CAUSTIC SODA

SODIUM HYDROXIDE PRODUCT STEWARDSHIP MANUAL

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Introduction

Olin has a long and rich history as a leading manufacturer of caustic soda. The production of high-purity caustic soda in the U.S. was pioneered by one of Olin's predecessor companies, Mathieson Alkali Works. Its first caustic soda plant came on stream on July 4, 1895, in Saltville, Virginia, using the lime soda process. In 1897, Olin introduced a more efficient caustic soda production process using mercury cell technology, which remained the industry's preferred manufacturing technology for more than 60 years. Today, Olin is the world's largest producer of caustic soda. Olin produces two grades of high-quality 50% caustic soda at production sites throughout the U.S. and Canada. Our strategically located distribution terminal system further augments our ability to provide rapid, reliable delivery across North America.

This product stewardship manual on the safe handling and storage of Olin Caustic Soda is offered by Olin Corporation as a service to its customers and others who handle, use, store, ship, or dispose of caustic soda. This manual contains information on the physical and chemical properties of caustic soda, 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.

Product Stewardship

Product Stewardship Statement

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 of our collaborators throughout the value chain to do the same. As a responsible corporate citizen and certified to RC14001®:2015, 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 each individual involved with Olin products – from the initial concept and research to the manufacture, sale, distribution, use, disposal, and recycling of each product.

Grades of Caustic Soda

Olin manufactures two grades of 50% caustic soda: membrane and commercial grade. In certain markets, diluted caustic soda may be available. We offer product certification upon request for various industry and regulatory standards, including the American Water Works Association (AWWA B300), NSF International's NSF/ANSI 60: Drinking Water Treatment Chemicals, and Food Chemicals Codex (FCC). Contact your Olin sales representative to discuss specifications, certifications, and product grades available in your particular market.

Membrane Grade

Membrane grade caustic soda is produced by the membrane electrolytic cell process. This high-purity grade is very low in salt (typically less than 100ppm as NaCl) and trace metal contents. This product is primarily used in applications that are sensitive to high chloride or trace metals. This product grade is often referred to as "Membrane," "Mb," "Low Salt," and "High Purity."

Commercial Grade

Commercial grade caustic soda has a higher salt content of approximately 1% by weight NaCl and elevated trace metal concentrations as compared to membrane caustic. However, for most applications, these components are not critical. Commercial grade caustic soda is typically manufactured using the diaphragm electrolytic cell process, but it can represent membrane grade or a blend of diaphragm and membrane production. Depending on the market, this product may be known as "Commercial," "Dp," "Diaphragm," or "Technical."

Physical & Chemical Properties

Caustic soda is the common name for sodium hydroxide solutions. Other common names include lye, caustic, and caustic lye. This chemical compound can exist both as a solid and as an aqueous solution. This manual focuses primarily on 50% (by weight) caustic soda solutions, the most prevalent strength that is commercially produced. However, for certain specialized uses, solution strengths other than 50% might be required.

Physical Properties

Caustic soda solutions (50% or less) will range in appearance from clear and colorless (membrane grade) to slightly hazy or milky-white (commercial grade). Caustic soda is essentially odor-free. Solid sodium hydroxide is a white, crystalline material that can sometimes be observed on pipe fittings or equipment when solution leaks have evaporated. Other physical properties including density, freezing point data, thermal properties, and viscosity information can be found in the Technical Data Section of this manual.

Chemical Properties

Caustic soda is very corrosive to human tissues, including skin and eyes. It is also corrosive to some metals and leather. Appropriate care must be taken when handling caustic soda to prevent injury to personnel and/or damage to equipment and the environment. This manual contains information on how to safely handle caustic soda solutions.

Sodium hydroxide is a very strong base. A 50% caustic soda solution has a pH greater than 14. In fact, caustic soda is such a strong base that a caustic soda solution would have to be diluted to less than 3.88% sodium hydroxide to detect a pH below 14. Even at a concentration of less than 0.005%, caustic soda still has a pH greater than 11. In many situations, particularly in the case of environmental impact, pH 11 is still considered very basic, and solutions with pH greater than this warrant further processing and/or special handling. It is important to keep caustic soda solutions separate from strong acids, as the reaction between them can be violent.

In addition to acids, other compounds including nitrogen-containing organics, explosives, carbohydrates, phosphorous, organic peroxides, and hydrocarbons can react (sometimes violently) with caustic soda. Care must be taken during storage and handling to prevent accidental mixing of caustic soda with any of these compounds. See the most current Safety Data Sheet (SDS) for additional information on compatible and incompatible chemicals.

Safety & Handling

The following health and safety information is intended to provide general guidelines only. Always review the SDS before handling caustic soda! Caustic soda is a highly corrosive and reactive compound. To prevent personnel injuries and environmental exposure, this manual and the most current SDS should be reviewed and understood. Never handle any caustic soda solution before you read and understand the relevant SDS. Always verify you are reviewing the most current SDS. SDS's are updated regularly and may contain new information. 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 caustic soda. To obtain an SDS, visit Olin's website at www.olinchloralkali.com or call Olin's Division Headquarters at (423) 336-4850.

To prevent injuries to personnel or the environment, follow the proper safety and handling procedures outlined in this manual carefully. All employees should be instructed in the properties of caustic soda and safe operating procedures and practices including:

- Toxicological Properties
- Personnel Protection
- Safe Handling Procedures
- First Aid Procedures
- Critical Equipment/Safety Shower & Eyewash
- Spill & Leak Procedures
- Disposal
- Emergency Response

Toxicological Properties

Danger: Caustic soda 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 eye contact with this material can cause permanent damage. Caustic dust or mist represents a hazard to the respiratory tract. If inhaled, symptoms may range from mild irritation to severe burns and permanent damage of the lungs and the respiratory system. Ingestion causes severe damage to the gastrointestinal tract with the potential to cause perforation. See the SDS for additional information.

Personnel Protection

Individual Personal Protective Equipment (PPE) requirements may vary based on the specific work duties and the surrounding area. A PPE hazard assessment can help determine what PPE is required for any process operation or situation.

Consult The Chlorine Institute's Pamphlet 65, "Personal Protective Equipment for Chlor Alkali Chemicals" before conducting a job hazard assessment for additional details. The typical PPE utilized for a number of common caustic soda handling situations likely to be encountered follow and are based on Pamphlet 65 guidance:

- Basic PPE required for routine work duties – like monitoring the process operations – should include a hard hat, safety glasses, and the availability of safety goggles and/or face shields. 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 there is sudden movement toward the face, both goggles and a face shield should be worn for eye and facial protection. This is especially important when performing "line-breaking" work.
- **When work duties include performing sampling activities, line breaking such as disconnecting unloading hoses, or maintenance activities, full PPE should be used, including rubber (Neoprene or equivalent) jacket and pants, hard hat, safety glasses, goggles, face shield, rubber (Neoprene or equivalent) gloves, and boots.**
- Additional PPE may be required when containing or cleaning up spilled chemical, especially if the caustic solution has dried. If there is potential for caustic mist or alkali dust in the area, an OSHA/NIOSH respirator approved for this situation should be available.
- In addition to each person's individual PPE, every caustic soda 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.

Figure 1: Personnel Protective Equipment

- Hard Hat
- Safety Glasses
- Face Shield
- Chemical Safety Goggles
- Full Protective Suit
- Rubber (Neoprene) Gloves
- Rubber (Neoprene) Boots

Handling Considerations

1. Always handle caustic soda in a way that prevents spillage. Liquid caustic soda makes floors slippery. Serious falls and injuries, complicated by caustic burns, may result if caustic soda is not immediately cleaned from floors, stairs, or other walkways. Caustic soda can be neutralized by the application of dilute acetic acid or other weak acid. Make sure that caustic soda spills, residues, or products of neutralization are not discharged directly into sewers or streams in violation of federal, province, state, and local requirements. Do not use dilute acetic acid or any other material to neutralize caustic soda on skin or eyes unless directed to do so by medical personnel. Doing so may significantly increase the severity of chemical burns. See First Aid section.

2. Avoid bodily contact with any form of caustic soda (liquid or dry), and immediately flush exposed area with copious amounts of water. See First Aid section.
3. Caustic soda will readily attack leather and cotton-based garments. Launder exposed clothing and jewelry prior to re-use.
4. Do not mix caustic soda with water or acids except under the direction of trained personnel. This should only be done in equipment or facilities that have been designed to accommodate these types of reactions. Because of the large heat of reaction, spattering may occur.
5. Know the location of the nearest safety shower and eyewash fountain and confirm it is functioning before performing any work in that area.
6. Carbon monoxide can form from the reaction of caustic 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 Shower & 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, please consult the ANSI Standard Z358.1.

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 SDS and provide it to medical personnel administering care to injured persons. To obtain an SDS, visit 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 easily removed. A sensation of heat indicates the water is effectively diluting the caustic – continue rinsing despite the temporary discomfort. Do not use soap. Seek medical attention immediately.

Skin Contact: Immediately flush with large quantities of clean water for at least 15 minutes. If there is caustic soda on the head and face, do not remove goggles until after this area has been thoroughly flushed with water. Remove jewelry and clothing. Clothing that has come in contact with caustic soda 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. DO NOT give anything by mouth if the person is unconscious or if having convulsions. Seek medical attention immediately.

Inhalation: Move to fresh air immediately. If breathing is difficult, give oxygen. If breathing stops, provide artificial respiration. Induce artificial respiration with 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.

In Case of Emergencies

Responding to Emergencies

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 10 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 reviewed with your Local Emergency Planning Committee (LEPC) to ensure compliance with local, province, and state 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 the safety of those around you. Consult your EAP or ERP regarding specific actions to take when encountering a spill event.

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

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)

THESE STEPS SHOULD PERFORMED BY TRAINED, KNOWLEDGEABLE PERSONNEL ONLY!

- Suit up with appropriate PPE per SDS and never respond alone.
- Isolate and contain the spill with use of inert materials (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.

Storage Tanks, Piping Systems & Other Equipment

Caustic soda users are responsible for building and maintaining properly designed storage and handling systems. A trained engineer is best suited to design systems that enhance safety, while at the same time minimizing maintenance needs. The initial capital cost should be secondary to these primary objectives. A properly installed system that meets the objectives of safety and maintenance will usually be the 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.

Four basic factors must be kept in mind in designing the storage and handling facility:

1. Caustic soda is highly corrosive and can be hazardous to personnel
2. The viscosity of caustic soda increases rapidly when its temperature falls below 65 °F (16 °C)
3. The weight of 50% caustic soda is 1.5 times that of water
4. Solution temperature, strength, and grade will affect the corrosion rates with various metals

Storage tanks should be located to minimize piping runs, especially exterior pipes in which caustic soda 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.

Labeling

Tanks, containment systems, and pumping stations should be clearly labeled to identify chemical contents. Labels or stencils noting the entire, formal product name, e.g., "sodium hydroxide" are 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. Certain local regulations, codes, or agencies may also dictate label content.

Storage Tanks

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 and compensate for likely transit times and tank heels. A general rule of thumb is to size the tank at least 1.5 times larger than the full shipping container, or this capacity plus two weeks of consumption. Having an adequately sized storage system can maximize freight savings, avoid tank overflows during filling, and minimizes issues associated with just-in-time or last-minute deliveries.

Materials of Construction

Mild steel tanks are suitable for most storage conditions and should be constructed to American Petroleum Institute (API) 12F, 620, or 650 standards, depending on the design parameters chosen. Weld annealing to prevent stress crack corrosion is required if tanks are to be heated to 120 °F (49 °C) or higher temperatures. A vertical tank design is generally preferred over horizontal tanks. The rate of change for a vertical tank inventory remains constant throughout the entire filling process, and in some applications, a lesser tendency for accidental tank overflows can be realized.

Carbon steel is typically the material of choice for 50% and weaker solutions of caustic soda, provided product temperatures are maintained below 120 °F (49 °C). Accelerated metallic corrosion and stress crack corrosion of carbon steel should be expected at higher strengths and temperatures. Applications where iron corrosion or pickup is a concern should utilize a lined tank with a suitable caustic soda-resistant coating or liner. Two-part epoxy coatings are common lining materials. Chlorinated or natural rubbers are also chemically compatible, but typically a filter is used to remove rubber particulates, which may periodically flake off of the liner surface over time. Performance and choice of liner will be influenced by temperature conditions.

Stainless steel grades 304L and 316L are often utilized for systems where temperatures do not exceed 160 °F (71 °C). Stress crack corrosion becomes more prevalent above this temperature, especially with higher chloride contents associated with Commercial Grade product.

Nickel and nickel alloys such as Monel® and Inconel® are preferred for high-temperature applications above 160 °F (71 °C). These materials and nickel-cladded steel are also frequently used in select areas of steel vessels, such as the attachment nozzle for steam coils, which will be subject to significant localized temperature during operation.

Fiberglass Reinforced Plastic (FRP) and High Density Polyethylene (HDPE) materials can be used for caustic soda storage, but are typically limited to applications involving small product volumes due to the high specific gravity of caustic soda and the expected shorter lifetime of non-metallic vessels. A compatible surface veil, corrosion barrier, and curing procedure are critical FRP design elements to review with your tank fabricator.

Components made of aluminum, zinc (example: galvanized pipe), tin, copper, and brass will be readily attacked from caustic soda exposure. These materials should NEVER be used in caustic soda service.

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. Vents should be open 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 vendor for specific guidance.

Conduct periodic inspections of vent openings, especially those which incorporate a protective mesh screen, to verify the mesh has not built up with dried caustic soda and carbonate. This phenomenon is most common for tanks that are often filled to near-capacity using compressed air. Vent discharge for indoor tanks should be routed outdoors and away from personnel or equipment.

Overflows

Tanks without overflow devices can spray chemical out of the vent or opened man-way during an over-fill 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.

Receiving Pipeline & Inlet Nozzles

Two-inch piping is typical for most tank trailer-serviced locations, while three or four-inch diameter pipelines are often used for tank car unloading to facilitate rapid product transfer. Pipe diameter guidance will vary depending on site layout. The receiving pipeline should be equipped with a drain valve within reach of the unloading connection and routed to containment. This drain valve can be used to collect delivery samples or relieve hose and pipeline pressure after unloading is completed.

Top-filling is generally preferred for caustic soda 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 back-flow protection.

Outlet Nozzles

Tanks should be designed to address normal product supply and periodic maintenance activities. A true low-point drain can facilitate periodic internal tank inspection and cleaning activities. Most outlet nozzles are located 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 man-way, typically 18 or 24 inches (45.7 – 60.9 cm) diameter, should be incorporated into the design to facilitate future maintenance needs.

Level Measurement and Overflow Protection

A level measurement system is important for monitoring process operation 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. Differential pressure or other electronic level indicators incorporating sonar or radar technology are frequently used for tank level 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. In addition to level indication, high-level alarms and/or automatic fill-valve shutoff systems 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 also desirable as an additional level of protection.

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

Heating

Storage tanks should be heated and insulated to minimize heat loss and potential product freezing. Insulation thickness will be influenced by heating costs. Insulation should be well-protected with jacketing to keep it dry and minimize external corrosion of the metallic surface. Jacketing materials made of aluminum can be easily damaged from potential caustic soda exposure and should be avoided.

Heating can be accomplished with steam or electric heat sources. A nickel or nickel alloy bayonet heating coil should be considered for internal heating. Carbon and stainless coils are not recommended due to the accelerated rate of corrosion expected during operation. The internal coil 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. 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 (20 cm) above the tank floor and extend across the center of the tank to about one foot (30 cm) of the opposite tank wall. A thermal agitation pattern will form in the tank, resulting in uniform contents heating as the caustic soda solution is warmed around the coils. Steam should be regulated to a maximum of 15 psig (104 kPa) when heating caustic soda.

A preferred steam heating system involves the use of an external heat exchanger and caustic recirculation loop. 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 exchanger.

