0.14	1.13
42	0.07	0.10	1.10
43	0.05	0.07	1.06
44	0.02	0.03	1.03
45	0.00	0.00	1.00

Desired % wt KOH	To Obtain Desired %, Add:		Diluted Volume (X original volume)
	kg water per kg 50% KOH	vol water per vol 50% KOH	
1	48.90	73.94	74.73
2	23.95	36.21	37.04
3	15.94	23.64	24.48
4	11.48	17.35	18.20
5	8.98	13.58	14.44
6	7.32	11.07	11.93
7	6.13	9.27	10.14
8	5.24	7.92	8.80
9	4.55	6.87	7.75
10	3.99	6.04	6.92
11	3.54	5.35	6.24
12	3.16	4.78	5.67
13	2.84	4.29	5.19
14	2.57	3.88	4.78
15	2.33	3.52	4.42
16	2.12	3.21	4.11
17	1.94	2.93	3.84
18	1.77	2.68	3.59
19	1.63	2.46	3.38
20	1.50	2.26	3.18
21	1.38	2.08	3.00
22	1.27	1.92	2.84
23	1.17	1.77	2.70
24	1.08	1.63	2.56
25	1.00	1.51	2.44
26	0.92	1.39	2.33
27	0.85	1.29	2.22
28	0.78	1.19	2.13
29	0.72	1.09	2.04
30	0.67	1.01	1.95
31	0.61	0.92	1.87
32	0.56	0.85	1.80
33	0.51	0.78	1.73
34	0.47	0.71	1.67
35	0.43	0.65	1.61
36	0.39	0.59	1.55
37	0.35	0.53	1.50
38	0.32	0.48	1.45
39	0.28	0.43	1.40
40	0.25	0.38	1.35
41	0.22	0.33	1.31
42	0.19	0.29	1.27
43	0.16	0.25	1.23
44	0.14	0.21	1.19
45	0.11	0.17	1.16
46	0.09	0.13	1.12
47	0.06	0.10	1.09
48	0.04	0.06	1.06
49	0.02	0.03	1.03
50	0.00	0.00	1.00

Units Conversions

Table 11 – Converting English to SI Units

Quantity	To Convert		Multiply By
	From	To	
Enthalpy	BTU/pound-mass	Joule/kilogram (J/kg)	2324.444
Heat	BTU	joule (J)	1054.35
Length	inch (in)	meter (m)	0.0254
Mass	pound-mass (lbm)	kilogram (kg)	0.4536
Pressure	pound-force/in^2 (psi)	pascal (Pa)	6894.757
Viscosity	centipoise (cps)	pascal-second (Pa-s)	0.001
Volume	US gallon	cubic meter (m^3)	0.0037854

Temperature Conversions

To convert degree Fahrenheit (°F) to degree Celsius (°C):

$$°C = (°F - 32) \div 1.8$$

To convert degree Celsius (°C) to degree Fahrenheit (°F):

$$°F = (°C \times 1.8) + 32$$

To convert degree Fahrenheit (°F) to Kelvin (K):

$$K = (°F + 459.67) \div 1.8$$

To convert degree Celsius (°C) to Kelvin (K):

$$K = °C + 273.15$$

Specific Gravity vs. Baumé Conversions

$$\text{Specific Gravity} = \frac{145}{(145 - °\text{Baumé})}$$

$$\text{Degrees Baumé} = 145 - \frac{145}{\text{Specific Gravity}}$$

Reference Materials

The Chlorine Institute – Reference Pamphlets

The Chlorine Institute offers a wide variety of safety and technical information associated with Potassium Hydroxide. Contact the Chlorine Institute at www.chlorineinstitute.org to access the pamphlets referenced in this publication.

Pamphlet 65 – "Personal Protective Equipment for Chlor Alkali Chemicals"

Pamphlet 80 – "Recommended Practices for Handling Sodium Hydroxide Solution and Potassium Hydroxide Solution (Caustic) Barges"

Pamphlet 87 – "Recommended Practices for Handling Sodium Hydroxide Solution and Potassium Hydroxide Solution (Caustic) Tank Cars" – Rail Transportation

Pamphlet 88 – "Recommended Practices for Handling Sodium Hydroxide Solution and Potassium Hydroxide Solution (Caustic) Cargo Tank" – Tank Trucks or Tank Trailers

Pamphlet 94 – "Sodium Hydroxide Solution and Potassium Hydroxide Solution (Caustic) Storage Equipment and Piping Systems"

Pamphlet 164 – "Reactivity and Compatibility of Chlorine and Sodium Hydroxide with Various Material

Product Safety Questions? Contact Us

At Olin, safety and environmental protection are top priorities. We provide technical assistance and resources for our customers to ensure the safe and environmentally sound use and handling of our products. Please contact your Olin representative for further information and support.

Global Contact Information

Americas

USA: +1 833 370 3737
Canada: +1 877 304 4442
Latin America +55 11 5188 4105

Info@olin.com

Asia

Chinese Mainland: +86 21 80223888
Hong Kong SAR, China: +852 37920389
Japan: +81 368608305
Singapore: +65 68010344
South Korea: +82 02 60072906
Taiwan: +866 277432017
Thailand: +662 2951326

www.olinchloralkali.com

Europe

Europe Middle East, Africa, India:
+44 8000869047

Toll free service not available in all countries

Emergency Telephone Numbers (Chemical Incident Only)

USA: +1 800 424 9300
Canada: +1 613 996 6666
Europe/Middle East/Africa/India: +32 3 575 55 55
Chinese Mainland: +86 532 83889090
Asia/Pacific: +65 6542 9595

Notice: No freedom from any patent or other intellectual property rights owned by Olin or others is to be inferred. Olin assumes no obligation or liability for the information in this document. The information provided herein is presented in good faith and is based on the best of Olin's knowledge, information, and belief. The information provided herein does not, and is not intended to, constitute legal advice; instead, all information and content are for general informational purposes only. Since use conditions at non-Olin facilities are beyond Olin's control and government requirements may differ from one location to another and may change with time, it is solely the Buyer's responsibility to determine whether Olin's products are appropriate for the Buyer's use, and to assure the Buyer's workplace, use, and disposal practices are in compliance with applicable government requirements. Consequently, Olin assumes no obligation or liability for use of these materials and makes no warranty, express or implied. The user of the information provided is solely responsible for compliance with any applicable government requirements. NO WARRANTIES ARE GIVEN; ALL IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE ARE EXPRESSLY EXCLUDED.

Teflon™ is a trademark of The Chemours Company FC, LLC.

Form No. 102-00568-0424