A temperature controller should be installed to maintain a caustic soda solution temperature range of 85 – 100 °F (29 – 38 °C) for most applications. 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 exterior offer another heating option. Additional insulation may be required to minimize ongoing heat loss if electric heat tracing 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 & Preparation

Tank cleaning and inspection should be part of a scheduled, periodic maintenance program for caustic soda storage equipment. Tank cleaning will be influenced by the amount of tank throughput as well as the grade of the caustic soda that is stored. Commercial Grade caustic soda has a higher level of dissolved salts that can precipitate over extended periods of storage and/or from significant drops in temperature. 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 hydrostatically tested to service pressure before being placed in caustic soda service.

New, unlined steel tanks or those that have undergone substantial repair will develop a fragile layer of ferric oxide surface scale. This scale will be readily dissolved upon the initial tank fill and will discolor clear caustic soda. Colors ranging from reddish-brown to dark grey or black are common. The tank 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 caustic soda 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% caustic soda maintained at a temperature of 80 – 100 °F (26 – 37 °C) for at least 2 hours have been found to be successful. Use of stronger and/or warmer caustic soda solutions can reduce passivation times. The amount of external heating can be minimized by diluting 50% caustic soda in the storage tank and relying on the heat of dilution to provide much of the heat source. Passivation should be considered for new, unlined steel piping systems as well.

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 or ring walls 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 minimize external corrosion of tank floors.

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 general, containment systems should be capable of holding at least 110% of the largest tank capacity found in the contained area. In high rainfall locations, additional capacity should be considered. Incompatible chemicals should be separated by walls within the overall containment area and in the drain-system piping.

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 should be avoided because of their porous nature and relatively weak strength.

Good maintenance and housekeeping practices that eliminate small piping or pump leaks soon after they develop and that keep the area clean and dry will extend the life of the enclosure. 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.

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 trailer 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 removed for future track maintenance purposes. Routing of the containment system drains should avoid exposure to incompatible chemicals.

Piping

Materials & Heating

Seamless carbon steel, butt-welded schedule 40 or greater, piping is suitable for most caustic soda applications. Flanged piping is preferred, especially for two-inch and larger diameters. The threads of threaded pipe tend to act as conduits for caustic soda to weep/leak from the threaded area due to caustic soda'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 or fall below 70 °F (21 °C), even for short periods of time. 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 caustic soda to protect against chemical exposure from a mechanical failure. Steam tracing is generally not recommended for intermittent flow piping as the temperature of caustic soda can quickly exceed 140 °F (60 °C) under static conditions, causing 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 heating and corrosion. Low pressure steam, regulated to 15 psig or less should be utilized.

Routing & Flange Guarding

The piping system should be sloped and free-draining to facilitate maintenance and avoid low spots and collection of caustic soda, 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. Buried pipelines should be avoided. Buried lines, if used, should include provisions for containment and inspection. Provisions to retard corrosion, such as cathodic protection should be utilized for buried pipe runs.

Facilities with long pipe runs or those not equipped with pipeline heating often consider pigging to remove residual product once chemical transfer is complete. Pipelines intended to be cleared by pigging should be carefully designed. Piping will require long-radius curvature and pig guide bars, as well as a motive force (typically compressed nitrogen or air) to initiate the pigging process.

Pumps & Meters

Centrifugal pumps are frequently utilized in caustic soda service. Positive displacement or other types of pumps can also be used in some conditions. Carbon and stainless steels are preferred for product temperatures maintained below 120 °F (49 °C). Nickel or nickel alloys are typical materials of construction for temperatures exceeding 120 °F. 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. Magnetically-driven pumps have the advantage of being sealless, so shielding is not necessary. Mag-drive pumps are typically plastic lined. Pumps should be equipped with a power (or pressure) monitor to protect against 'run-dry' or 'dead-head' conditions. This protective feature is especially important for magnetically driven pumps. 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 caustic soda 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 caustic soda.

Valves

A number of different valve designs can be used in caustic soda service 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. 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 Caustic Soda Solutions

The Hazardous Materials Transportation System

Hazardous Materials System

The safe transport of hazardous materials such as caustic soda involves four different organizations:

- Regulatory Agencies (Department of Transportation, United States Coast Guard, Transport Canada, etc.)
- The Manufacturer (Olin)
- The Carriers (Railroads, Trucking & Marine Towing Companies)
- The Receiving Customer

Each of those listed plays an important role in the safe shipment of hazardous materials.

Shipping Mode	Enforcement Agency
Rail	DOT-FRA; Transport Canada
Roadway	DOT-FMCSA; Transport Canada
Waterway	U.S. Coast Guard; Transport Canada
Pipeline	DOT-PHMSA; State Regulatory Commissions; Transport Canada

The 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 released 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 caustic soda, while effectively using our fleet and complying with all applicable laws.

The **carriers'** (railroads, trucking & marine towing companies) responsibility in the hazardous transportation system is to safely move the caustic soda shipping containers from the shipper to the customer. The carriers must comply with a variety of regulations and standards governing the movement of Hazardous Materials from agencies including the Department of Transportation, Transport Canada, the Association of American Railroads, and individual state governmental 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 offer the caustic soda container for shipment back to Olin. Carriers (rail and truck) rely on the shipper (Olin or the customer) to provide them with clean, safe, and secure caustic soda shipping equipment.

The caustic soda **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 caustic soda 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 caustic soda 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 and preparation of tank cars and barges released to the carrier. Failure to adequately prepare containers for reverse movement may result in regulatory violation, civil, and criminal penalty.**

Caustic Soda Shipping Containers

Caustic soda is shipped in a wide variety of container sizes, bulk and non-bulk, to meet the conditions of its many uses around the world. Olin ships caustic soda in bulk containers (tank cars, cargo tanks, 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 caustic soda. Capacities range from 600 to 1,000 tons (dry basis). These barges are double skinned, contain two to four 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 caustic soda customers located on navigable waterways may save substantial freight costs by taking advantage of barge delivery.

Tank Trucks

Olin contracts with trucking companies to deliver caustic soda by cargo tank. Customers may also have their own trucks or may prefer to use a contract carrier of their choice. Cargo tanks used in caustic soda 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 capacities vary from approximately 3,500 to 7,000 gallons, they usually contain no more than 12 tons of NaOH (dry basis) because of the over-the-road weight limitations. The tank is usually stainless steel and can be insulated or uninsulated. The typically short transit time of a cargo tank makes steam coils or other auxiliary heating of the caustic soda unnecessary.

Caustic soda 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.

Cargo tanks can be unloaded by the driver or by employees at the receiving site. If the driver unloads the tank truck, 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 Cars

Olin owns and leases a large fleet of tank cars for shipping caustic soda. Tank cars come in two different sizes and are built to DOT specification 111S100W1 or 111A100W1. The 10,000-gallon cars transport 31 tons of caustic soda (dry basis) and the 16,000-gallons cars transport 52 tons of caustic soda (dry basis). These cars are spray-lined with a caustic-resistant material to prevent iron contamination of the caustic soda. The insulation system has been designed to keep the car contents from freezing in cold weather over normal shipping times and consists of a four-inch layer of insulation covered by an 11-gauge steel jacket. Most Olin caustic soda 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.

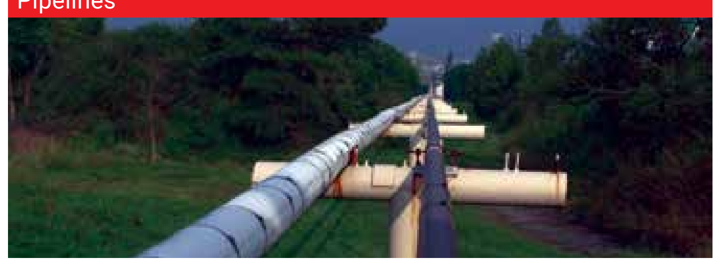
A variety of important regulatory, environmental, safety, and health information is available on each tank car. Tags and stenciling display required shipping, car maintenance, and operating information as well as safety, spill mitigation, first aid information, and emergency response contacts.

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.

Ocean Vessels

Olin has the capability to serve world markets with shipments of large quantities of caustic soda, from several Gulf Coast production facilities and coastal terminals. Contact an Olin representative for more information.

Pipelines



Olin's production locations are often near large users of caustic soda. In such cases, it may be possible for the customer to take caustic soda by pipeline, a factor that may be important in site selection. Olin can offer substantial help in planning for pipeline delivery.

Unloading Caustic Soda Solutions

Unloading Procedures & Hazmat Training

Establishment of robust unloading procedures should occur before product is received and then be 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 a number of 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 also should 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 potentially can 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 and certificate of quality) to verify they match the shipping container placard and receiving pipeline label
- Delivery address and purchase order numbers are verified
- Adequate tank space exists to safely receive the entire shipping container contents
- 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 it is a hazardous material (Hazmat), all personnel handling caustic soda 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. The Safety section of this manual and the Safety Data Sheet (SDS) for this product should be thoroughly reviewed before any person works with caustic soda or its residues.

General Unloading System Requirements

Customers should carefully consider the way that caustic soda 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. Caustic soda unloading operations must only be performed by properly trained personnel who understand the hazardous materials they are handling.
2. Contact with caustic soda can cause severe burns to skin and eyes. Therefore, all workers must wear proper protective equipment and clothing. They also must strictly observe all prescribed safe-handling procedures and practices. If caustic spray, mist, or dust is inhaled, it may cause mild irritation to severe burns of the lungs and respiratory tract. For this reason, emergency response PPE may include SCBA or full face air supply respirators.
3. Safety showers/eyewash stations and other personal protection equipment should be located in close proximity to the unloading connections. This critical equipment must be easily and quickly accessible by those who need it. For example, someone with caustic soda in their eyes will have impaired vision making it difficult to locate the eyewash unless it stands out very clearly from the surrounding equipment. This person would also have difficulty with stairs, curbs, narrow walkways, turns or other obstacles on the way to the safety shower/eye wash. According to ANSI Standard Z358.1, these safety appliances should be located on the same level as the hazard, void of access impediments such as steps, curbs, doors, and be located within 10 seconds of reach.
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 caustic soda. It is important to make sure that the materials of construction for the containment

equipment are compatible with all caustic soda 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. Liquids in containment 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), steam (thawing of frozen caustic soda), 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 caustic soda transportation equipment to the unloading piping. Generally, only one length of hose should be used to prevent safety and handling problems. If situations require more than one length, 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 during unloading operation to help ensure the safety of anyone passing by the area. Tank cars and tank trucks should be chocked to prevent accidental movement during the unloading operation.
10. 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.
11. If a pad gas unloading system is used, air is the preferred pad gas. 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. An oil and particulate trap should be installed on the source air to prevent carry-over into the caustic soda in the 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.
12. 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 caustic soda may be atomized in the air when the shipping container's pressure is relieved. If mist is discharged from the vent it could pose a hazard to nearby persons.
13. In the case of tank car unloading systems, access by roadway to the unloading station should be considered as a backup in case truck shipments becomes necessary.

Other sections of this manual contain additional information on the design and operation of caustic soda handling facilities. Information can also be found in the Chlorine Institute Pamphlet 87, Recommended Practices for Handling Sodium Hydroxide Solution and Potassium Hydroxide Solution (Caustic) Tank Cars. If you have any questions or need additional assistance, contact your Olin representative.

Tank Car Unloading

The Caustic Soda Tank Car – Top Connections/Equipment

The following equipment is on the top of every caustic soda tank car:

- 2" Ball Valve – Unloading Connection with Plug (Eduction Pipe below)
- 1" Ball Valve – Air Inlet with Plug
- Hinged & Bolted Manway Cover for Sample Collection
- Pressure Relief Valve (Or Rupture Disc)
- Protective Housing Cover

In addition to the above equipment, cars equipped with a top-operated bottom outlet valve also have a bottom outlet valve handle located on the top of the car.

Some cars have all these valves and fittings arranged inside a single Protective Housing while other cars have only the one- and two-inch valves inside a smaller protective housing. The rest of the equipment on these cars (Manway Cover, safety relief, bottom outlet valve handle) is located along the centerline near the protective housing. All valve plugs should have a chain securing them to the tank car. Figures 2 and 3 show two typical configurations.

The Caustic Soda Tank Car – 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 internal valve on the bottom of the tank. The valve handle forms a protective cover for the reach rod itself. To operate this bottom outlet valve, the reach rod cover (4 in Figure 2) 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.

Just below the bottom outlet valve (connected to handle (7 in Figure 3), there is an additional two-inch auxiliary or external ball valve (8 in Figure 3) provided for safety and operating ease. For bottom unloading, the operator connects the unloading line to the outlet of the auxiliary valve. Figure 3 shows typical bottom outlet valve configurations.

A steam chamber with individual steam inlet (9 in Figure 3) and outlets may enclose the bottom caustic soda 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).

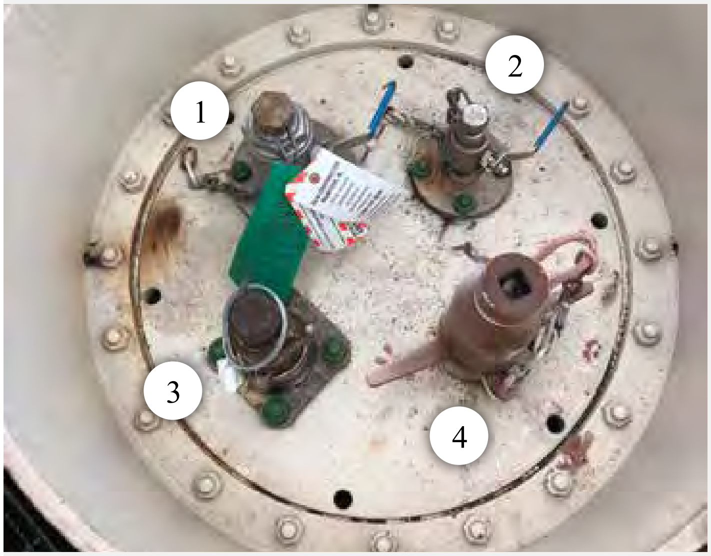
The Caustic Soda Tank Car – Pressure Relief Devices

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

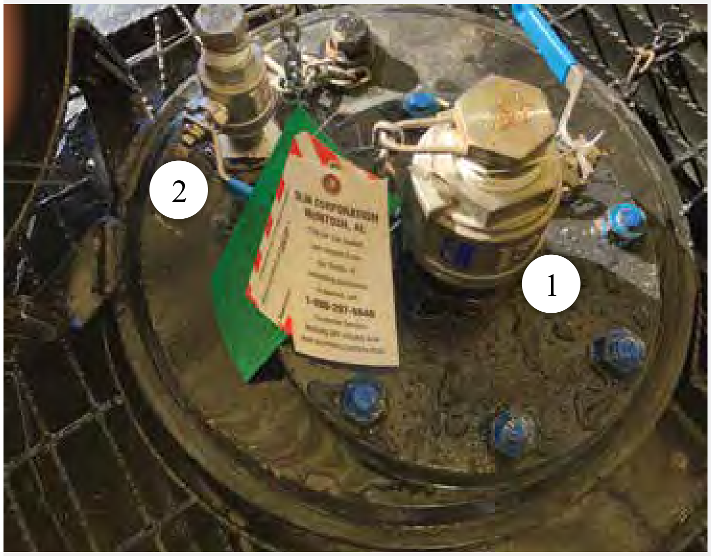
Figure 2: Typical Top Arrangement, Caustic Soda Car (16,000 gal.)

1. 2" Ball Valve (Product Outlet Connected to Eduction Pipe)
2. 1" Ball Valve – Air Inlet
3. Pressure Relief Valve (Or Rupture Disc)
4. Top-operated Bottom Valve Wrench Handle
5. Protective Housing Cover
6. Fill Hatch



Top Connections & Valves

Protective Housing Cover & Fill Hatch



1” Air Inlet Valve & Product Outlet Valve

Pressure Relief Valve

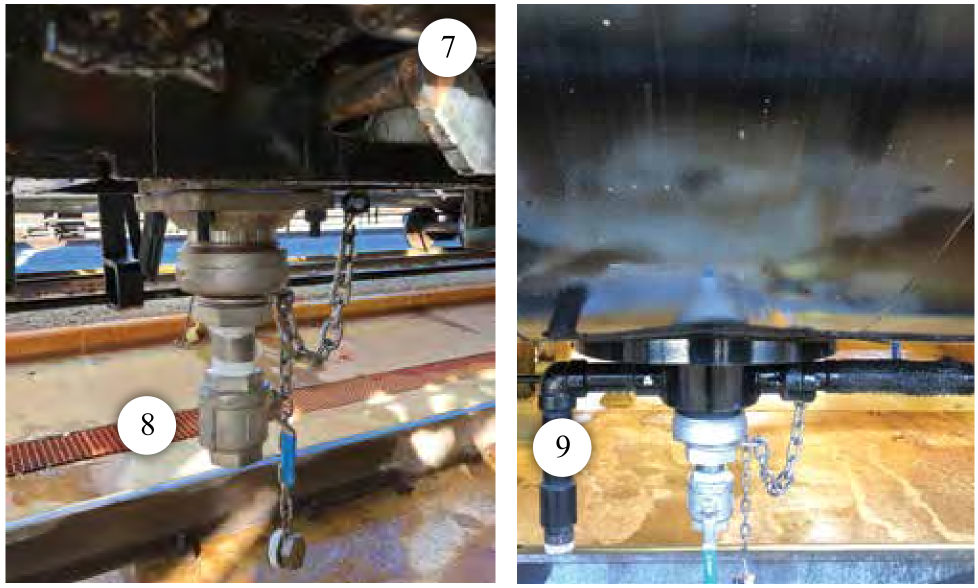
minimize such occurrences (such as increased rupture disc ratings and surge protection devices). Contact Olin immediately if tank cars are received with external residue or have blown rupture discs. Failure to install a disc or use of an improper disc can cause an extremely unsafe situation and is in violation of DOT regulations. Additionally, DOT regulations require that persons performing repair/maintenance activities be certified to DOT regulations.

The Caustic Soda Tank Car – Insulation and 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 caustic soda makes steaming necessary, connection must be made to the steam coil/jacket as well as to the caustic soda outlet chamber.

The steam inlet for the coils/jacket is usually located near the bottom outlet valve. Figure 6 on page 20 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).

Figure 3: Examples of Bottom Outlet Valves Found on Caustic Soda Tank Cars (valve designs may vary)



Bottom Outlet Valve & Handle; 2" Auxiliary Valve

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

Top or Bottom Unloading, Which Should You Be Using?

Although bottom unloading of caustic soda tank cars is fairly common, unloading caustic soda 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. A number of 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 of 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 to see everything that is going on, potentially increasing the risk to the worker.

Almost all of 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 the 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 your 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 caustic soda 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.

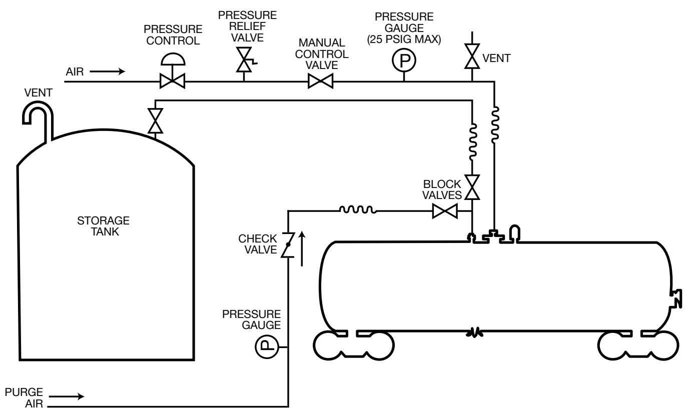
Pump Unloading

Pump Unloading from the Top of the Railcar: When pump unloading from the top of the railcar, the use of a self-priming pump is especially desirable. For unloading facilities without self-priming pumps, some air pressure is needed to lift the caustic soda solution up to the top of the eduction pipe or dip tube, at most 12.5 feet, and start the liquid flow to "prime" the unloading pump. To lift the caustic soda 12.5 feet requires approximately 10 psi air pressure. Once a pump prime has been established and pumping begins, it is important to safely depressurize the tank car and leave the manway cover open to prevent a vacuum from developing in the tank car. Some systems are designed to use a "dual-mode" unloading process which uses a transfer pump and a continuous positive compressed air pad. The positive pressure pad provides the motive force for pump priming (if needed) and also 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 a pump shutdown if a loss of air pressure occurs. If a "dual-mode" system is not utilized, it is extremely important to leave the manway open during pumping. Failure to do so could lead to an interruption of the unloading or even damage to the tank car.

Pump Unloading from the Bottom of the Railcar: In general, gravity flow of chemical from the tank car to the transfer pump is all that is needed to prime the unloading pump in a bottom unload process. As stated above, it is critical to leave the railcar manway open during pumping to prevent damage due to a vacuum being applied to the railcar.

Top Unloading Caustic Soda Tank Cars

Figure 4: 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. Protect the tank car from impact during unloading by using warning signs and either derails or locked switches.
   NOTE: Warning signs (Blue Flags) meeting DOT regulations and a closed derail device must be placed at least one tank car length on the open track side(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. Set the brakes on the tank car and place wheel chocks to prevent accidental movement.
3. While wearing proper PPE, relieve any tank car pressure or vacuum by removing the valve plug and opening the 1-inch vent valve on top of the railcar. **CAUTION: Make sure that the valve discharge is pointed away from all personnel.**
4. Open the manway cover 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.
5. Take any necessary samples, and/or look at the material to confirm that the contents are suitable for unloading.
6. <u>If unloading using a self-priming pump</u>, keep the manway cover open and skip to Step 12.

   <u>If unloading with air pad or a pump that requires priming</u>, continue to the next step.
7. Close the manway cover and all valves to ensure that there are no air leaks on top of the tank car.
   NOTE: Manway cover securement bolts should be evenly torqued using a "star" pattern when tightening.
8. Inspect all air line fittings for potential leaks and check that the oil trap is drained regularly to prevent carryover of oil and other contaminants into the caustic soda.
9. Verify that the unloading air system is designed and operated not to exceed a safe working pressure: 25 psig (172 kPa gauge) is suggested as a maximum, and lower pressures are desirable.
   NOTE: Contact Olin if pressures above 25 psig are required.
10. Connect the air line to the one-inch vent valve on top of the tank car. Be sure to install safety pins if quick connect couplings are used.
11. 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.
12. If needed, connect and apply steam to the steam chamber around the bottom tank well/unloading valve. NOTE: 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 eduction 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 eduction pipe will not thaw chemical inside the tank. Consult the Steaming section for additional details.
13. Connect and secure the transfer hose to the tank car's two-inch top unloading valve and to the unloading piping.
14. Open the two-inch ball valve on the car and the appropriate valves in the unloading line.
15. If unloading using a self-priming pump, ensure that the manway cover is open and start the pump to begin product flow to the tank.
    CAUTION: It is critical that the manway cover remain open to provide adequate venting capacity when pump or gravity unloading to prevent damage to the railcar.
    a. Check the unloading hose and lines for leaks. If a leak is found, shut off the pump and the appropriate valves and repair the leak before continuing to unload.
    b. Monitor the unloading and shut off the pump when the car is empty (product level is visible through the manway cover).
       NOTE: 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.
    c. Go to Step 18.
16. If unloading with a pump that requires priming, slowly open the air supply to the tank car to start product flowing to the pump.
    a. Check the unloading hose and lines for leaks. If a leak is found, shut off the appropriate valves and repair the leak before continuing to unload
    b. If there are no leaks, start the pump to begin product flow to the tank.
    c. Shut off the air supply from the railcar and the 1-inch vent valve on the car.
    d. Carefully disconnect the air line from the tank car and vent any pressure or vacuum from the car using the 1-inch air valve.
    e. Open the manway on the tank car to vent the car while continuing to unload.
    f. Monitor the unloading and shut off the pump when the car is empty (product level is visible through the manway cover).
    g. Go to Step 18.
17. If unloading using an air pad:
    a. Slowly open the air supply valves to pressurize the tank car. This will start the caustic flowing to the storage tank.
    b. Verify that there are no air leaks on the tank car valves or manway cover and that there are no leaks in the transfer hose and piping.
    c. Watch the unloading hose. The unloading hose will jump or surge when unloading is completed.
    d. Allow the air to blow through the transfer lines to the storage tank for three to four minutes to clear the lines.
    e. Shut off the air to the tank car and allow the pressure to relieve to the storage tank.
18. Close the tank car unloading ball valve and appropriate unloading line valves.
19. Disconnect the unloading line and allow it to drain to an appropriately contained area. **CAUTION: When disconnecting the hose, always assume caustic is present and under pressure until you are certain this is not the case.**
20. Replace 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 (DOT requirement).
21. Wash the tank car and unloading station of any incidental product drippage and collect rinse water in the containment system.
22. Secure the dome housings with pins and seals.

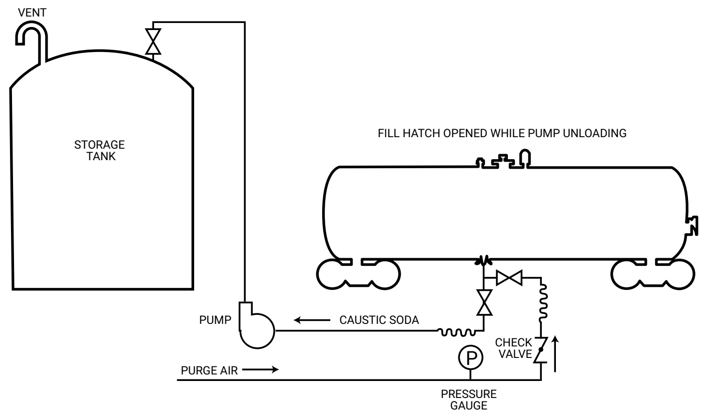
Final Notes

- 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 caustic residues.

- 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 determined by the DOT.

Bottom Unloading Procedures for Caustic Soda Tank Cars

Figure 5: Bottom Unloading Arrangement



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. 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. In general, gravity flow of chemical from the tank car to a transfer pump is the preferred method when bottom unloading. In some situations, a 'dual motive force' method using both modest air pressure pad and a transfer pump as described above can be used.

Regardless of bottom unloading mode chosen, Figure 5 shows a typical arrangement for bottom unloading caustic soda by pump. The exact configuration will vary by facility design, but unloading steps should follow this general sequence:

1. Protect the tank car from impact during unloading by using warning signs and either derails or locked switches. ***NOTE: Warning signs (Blue Flags) meeting DOT regulations and a closed derail device must be placed at least one tank car length on the open track side(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. Set the brakes on the tank car and place wheel chocks to prevent accidental movement.
3. While wearing proper PPE, relieve any tank car pressure or vacuum by removing the valve plug and opening the one-inch vent valve on top of the railcar. **CAUTION: Make sure that the valve discharge is pointed away from all personnel.**
4. Open the manway cover 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.
5. Take any necessary samples, and/or look at the material to confirm that the contents are suitable for unloading.
6. <u>For pump or gravity unloading</u>, keep the manway cover open.

   <u>For air pad unloading</u>, close the manway cover and all valves to ensure there are no air leaks on top of the car. ***NOTE: Manway cover securement bolts should be evenly torqued using a "star" pattern when tightening.***
7. Using extreme caution, remove the plug from the two-inch auxiliary bottom outlet valve. **CAUTION: If there has been any valve leakage on the railcar, this plug may have residual caustic behind it.**
8. Slowly open the two-inch auxiliary valve. 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).
9. Connect and secure the transfer hose to the tank car unloading valve and the unloading piping.
10. Slowly 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 this valve 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).**
11. Open the unloading valves in the transfer piping and any other closed valves in the transfer line to the tank.
12. Check for leaks on the unloading hose and connections. If leaks are visible, close the tank car outlet valves and repair immediately. Do not continue the unloading process until the hose, connections, and unloading piping are free from leaks.
13. If pump unloading, turn on the pump to start caustic soda flowing into the storage tank. **CAUTION: It is critical that the manway cover remain open to provide adequate venting capacity when pump or gravity unloading to prevent damage to the railcar.**
14. Monitor the entire transfer line for leaks after flow has started. Stop and repair immediately if leaks are discovered. Continue to Step 16.
15. <u>If using an air pad while unloading:</u>
    a. Inspect all air line fittings for potential leaks and check that the oil trap is drained regularly to prevent carryover of oil and other contaminants into the caustic soda.
    b. Ensure that the unloading air system is set so as not to exceed a safe working pressure: 25 psig (172 kPa gauge) is suggested as a maximum, and lower pressures are desirable. ***NOTE: Contact Olin if pressures above 25 psig are required.***
    c. Connect the air line to the one-inch vent valve on top of the car. Be sure to install safety pins if quick connect couplings are used.
    d. 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.
    e. Slowly open the air supply valves to pressurize the tank car. This will start the caustic flowing to the storage tank.
    f. Verify that there are no air leaks on the tank car valves or manway cover and that there are no leaks in the transfer hose and piping.
    g. Watch the unloading hose. The unloading hose will jump or surge when unloading is completed.
    h. Allow the air to blow through the transfer lines to the storage tank for three to four minutes to clear the lines.
    i. Shut off the air to the tank car and allow the pressure to relieve to the storage tank.
16. If pump unloading, shut off the pump when the car is empty (product level is visible through the manway cover). ***NOTE: 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.***
17. Close the tank car internal valve, auxiliary valve, and the appropriate unloading line valves.

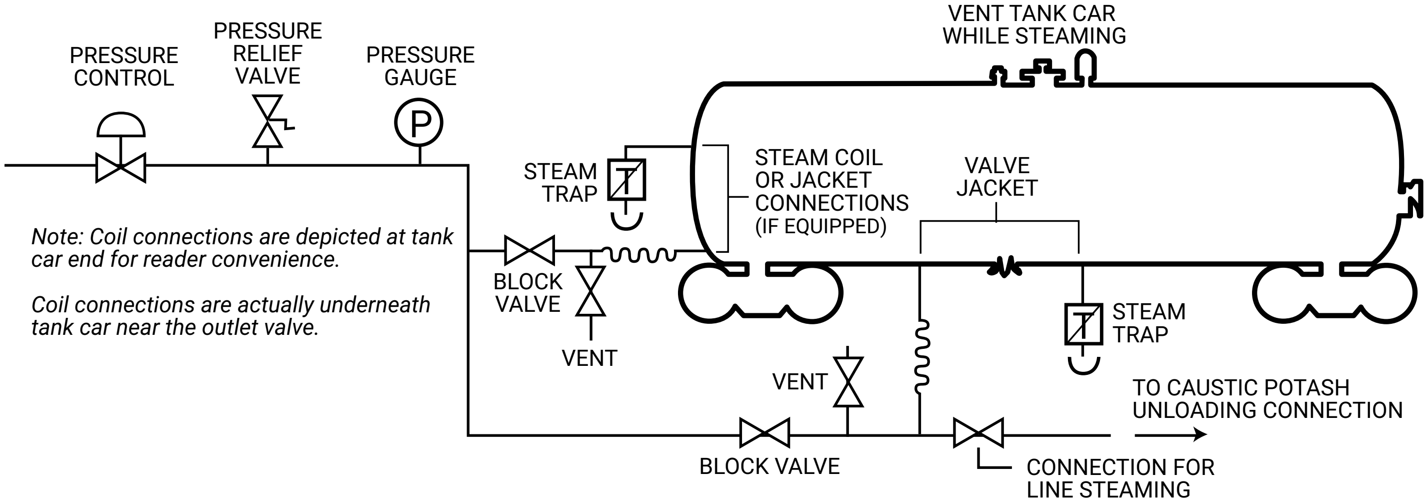
18. Vent residual pressure or liquid from the transfer hose using a bleed valve in the unloading line.
19. Disconnect the unloading hose and allow it to drain to an appropriately contained area. **CAUTION: When disconnecting the hose, always assume caustic is present and under pressure until you are certain this is not the case.**
20. Secure the tank car manway cover so there are no leaks. ***NOTE: Tighten the securement bolts evenly using a "star" pattern.***
21. Replace 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 (DOT requirement).
22. Wash the tank car exterior and unloading station of any incidental product drippage and collect rinse water in the containment system.
23. Secure the dome housings with pins and seals.

Final Notes

- 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 caustic residues.
- 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 determined by the DOT.

Steaming Procedures

Figure 6: Steaming Connections



Because of its relatively high freezing point (12-13 °C; 54-56 °F), caustic is shipped in heavily insulated tank cars. Tank cars almost always arrive at the user's site with the bulk of their contents in the liquid state. However, in cold weather, the outlet valves and the bottom of the eduction pipe are often plugged by a small amount of frozen caustic 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 that 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 caustic in the tank car may be frozen on arrival. 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 caustic soda.

The guidelines below are applicable to either top or bottom unloading of caustic cars:

1. Inspect all cars for evidence of freezing before starting to unload. This should be done when the manway cover is first opened and samples are taken. A good rule of thumb is that if the temperature of a dip sample of caustic is less than 65 °F (18 °C), steaming is required. Between 65 °F (18 °C) and 85 °F (29 °C), it is desirable to heat the tank car to reduce viscosity of the solution for easier and faster unloading. If the temperature of the 50% solution is above 85 °F (29 °C), it can generally be unloaded without steaming. Be sure to wear the appropriate personal protective equipment when taking the sample from the car.
2. Tank car valves and their attachment points are not insulated and therefore will typically be the first points to freeze, if any caustic 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 have dropped below 65°F (18°C). For tank cars without a steam chamber enveloping the bottom outlet valve assembly, heat can be provided via a steam lance (typically made of an L-shaped piece of metallic tubing) connected to low pressure steam and applied to the exterior of the two-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 two-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. PPE should be worn to protect personnel against thermal burns

and potential caustic soda contact. Always use low pressure (15 psig max.) steam. Never use gas fired cutting or blow torches to heat tank car valves.

3. 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.
4. Verify the receiving pipeline heating system is operable prior to unloading. Under extreme cold conditions, unheated receiving pipelines can experience 'flash product freezing' upon initial introduction of caustic soda.
5. To avoid pressure buildup during steaming, the tank car must be vented by opening the vent valve or manway cover.
6. Never inject steam or water directly into the tank car through the manway cover.
7. Electrical tracing used on caustic piping and equipment must be thermally rated to withstand a 300 °F (150 °C) pipe wall temperature to allow steaming without damaging the tracing (see Equipment section).
8. 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.
9. Use of a steam trap on the discharge of the steam heating connections helps melt solidified caustic soda 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 indicated when caustic temperature is greater than 85 °F (29 °C). Caustic should not be heated any higher than 130 °F (54 °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 caustic can also cause rapid corrosion of carbon steel and even stainless steel piping systems (caustic temperatures >170 °F).
10. Remove the steam trap when steaming is completed. In cold weather, condensate should be blown out of the coils to prevent damage from freezing. Caps should be left off the steam fittings to allow drainage in transit.

Additional information on steaming caustic soda 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*.

Tank Truck Unloading

Unloading Facilities

Tank truck 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 from the unloading operation. Where multiple chemicals are received in the same area as caustic soda, engineering and/or procedural provisions should be incorporated to avoid mixing of incompatible materials.

Rapid delivery typically makes steaming of the truck 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 two-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 directed to containment to relieve hose pressure or collect pre-unloading samples.
4. A clearly identified delivery hose connection area such as 50% Caustic Soda, Sodium Hydroxide, or Sodium Hydroxide UN 1824 to avoid accidental delivery of the wrong chemical.

Trucks 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.

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

Unloading Procedures

Detailed information on tank truck 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*. This document should be consulted prior to developing detailed chemical unloading procedures that are unique to your particular operation.

The delivery driver normally unloads tank trucks. 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 truck 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 caustic hose connection points, they should also wear all applicable personal protective equipment.

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. After review of delivery paperwork to affirm the correct chemical and quantity matches the purchase order for the delivery location, spot the tank trailer. Set the brakes and chock the wheels (if necessary) to prevent accidental movement. Place warning signs and/or barricades around the unloading area.
2. 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.
3. 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.
4. While wearing full PPE, 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.
5. If needed, 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. **CAUTION: Use proper fall protection when working on top of tanker trailers. Fall protection could be a stationary platform, portable stair/platform, or harness and lanyard attached to a suitable fall protection tie-off.**
6. Take any necessary samples and confirm that the contents are suitable for unloading.
7. <u>If using air pressure to unload</u>: 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.

   <u>If using a pump to unload:</u> Leave the fill hatch open, unless there is air pad system in place to prevent cargo tank collapse ***NOTE: Fill hatch securement bolts should be evenly torqued using a star pattern when tightening.***
8. Make sure the storage tank is adequately vented to handle the air pressure surge (air pad unloading) that occurs when the tank truck is empty and depressured.
9. 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. **CAUTION: The unloader should position their body and open the cap as if there were caustic soda in the unloading line in case some material may have leaked through the valve(s) during transit.**
10. If ambient temperatures are below 65°F, it may be necessary to apply low-pressure steam (15 psig max) via a steam lance to the exterior of the outlet valve to thaw any caustic residue inside the valve body before attempting to open the valves.
11. Attach the transfer hose to the tank trailer and to the facility's receiving pipeline connector. ***NOTE: Lock or strap the "ears" on all quick connect fittings to ensure that they do not accidentally open during the unloading operation.***
12. If air pad unloading, ensure that the air pressure supply is regulated to 25 psig or less and connect the air line to the trailer. (Be sure to use safety pins on all quick couple fittings.) *NOTE: Do not open the air line until initial leak check is done.*
13. Open the valves on the unloading lines. Open the tanker truck auxiliary (external valve) first, then the tanker internal valve, then the customer valve. Product should begin gravity flowing into the hose and customer piping.
14. Check the hose connections and piping for leaks before pressurizing the trailer or starting the pump.
15. Start the unloading pump or open the compressed air line depending on the unloading system.
16. Monitor the tank pressure in the air pad unloading system, keeping it below 25 psig.
17. Monitor the unloading hose, connections and piping for leaks.
18. When the caustic transfer is complete, shut off the pump or air pad. ***NOTE: If pump unloading with open dome, the level in the tank truck can be seen through the open fill hatch. If air pad unloading, the hose will jump or surge when the tank trailer is empty. Allow the line to blow clear for three to four minutes after this starts to ensure the hose and piping are empty.***
19. Shut off the air supply valves and allow the tank truck pressure to bleed down through the caustic unloading hose. When the pressure has bled down, disconnect the air hose.
20. Once the unloading hose and piping are empty, close the internal valve on the caustic tank trailer then the auxiliary valve.
21. Bleed off remaining pressure or product from the unloading hose and piping, using the drain valve located on the receiving pipeline or on the truck's unloading outlet valve system. *NOTE: Ensure that caustic residue is drained into a bucket or an appropriate caustic containment area.*
22. Close the customer unloading valve.
23. Disconnect the hose, first at the unloading line and then from the tank trailer, ensuring that caustic residue is drained into a bucket or an appropriate caustic containment area.
24. Wash down the trailer, hose, other equipment, and the containment area to remove any caustic 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 for unloading or sampling. 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 caustic soda 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 Solution and Potassium Hydroxide Solution (Caustic) Barges*.

General Information

Receipt of caustic soda 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, which also must be overseen by a licensed tankerperson. There are specific requirements that must be met to qualify as the Person-In-Charge. Contact the Coast Guard or your federal regulatory agency, e.g., 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 caustic soda 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 caustic barges. The following items should be included in all barge unloading procedures:

- Use all applicable personal protective equipment (see Personnel Protection 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 caustic 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.**

Technical Data

If the technical information you need is not included in this manual, please contact your Olin representative.

Tables

Charts

Sampling

Careful sampling is essential for accurate analysis of caustic soda. Exposure of samples to air must be minimized, since caustic soda rapidly absorbs water and carbon dioxide.

If possible, tank cars and tank trucks should be sampled from the top. 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 collected. 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 caustic soda will have different product and impurity concentrations, it should be thoroughly thawed before sampling.

Caustic soda samples should be transferred to clean, dry polyethylene sample bottles. Glass containers should not be used, as caustic soda will tend to etch the glass, possibly weakening the container and contaminating the caustic soda.

Methods of Analysis

Olin recommends the ASTM methods of analysis for caustic soda. 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, Sodium 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.

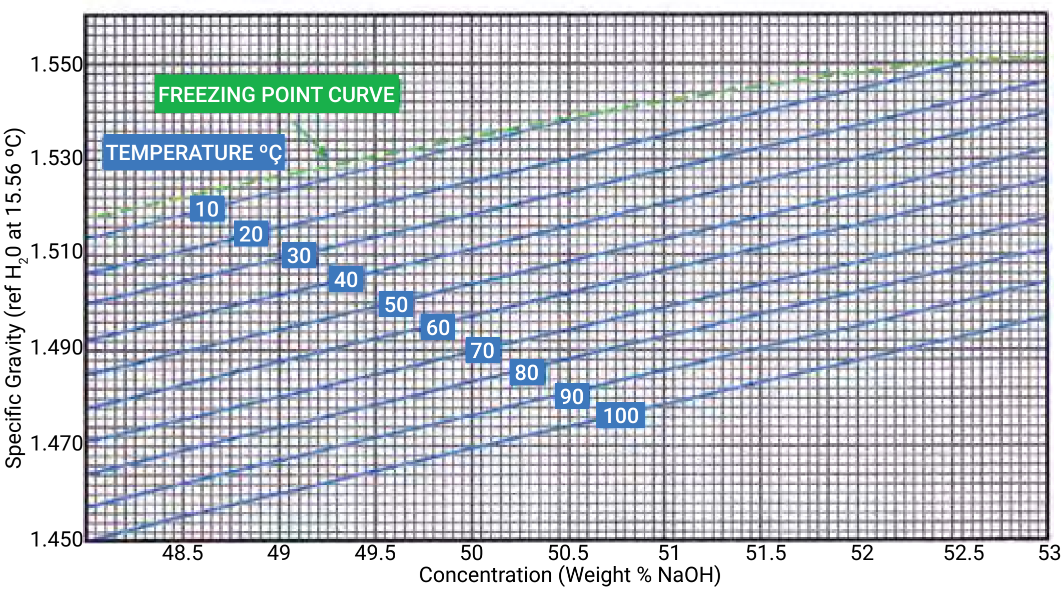
Table 1: Physical Constants of Pure Sodium Hydroxide (NaOH)

Molecular Weight[1]	39.997
Freezing Point (Melting Point)[2] °K °C °F	 596.00 322.85 613.13
Latent Heat of Fusion (ΔH_{fus})[3] kJ/mol kJ/kg Btu/lb	 6.611 165.3 71.1
Heat Capacity (C_p)[4] @ 298.15 K J/kmol*K @ 25 °C kJ/kg*K @ 77 °F Btu/lb*°F	 59,533 1.488 0.355
Heat of Formation ($\Delta H°_f$)[5] (298.15 K) kcal/mol (298.15 K) kJ/mol (25 °C) kJ/kg (77 °F) Btu/lb	 -101.8 -425.931 -10,649 -4,578
Free Energy of Formation ($\Delta G°_f$)[6] (298.15 K) kJ/mol (25 °C) kJ/kg (77 °F) Btu/lb	 -379.741 -9,494 -4,082
Specific Gravity (25 °C/4 °C)[7]	2.10

[1] Pure Applied Chemistry, 68, 2339-2359 (1996)
[2]Chase, M.W., Jr. ed., *NIST-JANAF Therochemical Tables, Fourth Edition*, J. Phys. Chem. Ref. Data, Monograph 9, 1998, Part II, p. 1293
[3]Chase, M.W., Jr. ed., *NIST-JANAF Therochemical Tables, Fourth Edition*, J. Phys. Chem. Ref. Data, Monograph 9, 1998, Part II, p. 1293
[4]Chase, M.W., Jr. ed., *NIST-JANAF Therochemical Tables, Fourth Edition*, J. Phys. Chem. Ref. Data, Monograph 9, 1998, Part II, p. 1293
[5]Chase, M.W., Jr. ed., *NIST-JANAF Therochemical Tables, Fourth Edition*, J. Phys. Chem. Ref. Data, Monograph 9, 1998, Part II, p. 1293
[6]Chase, M.W., Jr. ed., *NIST-JANAF Therochemical Tables, Fourth Edition*, J. Phys. Chem. Ref. Data, Monograph 9, 1998, Part II, p. 1293
[7]Perry's Chemical Engineering Handbook, 6th

Densities

Chart 1: Specific Gravity of 48 to 53% Caustic Soda Solutions (°C)



To convert degree Fahrenheit (°F) to degree Celsius (°C): °C = (°F – 32) ÷ 1.8
Referenced to the density of Water at 4°C = 999.972 kg/m3

Table 2: Specific Gravity of Caustic Soda Solutions (1-52%, °C)

wt% NaOH	0 °C	10 °C	15 °C	18 °C	20 °C	25 °C	30 °C	40 °C	50 °C	60 °C	70 °C	80 °C	90 °C	100 °C
1	1.0124	1.0115	1.0107	1.0101	1.0095	1.0084	1.0069	1.0033	0.9990	0.9941	0.9884	0.9824	0.9760	0.9693
2	1.0244	1.0230	1.0220	1.0213	1.0207	1.0193	1.0177	1.0139	1.0095	1.0045	0.9989	0.9929	0.9865	0.9797
3	1.0364	1.0345	1.0332	1.0324	1.0318	1.0303	1.0285	1.0246	1.0201	1.0150	1.0094	1.0035	0.9970	0.9903
4	1.0482	1.0459	1.0444	1.0435	1.0428	1.0412	1.0393	1.0352	1.0305	1.0254	1.0198	1.0139	1.0075	1.0009
5	1.0598	1.0571	1.0556	1.0546	1.0538	1.0521	1.0501	1.0458	1.0412	1.0359	1.0302	1.0243	1.0179	1.0115
6	1.0713	1.0683	1.0667	1.0656	1.0648	1.0630	1.0609	1.0564	1.0517	1.0463	1.0407	1.0347	1.0284	1.0220
7	1.0828	1.0795	1.0778	1.0767	1.0758	1.0739	1.0717	1.0672	1.0623	1.0569	1.0513	1.0453	1.0390	1.0326
8	1.0943	1.0908	1.0889	1.0877	1.0869	1.0848	1.0826	1.0780	1.0730	1.0676	1.0619	1.0560	1.0497	1.0432
9	1.1057	1.1020	1.1000	1.0988	1.0979	1.0957	1.0934	1.0887	1.0836	1.0782	1.0725	1.0665	1.0602	1.0537
10	1.1171	1.1132	1.1111	1.1098	1.1089	1.1067	1.1043	1.0995	1.0942	1.0889	1.0831	1.0771	1.0708	1.0643
11	1.1285	1.1244	1.1222	1.1208	1.1199	1.1176	1.1152	1.1103	1.1050	1.0995	1.0937	1.0876	1.0813	1.0748
12	1.1399	1.1355	1.1333	1.1319	1.1309	1.1286	1.1261	1.1210	1.1157	1.1101	1.1043	1.0983	1.0920	1.0855
13	1.1511	1.1468	1.1445	1.1431	1.1421	1.1397	1.1372	1.1320	1.1266	1.1210	1.1151	1.1090	1.1026	1.0961
14	1.1624	1.1578	1.1555	1.1540	1.1530	1.1506	1.1480	1.1428	1.1373	1.1316	1.1257	1.1195	1.1132	1.1066
15	1.1737	1.1691	1.1668	1.1653	1.1643	1.1617	1.1591	1.1538	1.1483	1.1425	1.1366	1.1303	1.1239	1.1174
16	1.1849	1.1801	1.1776	1.1761	1.1751	1.1725	1.1699	1.1645	1.1588	1.1531	1.1471	1.1408	1.1343	1.1277
17	1.1961	1.1914	1.1890	1.1875	1.1864	1.1838	1.1811	1.1756	1.1699	1.1641	1.1580	1.1517	1.1453	1.1387
18	1.2073	1.2023	1.1998	1.1982	1.1972	1.1945	1.1918	1.1863	1.1805	1.1746	1.1685	1.1621	1.1556	1.1489
19	1.2185	1.2137	1.2111	1.2095	1.2085	1.2058	1.2030	1.1974	1.1916	1.1856	1.1795	1.1731	1.1666	1.1599
20	1.2296	1.2244	1.2219	1.2203	1.2191	1.2164	1.2136	1.2079	1.2020	1.1960	1.1898	1.1833	1.1768	1.1700
21	1.2408	1.2358	1.2332	1.2316	1.2305	1.2277	1.2248	1.2191	1.2132	1.2071	1.2009	1.1944	1.1879	1.1811
22	1.2519	1.2465	1.2439	1.2422	1.2411	1.2383	1.2354	1.2296	1.2236	1.2174	1.2111	1.2046	1.1980	1.1912
23	1.2631	1.2578	1.2551	1.2534	1.2523	1.2495	1.2466	1.2407	1.2346	1.2285	1.2222	1.2156	1.2090	1.2022
24	1.2741	1.2686	1.2659	1.2642	1.2629	1.2601	1.2571	1.2512	1.2451	1.2388	1.2324	1.2259	1.2192	1.2124
25	1.2853	1.2797	1.2769	1.2752	1.2740	1.2711	1.2682	1.2622	1.2560	1.2497	1.2433	1.2367	1.2301	1.2232
26	1.2963	1.2906	1.2877	1.2860	1.2848	1.2819	1.2789	1.2728	1.2666	1.2603	1.2538	1.2472	1.2405	1.2336
27	1.3073	1.3014	1.2985	1.2967	1.2956	1.2926	1.2896	1.2835	1.2772	1.2708	1.2644	1.2577	1.2510	1.2441
28	1.3182	1.3124	1.3094	1.3076	1.3064	1.3034	1.3002	1.2942	1.2878	1.2814	1.2750	1.2682	1.2615	1.2546
29	1.3291	1.3230	1.3199	1.3181	1.3169	1.3139	1.3108	1.3046	1.2982	1.2918	1.2852	1.2785	1.2717	1.2648
30		1.3340	1.3309	1.3290	1.3279	1.3248	1.3217	1.3154	1.3090	1.3025	1.2959	1.2892	1.2824	1.2755
31		1.3443	1.3411	1.3393	1.3381	1.3350	1.3318	1.3255	1.3190	1.3125	1.3058	1.2991	1.2923	1.2853
32		1.3552	1.3520	1.3502	1.3490	1.3459	1.3427	1.3362	1.3298	1.3232	1.3165	1.3097	1.3029	1.2960
33		1.3655	1.3621	1.3602	1.3590	1.3558	1.3526	1.3462	1.3396	1.3330	1.3263	1.3195	1.3126	1.3057
34			1.3728	1.3708	1.3696	1.3664	1.3632	1.3566	1.3501	1.3434	1.3367	1.3299	1.3230	1.3161
35			1.3829	1.3809	1.3796	1.3764	1.3732	1.3666	1.3600	1.3532	1.3465	1.3396	1.3327	1.3258
36			1.3933	1.3913	1.3900	1.3868	1.3835	1.3768	1.3702	1.3634	1.3567	1.3498	1.3429	1.3360
37			1.4033	1.4013	1.4000	1.3967	1.3934	1.3867	1.3800	1.3732	1.3664	1.3596	1.3526	1.3457
38				1.4115	1.4101	1.4069	1.4035	1.3967	1.3900	1.3832	1.3763	1.3695	1.3626	1.3556
39				1.4215	1.4201	1.4168	1.4134	1.4066	1.3998	1.3930	1.3861	1.3792	1.3723	1.3654
40				1.4314	1.4300	1.4267	1.4232	1.4164	1.4095	1.4027	1.3958	1.3889	1.3820	1.3750
41				1.4413	1.4399	1.4365	1.4331	1.4262	1.4193	1.4124	1.4055	1.3986	1.3917	1.3848
42			1.4529	1.4508	1.4494	1.4460	1.4425	1.4356	1.4287	1.4217	1.4148	1.4079	1.4009	1.3940
43			1.4629	1.4608	1.4594	1.4559	1.4525	1.4455	1.4385	1.4316	1.4246	1.4177	1.4108	1.4039
44			1.4720	1.4699	1.4685	1.4650	1.4615	1.4545	1.4475	1.4405	1.4335	1.4266	1.4196	1.4127
45		1.4860	1.4821	1.4800	1.4785	1.4750	1.4715	1.4644	1.4574	1.4504	1.4435	1.4365	1.4296	1.4227
46		1.4947	1.4911	1.4890	1.4873	1.4840	1.4805	1.4734	1.4663	1.4593	1.4523	1.4454	1.4384	1.4315
47		1.5048	1.5010	1.4988	1.4973	1.4938	1.4902	1.4831	1.4760	1.4690	1.4620	1.4550	1.4481	1.4412
48		1.5138	1.5102	1.5080	1.5065	1.5030	1.4994	1.4922	1.4851	1.4781	1.4711	1.4641	1.4572	1.4503
49			1.5194	1.5173	1.5157	1.5122	1.5086	1.5014	1.4943	1.4872	1.4802	1.4732	1.4664	1.4595
50			1.5290	1.5268	1.5253	1.5218	1.5181	1.5109	1.5038	1.4967	1.4897	1.4827	1.4759	1.4690
51			1.5375	1.5353	1.5338	1.5302	1.5267	1.5195	1.5123	1.5052	1.4982	1.4911	1.4843	1.4773
52					1.5427	1.5391	1.5356	1.5284	1.5211	1.5141	1.5070	1.4999	1.4931	1.4861

Referenced to the density of Water at 4 °C = 999.972 kg/m3

Table 3: Specific Gravity of Caustic Soda Solutions (1-52%, °F)

wt% NaOH	32 °F	40 °F	50 °F	60 °F	70 °F	80 °F	90 °F	100 °F	120 °F	140 °F	160 °F	180 °F	200 °F	212 °F
1	1.0124	1.0121	1.0115	1.0106	1.0094	1.0079	1.0062	1.0042	0.9996	0.9941	0.9878	0.9810	0.9738	0.9693
2	1.0244	1.0239	1.0230	1.0219	1.0205	1.0188	1.0169	1.0148	1.0100	1.0045	0.9983	0.9915	0.9843	0.9797
3	1.0364	1.0357	1.0345	1.0331	1.0315	1.0297	1.0277	1.0255	1.0206	1.0150	1.0088	1.0021	0.9948	0.9903
4	1.0482	1.0473	1.0459	1.0443	1.0425	1.0406	1.0384	1.0362	1.0311	1.0254	1.0192	1.0125	1.0054	1.0009
5	1.0598	1.0587	1.0571	1.0554	1.0535	1.0514	1.0492	1.0469	1.0417	1.0359	1.0296	1.0229	1.0158	1.0115
6	1.0713	1.0701	1.0683	1.0665	1.0644	1.0623	1.0600	1.0575	1.0522	1.0463	1.0401	1.0333	1.0263	1.0220
7	1.0828	1.0814	1.0795	1.0776	1.0754	1.0732	1.0708	1.0683	1.0629	1.0569	1.0506	1.0439	1.0369	1.0326
8	1.0943	1.0928	1.0908	1.0887	1.0865	1.0841	1.0817	1.0791	1.0736	1.0676	1.0613	1.0546	1.0476	1.0432
9	1.1057	1.1041	1.1020	1.0998	1.0974	1.0950	1.0925	1.0898	1.0842	1.0782	1.0719	1.0652	1.0581	1.0537
10	1.1171	1.1154	1.1132	1.1109	1.1084	1.1059	1.1033	1.1006	1.0949	1.0889	1.0825	1.0758	1.0687	1.0643
11	1.1285	1.1267	1.1244	1.1219	1.1194	1.1168	1.1141	1.1114	1.1056	1.0995	1.0930	1.0862	1.0792	1.0748
12	1.1399	1.1380	1.1355	1.1330	1.1304	1.1278	1.1250	1.1222	1.1163	1.1101	1.1037	1.0969	1.0899	1.0855
13	1.1511	1.1492	1.1468	1.1442	1.1416	1.1389	1.1361	1.1332	1.1272	1.1210	1.1144	1.1076	1.1005	1.0961
14	1.1624	1.1604	1.1578	1.1552	1.1525	1.1497	1.1469	1.1440	1.1380	1.1316	1.1250	1.1182	1.1110	1.1066
15	1.1737	1.1717	1.1691	1.1665	1.1637	1.1609	1.1580	1.1550	1.1489	1.1425	1.1359	1.1290	1.1218	1.1174
16	1.1849	1.1828	1.1801	1.1774	1.1746	1.1717	1.1687	1.1657	1.1595	1.1531	1.1464	1.1394	1.1322	1.1277
17	1.1961	1.1941	1.1914	1.1887	1.1858	1.1829	1.1799	1.1769	1.1706	1.1641	1.1573	1.1503	1.1431	1.1387
18	1.2073	1.2051	1.2023	1.1995	1.1966	1.1936	1.1906	1.1876	1.1812	1.1746	1.1678	1.1607	1.1534	1.1489
19	1.2185	1.2164	1.2137	1.2108	1.2079	1.2049	1.2018	1.1987	1.1922	1.1856	1.1787	1.1717	1.1644	1.1599
20	1.2296	1.2274	1.2244	1.2215	1.2185	1.2155	1.2124	1.2092	1.2027	1.1960	1.1891	1.1819	1.1746	1.1700
21	1.2408	1.2386	1.2358	1.2329	1.2298	1.2268	1.2236	1.2204	1.2138	1.2071	1.2001	1.1930	1.1856	1.1811
22	1.2519	1.2496	1.2465	1.2436	1.2405	1.2374	1.2342	1.2309	1.2243	1.2174	1.2104	1.2032	1.1958	1.1912
23	1.2631	1.2608	1.2578	1.2548	1.2517	1.2485	1.2453	1.2420	1.2353	1.2285	1.2214	1.2142	1.2068	1.2022
24	1.2741	1.2717	1.2686	1.2655	1.2623	1.2591	1.2559	1.2526	1.2458	1.2388	1.2317	1.2244	1.2170	1.2124
25	1.2853	1.2828	1.2797	1.2766	1.2734	1.2701	1.2668	1.2635	1.2567	1.2497	1.2426	1.2353	1.2278	1.2232
26	1.2963	1.2938	1.2906	1.2874	1.2842	1.2809	1.2776	1.2742	1.2673	1.2603	1.2531	1.2458	1.2382	1.2336
27	1.3073	1.3047	1.3014	1.2982	1.2949	1.2916	1.2882	1.2848	1.2779	1.2708	1.2636	1.2562	1.2487	1.2441
28	1.3182	1.3157	1.3124	1.3091	1.3058	1.3024	1.2990	1.2955	1.2886	1.2814	1.2742	1.2668	1.2592	1.2546
29	1.3291	1.3263	1.3230	1.3196	1.3163	1.3129	1.3094	1.3060	1.2989	1.2918	1.2844	1.2770	1.2694	1.2648
30		1.3374	1.3340	1.3306	1.3272	1.3238	1.3203	1.3168	1.3098	1.3025	1.2952	1.2877	1.2801	1.2755
31		1.3477	1.3443	1.3408	1.3374	1.3339	1.3304	1.3269	1.3198	1.3125	1.3051	1.2976	1.2899	1.2853
32			1.3552	1.3518	1.3483	1.3448	1.3413	1.3377	1.3305	1.3232	1.3158	1.3082	1.3006	1.2960
33			1.3655	1.3618	1.3583	1.3547	1.3512	1.3476	1.3404	1.3330	1.3255	1.3179	1.3103	1.3057
34				1.3725	1.3689	1.3653	1.3617	1.3581	1.3508	1.3434	1.3360	1.3284	1.3207	1.3161
35				1.3825	1.3789	1.3753	1.3717	1.3681	1.3607	1.3532	1.3457	1.3381	1.3304	1.3258
36				1.3930	1.3893	1.3857	1.3820	1.3784	1.3710	1.3634	1.3559	1.3483	1.3406	1.3360
37				1.4029	1.3993	1.3956	1.3919	1.3882	1.3808	1.3732	1.3657	1.3580	1.3503	1.3457
38					1.4095	1.4057	1.4020	1.3983	1.3908	1.3832	1.3756	1.3680	1.3603	1.3556
39					1.4194	1.4156	1.4119	1.4081	1.4006	1.3930	1.3853	1.3777	1.3700	1.3654
40					1.4293	1.4255	1.4217	1.4179	1.4103	1.4027	1.3951	1.3874	1.3797	1.3750
41				1.4430	1.4392	1.4353	1.4315	1.4277	1.4201	1.4124	1.4048	1.3971	1.3894	1.3848
42				1.4525	1.4487	1.4448	1.4410	1.4372	1.4295	1.4217	1.4141	1.4064	1.3986	1.3940
43				1.4625	1.4586	1.4547	1.4509	1.4470	1.4393	1.4316	1.4239	1.4162	1.4085	1.4039
44				1.4717	1.4678	1.4639	1.4600	1.4561	1.4483	1.4405	1.4328	1.4251	1.4174	1.4127
45			1.4860	1.4817	1.4778	1.4738	1.4699	1.4660	1.4582	1.4504	1.4427	1.4350	1.4273	1.4227
46			1.4947	1.4907	1.4868	1.4828	1.4789	1.4750	1.4672	1.4593	1.4516	1.4438	1.4361	1.4315
47			1.5048	1.5006	1.4965	1.4925	1.4886	1.4846	1.4768	1.4690	1.4612	1.4535	1.4458	1.4412
48			1.5138	1.5098	1.5058	1.5018	1.4978	1.4938	1.4860	1.4781	1.4703	1.4626	1.4549	1.4503
49				1.5190	1.5150	1.5110	1.5070	1.5030	1.4951	1.4872	1.4795	1.4717	1.4640	1.4595
50				1.5286	1.5246	1.5205	1.5165	1.5125	1.5046	1.4967	1.4890	1.4813	1.4736	1.4690
51				1.5370	1.5331	1.5291	1.5251	1.5211	1.5131	1.5052	1.4974	1.4896	1.4819	1.4773
52					1.5420	1.5380	1.5340	1.5300	1.5220	1.5141	1.5062	1.4985	1.4908	1.4861

Referenced to the density of Water at 39.2 °F = 999.972 kg/m3

Table 4a: Density of Caustic Soda Solutions (0 to 52%, SI Units)*

wt% NaOH	0 °C		10 °C		15 °C		18 °C		20 °C		25 °C		30 °C	
	kg sol./m³	kg NaOH/m³	kg sol./m³	kg NaOH/m³	kg sol./m³	kg NaOH/m³	kg sol./m³	kg NaOH/m³	kg sol./m³	kg NaOH/m³	kg sol./m³	kg NaOH/m³	kg sol./m³	kg NaOH/m³
0	999.8	0.00	999.7	0.00	999.1	0.00	998.6	0.00	998.2	0.00	997.0	0.00	995.6	0.00
1	1012.4	10.12	1011.5	10.12	1010.7	10.11	1010.0	10.10	1009.5	10.10	1008.3	10.08	1006.9	10.07
2	1024.4	20.49	1023.0	20.46	1022.0	20.44	1021.3	20.43	1020.7	20.41	1019.3	20.39	1017.7	20.35
3	1036.4	31.09	1034.5	31.04	1033.2	31.00	1032.4	30.97	1031.8	30.95	1030.3	30.91	1028.5	30.86
4	1048.2	41.93	1045.9	41.84	1044.4	41.78	1043.5	41.74	1042.8	41.71	1041.1	41.65	1039.3	41.57
5	1059.8	52.99	1057.1	52.86	1055.5	52.78	1054.5	52.73	1053.8	52.69	1052.0	52.60	1050.1	52.51
6	1071.3	64.28	1068.3	64.10	1066.7	64.00	1065.6	63.94	1064.8	63.89	1062.9	63.78	1060.9	63.65
7	1082.8	75.80	1079.5	75.57	1077.8	75.44	1076.6	75.36	1075.8	75.31	1073.8	75.17	1071.7	75.02
8	1094.3	87.54	1090.8	87.26	1088.9	87.11	1087.7	87.02	1086.9	86.95	1084.8	86.78	1082.6	86.61
9	1105.7	99.51	1102.0	99.18	1100.0	99.00	1098.7	98.88	1097.9	98.81	1095.7	98.61	1093.4	98.41
10	1117.1	111.7	1113.2	111.3	1111.1	111.1	1109.8	111.0	1108.9	110.9	1106.7	110.7	1104.3	110.4
11	1128.5	124.1	1124.3	123.7	1122.2	123.4	1120.8	123.3	1119.9	123.2	1117.6	122.9	1115.2	122.7
12	1139.9	136.8	1135.5	136.3	1133.3	136.0	1131.9	135.8	1130.9	135.7	1128.5	135.4	1126.1	135.1
13	1151.1	149.6	1146.8	149.1	1144.5	148.8	1143.0	148.6	1142.1	148.5	1139.6	148.2	1137.1	147.8
14	1162.4	162.7	1157.8	162.1	1155.5	161.8	1154.0	161.6	1153.0	161.4	1150.5	161.1	1148.0	160.7
15	1173.6	176.0	1169.1	175.4	1166.7	175.0	1165.2	174.8	1164.3	174.6	1161.7	174.3	1159.1	173.9
16	1184.9	189.6	1180.1	188.8	1177.6	188.4	1176.1	188.2	1175.1	188.0	1172.5	187.6	1169.9	187.2
17	1196.1	203.3	1191.4	202.5	1189.0	202.1	1187.4	201.9	1186.4	201.7	1183.7	201.2	1181.1	200.8
18	1207.3	217.3	1202.3	216.4	1199.7	216.0	1198.2	215.7	1197.2	215.5	1194.5	215.0	1191.8	214.5
19	1218.5	231.5	1213.6	230.6	1211.1	230.1	1209.5	229.8	1208.5	229.6	1205.7	229.1	1203.0	228.6
20	1229.6	245.9	1224.4	244.9	1221.8	244.4	1220.2	244.0	1219.1	243.8	1216.4	243.3	1213.6	242.7
21	1240.8	260.6	1235.8	259.5	1233.2	259.0	1231.5	258.6	1230.4	258.4	1227.6	257.8	1224.8	257.2
22	1251.9	275.4	1246.5	274.2	1243.9	273.6	1242.2	273.3	1241.1	273.0	1238.3	272.4	1235.4	271.8
23	1263.1	290.5	1257.8	289.3	1255.1	288.7	1253.4	288.3	1252.3	288.0	1249.4	287.4	1246.5	286.7
24	1274.1	305.8	1268.6	304.5	1265.8	303.8	1264.1	303.4	1262.9	303.1	1260.1	302.4	1257.1	301.7
25	1285.2	321.3	1279.6	319.9	1276.9	319.2	1275.1	318.8	1274.0	318.5	1271.1	317.8	1268.1	317.0
26	1296.3	337.0	1290.6	335.6	1287.7	334.8	1286.0	334.4	1284.8	334.0	1281.9	333.3	1278.9	332.5
27	1307.3	353.0	1301.4	351.4	1298.5	350.6	1296.7	350.1	1295.5	349.8	1292.6	349.0	1289.5	348.2
28	1318.2	369.1	1312.4	367.5	1309.4	366.6	1307.6	366.1	1306.4	365.8	1303.4	364.9	1300.2	364.1
29	1329.1	385.4	1322.9	383.6	1319.9	382.8	1318.1	382.2	1316.9	381.9	1313.8	381.0	1310.8	380.1
30			1334.0	400.2	1330.9	399.3	1329.0	398.7	1327.9	398.4	1324.8	397.4	1321.7	396.5
31			1344.3	416.7	1341.1	415.7	1339.3	415.2	1338.0	414.8	1334.9	413.8	1331.8	412.9
32			1355.2	433.7	1352.0	432.6	1350.2	432.1	1349.0	431.7	1345.8	430.7	1342.7	429.7
33			1365.4	450.6	1362.1	449.5	1360.2	448.9	1358.9	448.5	1355.8	447.4	1352.6	446.4
34					1372.8	466.8	1370.8	466.1	1369.6	465.7	1366.4	464.6	1363.2	463.5
35					1382.8	484.0	1380.9	483.3	1379.6	482.9	1376.4	481.7	1373.1	480.6
36					1393.3	501.6	1391.3	500.9	1390.0	500.4	1386.7	499.2	1383.5	498.1
37					1403.3	519.2	1401.3	518.5	1400.0	518.0	1396.7	516.8	1393.4	515.6
38							1411.5	536.4	1410.1	535.8	1406.8	534.6	1403.5	533.3
39							1421.4	554.4	1420.1	553.8	1416.7	552.5	1413.4	551.2
40							1431.4	572.6	1430.0	572.0	1426.6	570.6	1423.2	569.3
41							1441.3	590.9	1439.8	590.3	1436.4	588.9	1433.0	587.5
42					1452.9	610.2	1450.8	609.3	1449.4	608.7	1446.0	607.3	1442.5	605.9
43					1462.9	629.0	1460.8	628.1	1459.3	627.5	1455.9	626.0	1452.4	624.5
44					1472.0	647.7	1469.9	646.8	1468.5	646.1	1465.0	644.6	1461.5	643.1
45			1486.0	668.7	1482.1	666.9	1479.9	666.0	1478.4	665.3	1475.0	663.7	1471.5	662.2
46			1494.7	687.6	1491.1	685.9	1489.0	684.9	1487.3	684.2	1483.9	682.6	1480.5	681.0
47			1504.8	707.2	1500.9	705.4	1498.8	704.4	1497.2	703.7	1493.7	702.0	1490.2	700.4
48			1513.8	726.6	1510.2	724.9	1508.0	723.8	1506.5	723.1	1502.9	721.4	1499.4	719.7
49					1519.4	744.5	1517.2	743.4	1515.7	742.7	1512.1	740.9	1508.6	739.2
50					1529.0	764.5	1526.8	763.4	1525.3	762.7	1521.7	760.9	1518.1	759.1
51					1537.5	784.1	1535.3	783.0	1533.7	782.2	1530.2	780.4	1526.6	778.6
52									1542.6	802.2	1539.1	800.3	1535.5	798.5

Adapted from the International Critical Tables, 3, p. 7

Table 4b: Density of Caustic Soda Solutions (0 to 52%, SI Units)*

wt% NaOH	40 °C		50 °C		60 °C		70 °C		80 °C		90 °C		100 °C	
	kg sol./m³	kg NaOH/m³	kg sol./m³	kg NaOH/m³	kg sol./m³	kg NaOH/m³	kg sol./m³	kg NaOH/m³	kg sol./m³	kg NaOH/m³	kg sol./m³	kg NaOH/m³	kg sol./m³	kg NaOH/m³
0	992.2	0.00	988.0	0.00	983.2	0.00	977.8	0.00	971.8	0.00	965.3	0.00	958.4	0.00
1	1003.3	10.03	999.0	9.99	994.1	9.94	988.4	9.88	982.4	9.82	976.0	9.76	969.3	9.69
2	1013.9	20.28	1009.5	20.19	1004.5	20.09	998.9	19.98	992.9	19.86	986.5	19.73	979.7	19.59
3	1024.6	30.74	1020.1	30.60	1015.0	30.45	1009.4	30.28	1003.5	30.11	997.0	29.91	990.3	29.71
4	1035.2	41.41	1030.5	41.22	1025.4	41.02	1019.8	40.79	1013.9	40.56	1007.5	40.30	1000.9	40.04
5	1045.8	52.29	1041.2	52.06	1035.9	51.80	1030.2	51.51	1024.3	51.22	1017.9	50.90	1011.5	50.58
6	1056.4	63.38	1051.7	63.10	1046.3	62.78	1040.7	62.44	1034.7	62.08	1028.4	61.70	1022.0	61.32
7	1067.2	74.70	1062.3	74.36	1056.9	73.98	1051.3	73.59	1045.3	73.17	1039.0	72.73	1032.6	72.28
8	1078.0	86.24	1073.0	85.84	1067.6	85.41	1061.9	84.95	1056.0	84.48	1049.7	83.98	1043.2	83.46
9	1088.7	97.98	1083.6	97.52	1078.2	97.04	1072.5	96.53	1066.5	95.99	1060.2	95.42	1053.7	94.83
10	1099.5	110.0	1094.2	109.4	1088.9	108.9	1083.1	108.3	1077.1	107.7	1070.8	107.1	1064.3	106.4
11	1110.2	122.1	1105.0	121.5	1099.4	120.9	1093.6	120.3	1087.6	119.6	1081.3	118.9	1074.8	118.2
12	1121.0	134.5	1115.7	133.9	1110.1	133.2	1104.3	132.5	1098.3	131.8	1092.0	131.0	1085.5	130.3
13	1132.0	147.2	1126.6	146.5	1120.9	145.7	1115.1	145.0	1108.9	144.2	1102.6	143.3	1096.0	142.5
14	1142.8	160.0	1137.3	159.2	1131.6	158.4	1125.7	157.6	1119.5	156.7	1113.2	155.8	1106.6	154.9
15	1153.8	173.1	1148.2	172.2	1142.5	171.4	1136.5	170.5	1130.3	169.5	1123.9	168.6	1117.3	167.6
16	1164.5	186.3	1158.8	185.4	1153.1	184.5	1147.1	183.5	1140.8	182.5	1134.3	181.5	1127.7	180.4
17	1175.6	199.9	1169.9	198.9	1164.0	197.9	1158.0	196.9	1151.7	195.8	1145.3	194.7	1138.6	193.6
18	1186.3	213.5	1180.5	212.5	1174.6	211.4	1168.5	210.3	1162.1	209.2	1155.6	208.0	1148.9	206.8
19	1197.4	227.5	1191.5	226.4	1185.6	225.3	1179.4	224.1	1173.1	222.9	1166.6	221.6	1159.9	220.4
20	1207.9	241.6	1202.0	240.4	1196.0	239.2	1189.8	238.0	1183.3	236.7	1176.8	235.4	1170.0	234.0
21	1219.1	256.0	1213.1	254.8	1207.1	253.5	1200.8	252.2	1194.4	250.8	1187.8	249.4	1181.1	248.0
22	1229.6	270.5	1223.6	269.2	1217.4	267.8	1211.1	266.4	1204.6	265.0	1198.0	263.6	1191.2	262.1
23	1240.7	285.4	1234.6	284.0	1228.4	282.5	1222.1	281.1	1215.6	279.6	1209.0	278.1	1202.2	276.5
24	1251.2	300.3	1245.1	298.8	1238.8	297.3	1232.4	295.8	1225.9	294.2	1219.2	292.6	1212.4	291.0
25	1262.1	315.5	1256.0	314.0	1249.7	312.4	1243.3	310.8	1236.7	309.2	1230.0	307.5	1223.2	305.8
26	1272.8	330.9	1266.6	329.3	1260.3	327.7	1253.8	326.0	1247.2	324.3	1240.5	322.5	1233.6	320.7
27	1283.4	346.5	1277.2	344.8	1270.8	343.1	1264.3	341.4	1257.6	339.6	1250.9	337.7	1244.0	335.9
28	1294.2	362.4	1287.8	360.6	1281.4	358.8	1275.0	357.0	1268.2	355.1	1261.5	353.2	1254.6	351.3
29	1304.5	378.3	1298.2	376.5	1291.7	374.6	1285.2	372.7	1278.4	370.7	1271.7	368.8	1264.7	366.8
30	1315.4	394.6	1309.0	392.7	1302.5	390.8	1295.9	388.8	1289.2	386.8	1282.4	384.7	1275.5	382.7
31	1325.4	410.9	1319.0	408.9	1312.5	406.9	1305.8	404.8	1299.0	402.7	1292.2	400.6	1285.3	398.4
32	1336.2	427.6	1329.8	425.5	1323.2	423.4	1316.5	421.3	1309.7	419.1	1302.9	416.9	1296.0	414.7
33	1346.1	444.2	1339.6	442.1	1333.0	439.9	1326.2	437.7	1319.4	435.4	1312.6	433.1	1305.6	430.9
34	1356.6	461.2	1350.1	459.0	1343.4	456.8	1336.7	454.5	1329.9	452.2	1323.0	449.8	1316.1	447.5
35	1366.5	478.3	1359.9	476.0	1353.2	473.6	1346.4	471.3	1339.6	468.9	1332.7	466.4	1325.7	464.0
36	1376.8	495.6	1370.2	493.3	1363.4	490.8	1356.7	488.4	1349.8	485.9	1342.9	483.4	1336.0	481.0
37	1386.7	513.1	1380.0	510.6	1373.2	508.1	1366.4	505.6	1359.5	503.0	1352.6	500.5	1345.7	497.9
38	1396.7	530.7	1390.0	528.2	1383.2	525.6	1376.3	523.0	1369.5	520.4	1362.6	517.8	1355.6	515.1
39	1406.6	548.6	1399.8	545.9	1392.9	543.2	1386.1	540.6	1379.2	537.9	1372.2	535.2	1365.3	532.5
40	1416.4	566.6	1409.5	563.8	1402.7	561.1	1395.8	558.3	1388.9	555.6	1382.0	552.8	1375.0	550.0
41	1426.1	584.7	1419.3	581.9	1412.4	579.1	1405.5	576.2	1398.6	573.4	1391.6	570.6	1384.7	567.7
42	1435.6	603.0	1428.7	600.1	1421.7	597.1	1414.8	594.2	1407.9	591.3	1400.9	588.4	1394.0	585.5
43	1445.4	621.5	1438.5	618.5	1431.5	615.6	1424.6	612.6	1417.7	609.6	1410.7	606.6	1403.8	603.7
44	1454.5	640.0	1447.5	636.9	1440.5	633.8	1433.5	630.7	1426.6	627.7	1419.6	624.6	1412.7	621.6
45	1464.4	659.0	1457.4	655.8	1450.4	652.7	1443.4	649.5	1436.5	646.4	1429.6	643.3	1422.7	640.2
46	1473.4	677.8	1466.3	674.5	1459.3	671.3	1452.3	668.1	1445.4	664.9	1438.4	661.7	1431.5	658.5
47	1483.0	697.0	1476.0	693.7	1468.9	690.4	1461.9	687.1	1455.0	683.9	1448.1	680.6	1441.2	677.4
48	1492.2	716.3	1485.1	712.8	1478.1	709.5	1471.1	706.1	1464.1	702.8	1457.2	699.5	1450.3	696.1
49	1501.4	735.7	1494.3	732.2	1487.2	728.7	1480.2	725.3	1473.2	721.9	1466.3	718.5	1459.4	715.1
50	1510.9	755.5	1503.8	751.9	1496.7	748.4	1489.7	744.9	1482.7	741.4	1475.9	738.0	1469.0	734.5
51	1519.4	774.9	1512.2	771.2	1505.2	767.6	1498.1	764.0	1491.1	760.4	1484.2	757.0	1477.3	753.4
52	1528.3	794.7	1521.1	791.0	1514.0	787.3	1507.0	783.6	1499.9	779.9	1493.1	776.4	1486.1	772.8

Adapted from the International Critical Tables, 3, p. 7

Table 5a: Density of Caustic Soda Solutions (0 to 52%, English Units)*

wt% NaOH	32 °F		40 °F		50 °F		60 °F		70 °F		80 °F		90 °F	
	lbs. sol. per gal	lbs. NaOH per gal	lbs. sol. per gal	lbs. NaOH per gal	lbs. sol. per gal	lbs. NaOH per gal	lbs. sol. per gal	lbs. NaOH per gal	lbs. sol. per gal	lbs. NaOH per gal	lbs. sol. per gal	lbs. NaOH per gal	lbs. sol. per gal	lbs. NaOH per gal
0	8.344	0.000	8.345	0.000	8.343	0.000	8.337	0.000	8.329	0.000	8.317	0.000	8.304	0.000
1	8.449	0.084	8.447	0.084	8.442	0.084	8.433	0.084	8.423	0.084	8.411	0.084	8.397	0.084
2	8.549	0.171	8.545	0.171	8.538	0.171	8.528	0.171	8.516	0.170	8.502	0.170	8.487	0.170
3	8.649	0.259	8.643	0.259	8.634	0.259	8.622	0.259	8.608	0.258	8.593	0.258	8.577	0.257
4	8.748	0.350	8.740	0.350	8.729	0.349	8.715	0.349	8.700	0.348	8.684	0.347	8.666	0.347
5	8.845	0.442	8.835	0.442	8.822	0.441	8.807	0.440	8.792	0.440	8.775	0.439	8.756	0.438
6	8.941	0.536	8.930	0.536	8.916	0.535	8.900	0.534	8.883	0.533	8.865	0.532	8.846	0.531
7	9.037	0.633	9.025	0.632	9.009	0.631	8.993	0.629	8.975	0.628	8.956	0.627	8.936	0.626
8	9.133	0.731	9.120	0.730	9.103	0.728	9.086	0.727	9.067	0.725	9.047	0.724	9.027	0.722
9	9.228	0.830	9.214	0.829	9.197	0.828	9.178	0.826	9.159	0.824	9.138	0.822	9.117	0.821
10	9.323	0.932	9.309	0.931	9.290	0.929	9.271	0.927	9.250	0.925	9.229	0.923	9.207	0.921
11	9.418	1.036	9.403	1.034	9.383	1.032	9.363	1.030	9.342	1.028	9.320	1.025	9.298	1.023
12	9.513	1.142	9.497	1.140	9.476	1.137	9.456	1.135	9.434	1.132	9.412	1.129	9.389	1.127
13	9.607	1.249	9.591	1.247	9.570	1.244	9.549	1.241	9.527	1.238	9.504	1.236	9.481	1.233
14	9.701	1.358	9.684	1.356	9.663	1.353	9.641	1.350	9.618	1.347	9.595	1.343	9.571	1.340
15	9.795	1.469	9.778	1.467	9.757	1.464	9.735	1.460	9.712	1.457	9.688	1.453	9.664	1.450
16	9.889	1.582	9.871	1.579	9.849	1.576	9.826	1.572	9.802	1.568	9.778	1.564	9.754	1.561
17	9.982	1.697	9.965	1.694	9.943	1.690	9.920	1.686	9.896	1.682	9.872	1.678	9.847	1.674
18	10.076	1.814	10.057	1.810	10.034	1.806	10.010	1.802	9.986	1.797	9.961	1.793	9.936	1.789
19	10.169	1.932	10.151	1.929	10.129	1.924	10.105	1.920	10.080	1.915	10.055	1.911	10.030	1.906
20	10.262	2.052	10.243	2.049	10.218	2.044	10.194	2.039	10.169	2.034	10.144	2.029	10.118	2.024
21	10.355	2.175	10.337	2.171	10.313	2.166	10.289	2.161	10.264	2.155	10.238	2.150	10.212	2.144
22	10.448	2.299	10.428	2.294	10.403	2.289	10.378	2.283	10.352	2.278	10.326	2.272	10.300	2.266
23	10.541	2.424	10.522	2.420	10.497	2.414	10.472	2.408	10.446	2.403	10.419	2.396	10.393	2.390
24	10.633	2.552	10.613	2.547	10.587	2.541	10.561	2.535	10.535	2.528	10.508	2.522	10.481	2.515
25	10.726	2.681	10.706	2.676	10.679	2.670	10.654	2.663	10.627	2.657	10.600	2.650	10.572	2.643
26	10.818	2.813	10.797	2.807	10.771	2.800	10.744	2.793	10.717	2.786	10.690	2.779	10.662	2.772
27	10.910	2.946	10.888	2.940	10.861	2.932	10.834	2.925	10.806	2.918	10.779	2.910	10.751	2.903
28	11.001	3.080	10.980	3.074	10.953	3.067	10.925	3.059	10.897	3.051	10.869	3.043	10.841	3.035
29	11.092	3.217	11.068	3.210	11.041	3.202	11.013	3.194	10.985	3.186	10.956	3.177	10.928	3.169
30			11.161	3.348	11.133	3.340	11.105	3.331	11.076	3.323	11.047	3.314	11.019	3.306
31			11.247	3.487	11.219	3.478	11.190	3.469	11.161	3.460	11.132	3.451	11.103	3.442
32					11.310	3.619	11.281	3.610	11.252	3.601	11.223	3.591	11.194	3.582
33					11.395	3.760	11.365	3.750	11.335	3.741	11.306	3.731	11.276	3.721
34							11.454	3.894	11.424	3.884	11.394	3.874	11.364	3.864
35							11.537	4.038	11.508	4.028	11.478	4.017	11.447	4.007
36							11.625	4.185	11.594	4.174	11.564	4.163	11.534	4.152
37							11.708	4.332	11.678	4.321	11.647	4.309	11.616	4.298
38									11.762	4.470	11.731	4.458	11.700	4.446
39									11.845	4.620	11.814	4.607	11.783	4.595
40									11.928	4.771	11.897	4.759	11.865	4.746
41							12.042	4.937	12.010	4.924	11.979	4.911	11.947	4.898
42							12.122	5.091	12.090	5.078	12.058	5.064	12.026	5.051
43							12.205	5.248	12.173	5.234	12.140	5.220	12.108	5.207
44							12.282	5.404	12.249	5.390	12.217	5.375	12.184	5.361
45					12.402	5.581	12.365	5.564	12.332	5.550	12.300	5.535	12.267	5.520
46					12.474	5.738	12.441	5.723	12.408	5.707	12.375	5.692	12.342	5.677
47					12.558	5.902	12.523	5.886	12.489	5.870	12.456	5.854	12.423	5.839
48					12.634	6.064	12.600	6.048	12.566	6.032	12.533	6.016	12.500	6.000
49							12.677	6.212	12.643	6.195	12.610	6.179	12.576	6.162
50							12.757	6.378	12.723	6.362	12.690	6.345	12.656	6.328
51							12.827	6.542	12.794	6.525	12.761	6.508	12.727	6.491
52									12.868	6.692	12.835	6.674	12.802	6.657

Adapted from the International Critical Tables, 3, p. 7

Table 5b: Density of Caustic Soda Solutions (0 to 52%, English Units)*

wt% NaOH	100 °F		120 °F		140 °F		160 °F		180 °F		200 °F		212 °F	
	lbs. sol. per gal	lbs. NaOH per gal	lbs. sol. per gal	lbs. NaOH per gal	lbs. sol. per gal	lbs. NaOH per gal	lbs. sol. per gal	lbs. NaOH per gal	lbs. sol. per gal	lbs. NaOH per gal	lbs. sol. per gal	lbs. NaOH per gal	lbs. sol. per gal	lbs. NaOH per gal
0	8.288	0.000	8.250	0.000	8.205	0.000	8.155	0.000	8.099	0.000	8.037	0.000	7.998	0.000
1	8.380	0.084	8.342	0.083	8.296	0.083	8.244	0.082	8.187	0.082	8.127	0.081	8.089	0.081
2	8.469	0.169	8.429	0.169	8.383	0.168	8.331	0.167	8.275	0.165	8.214	0.164	8.176	0.164
3	8.559	0.257	8.518	0.256	8.471	0.254	8.419	0.253	8.363	0.251	8.302	0.249	8.265	0.248
4	8.647	0.346	8.605	0.344	8.558	0.342	8.506	0.340	8.450	0.338	8.390	0.336	8.353	0.334
5	8.737	0.437	8.693	0.435	8.645	0.432	8.593	0.430	8.536	0.427	8.478	0.424	8.442	0.422
6	8.826	0.530	8.781	0.527	8.732	0.524	8.680	0.521	8.624	0.517	8.565	0.514	8.529	0.512
7	8.915	0.624	8.870	0.621	8.821	0.617	8.768	0.614	8.712	0.610	8.654	0.606	8.618	0.603
8	9.005	0.720	8.959	0.717	8.910	0.713	8.857	0.709	8.801	0.704	8.743	0.699	8.706	0.696
9	9.095	0.819	9.048	0.814	8.998	0.810	8.945	0.805	8.889	0.800	8.830	0.795	8.794	0.791
10	9.185	0.918	9.137	0.914	9.088	0.909	9.034	0.903	8.978	0.898	8.919	0.892	8.882	0.888
11	9.275	1.020	9.227	1.015	9.175	1.009	9.122	1.003	9.065	0.997	9.006	0.991	8.970	0.987
12	9.365	1.124	9.316	1.118	9.264	1.112	9.211	1.105	9.154	1.099	9.096	1.091	9.059	1.087
13	9.457	1.229	9.407	1.223	9.355	1.216	9.300	1.209	9.243	1.202	9.184	1.194	9.147	1.189
14	9.547	1.337	9.497	1.330	9.444	1.322	9.389	1.314	9.332	1.306	9.272	1.298	9.235	1.293
15	9.639	1.446	9.588	1.438	9.535	1.430	9.479	1.422	9.422	1.413	9.362	1.404	9.325	1.399
16	9.729	1.557	9.677	1.548	9.623	1.540	9.567	1.531	9.509	1.521	9.449	1.512	9.411	1.506
17	9.821	1.670	9.769	1.661	9.715	1.651	9.658	1.642	9.600	1.632	9.540	1.622	9.503	1.615
18	9.911	1.784	9.858	1.774	9.803	1.765	9.746	1.754	9.687	1.744	9.626	1.733	9.588	1.726
19	10.003	1.901	9.950	1.890	9.894	1.880	9.837	1.869	9.778	1.858	9.717	1.846	9.680	1.839
20	10.091	2.018	10.037	2.007	9.981	1.996	9.923	1.985	9.864	1.973	9.802	1.960	9.764	1.953
21	10.185	2.139	10.130	2.127	10.074	2.115	10.016	2.103	9.956	2.091	9.895	2.078	9.857	2.070
22	10.273	2.260	10.217	2.248	10.160	2.235	10.101	2.222	10.041	2.209	9.979	2.195	9.941	2.187
23	10.365	2.384	10.309	2.371	10.252	2.358	10.193	2.344	10.133	2.331	10.071	2.316	10.033	2.308
24	10.453	2.509	10.397	2.495	10.339	2.481	10.279	2.467	10.218	2.452	10.156	2.437	10.118	2.428
25	10.545	2.636	10.488	2.622	10.430	2.607	10.370	2.592	10.309	2.577	10.246	2.562	10.208	2.552
26	10.634	2.765	10.576	2.750	10.518	2.735	10.458	2.719	10.396	2.703	10.334	2.687	10.295	2.677
27	10.722	2.895	10.665	2.880	10.606	2.864	10.545	2.847	10.483	2.831	10.420	2.814	10.382	2.803
28	10.812	3.027	10.754	3.011	10.694	2.994	10.634	2.977	10.572	2.960	10.509	2.943	10.470	2.932
29	10.899	3.161	10.840	3.144	10.780	3.126	10.719	3.109	10.657	3.091	10.594	3.072	10.555	3.061
30	10.989	3.297	10.930	3.279	10.870	3.261	10.809	3.243	10.747	3.224	10.683	3.205	10.645	3.193
31	11.073	3.433	11.014	3.414	10.953	3.396	10.892	3.376	10.829	3.357	10.765	3.337	10.726	3.325
32	11.164	3.572	11.104	3.553	11.043	3.534	10.981	3.514	10.918	3.494	10.854	3.473	10.816	3.461
33	11.246	3.711	11.186	3.691	11.124	3.671	11.062	3.651	10.999	3.630	10.935	3.608	10.896	3.596
34	11.334	3.854	11.273	3.833	11.212	3.812	11.149	3.791	11.086	3.769	11.022	3.748	10.984	3.734
35	11.417	3.996	11.356	3.974	11.293	3.953	11.231	3.931	11.167	3.908	11.103	3.886	11.064	3.872
36	11.503	4.141	11.441	4.119	11.378	4.096	11.316	4.074	11.252	4.051	11.188	4.028	11.150	4.014
37	11.585	4.287	11.523	4.264	11.460	4.240	11.397	4.217	11.333	4.193	11.269	4.170	11.230	4.155
38	11.669	4.434	11.606	4.410	11.544	4.387	11.480	4.362	11.416	4.338	11.352	4.314	11.313	4.299
39	11.751	4.583	11.688	4.558	11.625	4.534	11.561	4.509	11.497	4.484	11.433	4.459	11.394	4.444
40	11.833	4.733	11.770	4.708	11.706	4.683	11.643	4.657	11.579	4.631	11.514	4.606	11.475	4.590
41	11.915	4.885	11.851	4.859	11.787	4.833	11.723	4.807	11.659	4.780	11.595	4.754	11.556	4.738
42	11.994	5.037	11.930	5.010	11.865	4.983	11.801	4.956	11.737	4.929	11.672	4.902	11.634	4.886
43	12.076	5.193	12.011	5.165	11.947	5.137	11.883	5.110	11.819	5.082	11.754	5.054	11.716	5.038
44	12.152	5.347	12.087	5.318	12.022	5.290	11.957	5.261	11.893	5.233	11.828	5.204	11.790	5.188
45	12.234	5.505	12.169	5.476	12.104	5.447	12.040	5.418	11.976	5.389	11.911	5.360	11.873	5.343
46	12.309	5.662	12.244	5.632	12.179	5.602	12.114	5.573	12.049	5.543	11.985	5.513	11.947	5.496
47	12.390	5.823	12.325	5.793	12.259	5.762	12.195	5.731	12.130	5.701	12.066	5.671	12.028	5.653
48	12.467	5.984	12.401	5.952	12.336	5.921	12.271	5.890	12.206	5.859	12.142	5.828	12.104	5.810
49	12.543	6.146	12.477	6.114	12.412	6.082	12.347	6.050	12.282	6.018	12.218	5.987	12.180	5.968
50	12.623	6.311	12.557	6.278	12.491	6.245	12.426	6.213	12.362	6.181	12.298	6.149	12.260	6.130
51	12.694	6.474	12.627	6.440	12.562	6.406	12.496	6.373	12.432	6.340	12.367	6.307	12.329	6.288
52	12.768	6.640	12.701	6.605	12.636	6.571	12.570	6.536	12.505	6.503	12.441	6.469	12.402	6.449

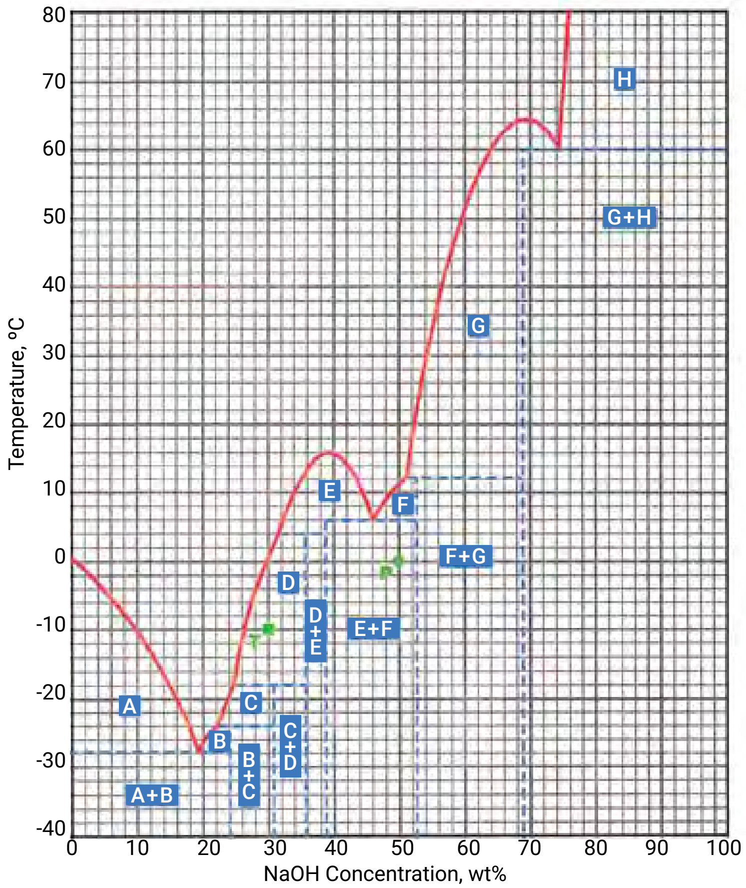
Adapted from the International Critical Tables, 3, p. 7

Caustic Soda Phase Diagram

The tendency of caustic soda to solidify when subjected to cold temperatures is an important attribute to understand when handling this product and designing storage systems. The phase diagram shows the temperature at which caustic soda solutions of any given concentration start to solidify. The composition of the various hydrates of sodium hydroxide, which can exist at a stated temperature, are also depicted.

At a given temperature and concentration, caustic soda is either all liquid, a mixture of liquid and solid, or all solid. The phase diagram makes it possible to calculate the degree of solidification that may exist and the composition of the solids present.

Chart 2: Caustic Soda Phase Diagram



To convert degree Fahrenheit (°F) to degree Celsius (°C): °C = (°F – 32) ÷ 1.8

Note: Chart 2's components A through H are described in Table 6

Freezing Point Curve

The heavy line is frequently called the "freezing point curve." If the temperature of caustic soda at a given concentration is above this curve, the solution is all liquid. When the temperature drops below the curve into an area that contains a single solid compound, both liquid and solids will be present and the solution can be described as partly frozen. If the temperature of the caustic soda drops into an area that contains two solid compounds, then there will no longer be any liquid present and the material will be completely frozen.

Caustic soda has three eutectic points. These points, sometimes called minimum freezing points, define the caustic soda concentrations that will not undergo partial freezing as they are cooled. Since caustic soda solutions at these concentrations continue to behave as a liquid instead of as a slurry at temperatures down to the actual freezing point, they are generally easier to handle. The caustic concentration that freezes at the lowest temperature, -18.4 ºF (-28.0 ºC), is 19% sodium hydroxide. For this reason, many systems are designed to store and handle caustic soda at about 20% concentration. As can be seen from Chart 2, the other two eutectic points are at 46% and 74.5% NaOH, which led to the selection of 50% and 73% caustic soda solutions as the preferred concentrations for shipping and handling.

Solid Phases

Table 6 shows the composition of the various solids formed when caustic soda solutions are cooled. The letters next to these compounds correspond to the letters shown on Chart 2. Each labeled area of the chart shows the stable compound, or compounds, which will crystallize out when a solution of a given concentration is cooled below its freezing point.

The column headed "Maximums" (see Table 6) gives the maximum temperature and concentration at which each solid compound can exist. The maximum concentrations have a further significance. They locate the eight vertical lines (including 0% and 100%), which define the limits of concentration for the various areas representing two solid components.

The column giving transition points is of special interest when one is considering the behavior of a solution upon cooling. The transition temperatures define the upper temperature limits for areas representing two solid components.

On Chart 2, each vertical line dividing an area below the freezing curve represents the composition of a stable hydrated form of sodium hydroxide. If the concentration of the product is such that it coincides with one of the

Table 6: Key to Phase Diagram – Composition of Solids

Compounds	Maximums Diluted Volume				Transition Points		
	Concentration	Temperature			Concentration	Temperature	
	(Wt. %)	(°C)	(°F)		(Wt. %)	(°C)	(°F)
A Ice	0.0	0.0	32.0	**A to B**	19.10	-28.0	-18.4
B $NaOH•7H_2O$	24.08	-23.5	-10.3	**B to C**	21.88	-24.3	-11.7
C $NaOH•5H_2O$	30.75	-12.3	9.9	**C to D**	24.70	-18.0	-0.4
D $NaOH•4H_2O$	35.70	7.8	46.0	**D to E**	31.32	3.6	38.5
E $NaOH•3.5H_2O$	38.79	15.8	60.4	**E to F**	45.89	5.9	42.6
F $NaOH•2H_2O$	52.61	12.8	55.0	**F to G**	50.50	12.2	54.0
G $NaOH•H_2O$	68.95	64.5	148.1	**G to H**	74.47	60	140.0
H NaOH	100.00	322.85	613.1				

vertical lines on the chart, only the compound represented by that vertical line will be present at temperatures below the upper limit of that region.

Behavior on Cooling

The phase diagram is used to predict the behavior of caustic soda solutions as they are cooled or heated. This is illustrated by the following three examples.

Example 1: What happens when a solution reaches the solid-liquid equilibrium (freezing point curve)? When a storage tank containing 50% caustic soda is cooled to its freezing point, 54 ºF (12.2 ºC), crystals begin to form. As the temperature continues to decrease, the crystallization continues and the concentration of the remaining solution changes along the freezing point curve. The remaining liquid, supernatant, becomes less concentrated if the initial concentration of the solution is to the left of the maximum freezing point and to the right of the minimum point as in the case of the 50% solution. If the initial solution concentration is to the right of the maximum and left of the minimum, such as 44%, the supernatant becomes more concentrated. This change in liquid concentration continues until the final temperature is reached. The concentration of the remaining solution is found at the intersection of the freezing point curve with the final temperature.

Note: For the solution to contain solid and liquid at equilibrium, the temperature must be above the temperature that marks the boundary of two solid compounds, 42.6 ºF (5.9 ºC) in this case.

Example 2: What happens when the solution freezes completely into two solid compounds? If the material in example 1 is cooled further, it will become completely solidified when the temperature drops into an area of the phase diagram that contains two solid compounds. In the case of mixtures at the eutectic concentrations (19.1%, 45.9% or 74.5%), cooling will result in complete solidification at the eutectic temperature.

Example 3: What happens when the solution freezes into a single hydrate? This occurs only when the composition of the initial solution corresponds to the composition of a hydrate (vertical lines showing the boundaries between regions containing two solids). If the composition of the solution corresponds to NaOH•3½ H_2O or NaOH•H_2O (E and G on Chart II), crystallization of the specific hydrate begins when the freezing temperature is reached. The crystallization process continues until the entire mass is solid. When solidification is complete, the temperature drops until the final temperature is reached.

In the case of the hydrates labeled B, C, D and F, crystals of the next lower state of hydration are precipitated initially. Cooling continues as described in example 1 until a transition temperature is reached. At this temperature, the originally precipitated hydrate is transformed into the hydrate with the same composition as the initial solution, and the remaining solution freezes as that hydrate.

Calculating the Amount of Solids Formed on Cooling

The amount of any compound, which has crystallized from a given solution cooled to a given temperature, may be calculated by means of this chart. All such problems are solved by first drawing a horizontal line through the point representing the initial concentration and final temperature of the solution. This line is extended to the boundaries of the area in which the point lies. The intersection of the horizontal line with a boundary line indicates the composition, whether liquid or solid, of whatever materials can exist. The proportion of the materials present may be calculated by dividing the distance (absolute value) from the starting concentration to the boundary line, by the total length of the line.

For example, in Chart 2, if G and H are boundary concentrations and P is a starting concentration, the fraction of G in the mixture is the difference between P and H divided by the difference between G and H, and conversely, the fraction of H in the mixture is the difference between G and P divided by the difference between G and H.

Example 1: If a 50% solution of caustic soda is cooled to 32 ºF (0 ºC), what is the percent of dihydrate caustic soda (F on the chart) in the resulting solid?

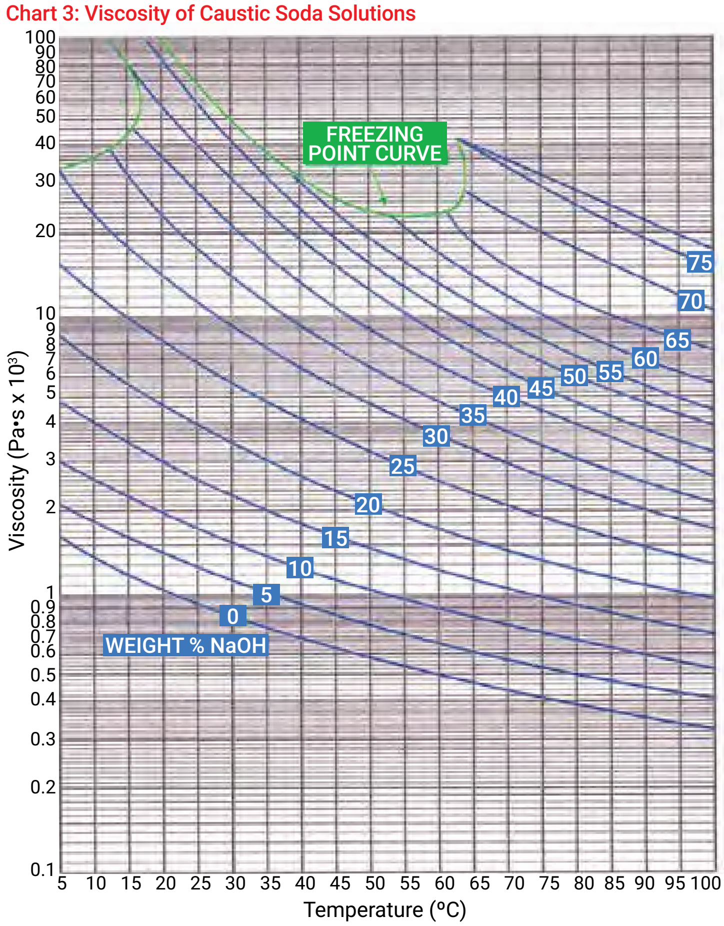
A horizontal line through this point (P on the chart) extends from 39% to 53%. The amount of NaOH in the solid is found by dividing 50-39 by 53-50. The answer is 11 ÷ 3, or 3.67 % dihydrate NaOH. The remaining 96.3% is NaOH-3 ½H2O (E on the chart).

Example 2: If a 30% solution of caustic soda is cooled to 10 ºF (-12.2ºC), what percent of the solution will precipitate as NaOH•$4H_20$ (D on the chart)?

A horizontal line through this point (T on the chart) extends from 25.7% to 35.7%. The amount of solid (NaOH•$4H_2O$) is found by dividing (30 - 25.7) by (35.7 - 25.7). The answer is 4.3 ÷ 10, or 43% tetrahydrate (NaOH•$4H_2O$). The remaining 57% is a saturated solution containing 25.7% NaOH.

Viscosity of Caustic Soda Solutions

Chart 3: Viscosity of Caustic Soda Solutions

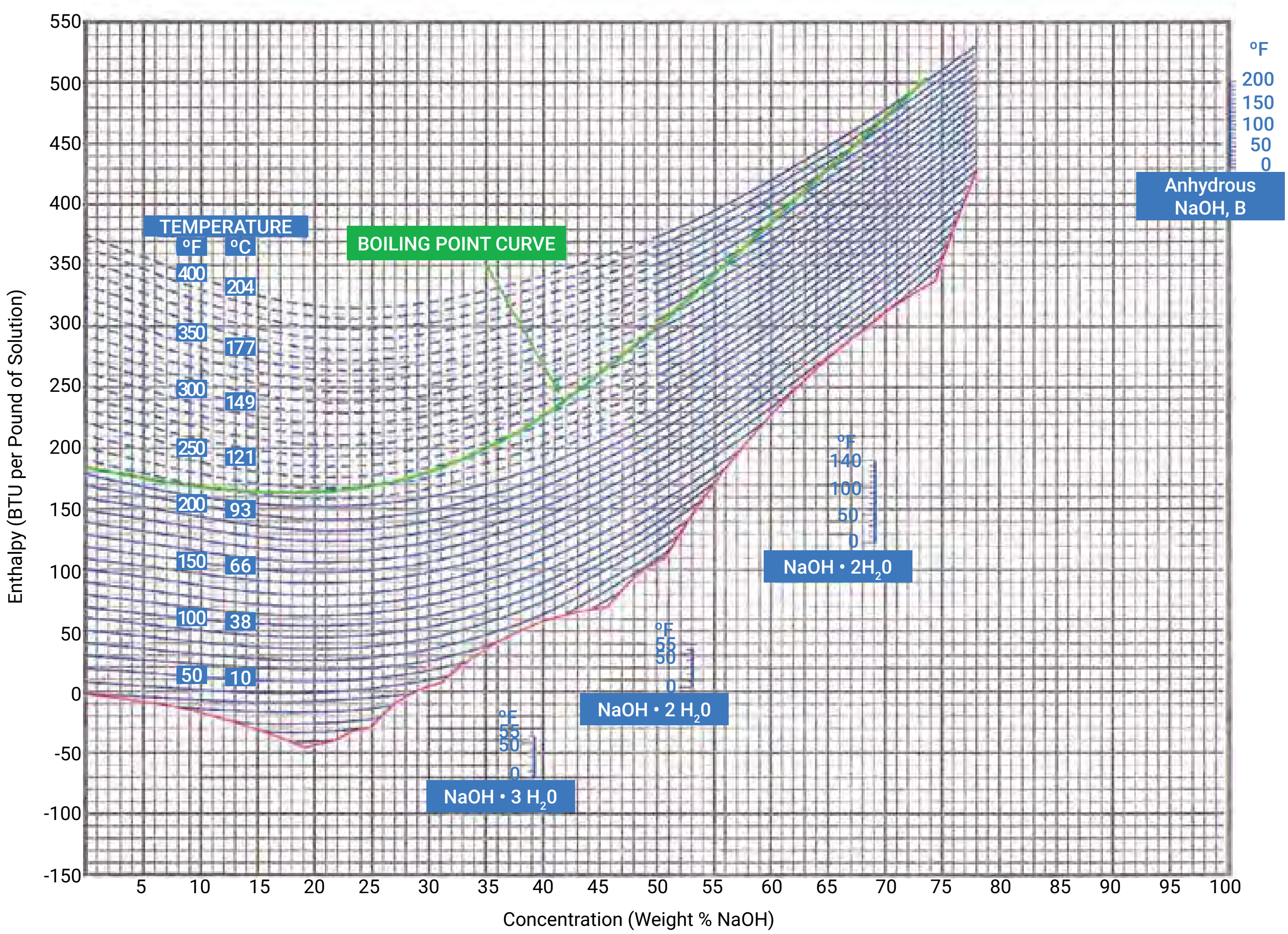


To convert degree Fahrenheit (ºF) to degree Celsius (ºC): ºC = (ºF – 32) ÷ 1.8

Enthalpy of Caustic Soda Solutions

Chart 4 is convenient for the calculation of any heat effects in NaOH-H_2O systems. It was developed by W.L. McCabe and co-workers at the University of Michigan under the sponsorship of the alkali industry including Mathieson Chemical Corporation (a predecessor company of the Olin Corporation). This chart may be used to solve problems concerning the heat evolved when a caustic soda solution is diluted.

Chart 4: Enthalpy vs. Concentration



Heat of Dilution

When a caustic soda solution is diluted, heat is evolved. The temperature of a solution after it has been diluted may exceed the temperature of either of the starting materials. This often presents a practical problem in making and handling the diluted solution.

Example 1: If 50% caustic soda at 120ºF (48.9 ºC) is diluted to 25% with water at 70 ºF (21.1 ºC)

a. What is the final temperature of the solution?

b. How much heat must be removed to cool a pound of the solution to 80 ºF (26.7 ºC)?

This problem may be solved by means of a tie line. Locate the point representing 70 ºF water (0% NaOH) and the point representing 120 ºF, 50% NaOH. Connect these two points by a straight line.

Solution to part (a). Find the intersection of the tie line with the line representing 25% solution. Then read the temperature at this point: 162 ºF (72.2 ºC).

Solution to part (b). Read the enthalpy of 25% solution at this temperature (102 Btu per pound). Then read the enthalpy of 25% solution at 80ºF (39 Btu per pound). The difference between these two values is the quantity of heat per pound of 25% solution that must be removed (63 Btu).

Boiling Point

The Enthalpy vs. Concentration chart can be used to determine when dilution of a caustic soda solution will exceed the boiling point of that solution. If a straight line connecting the point of the initial caustic soda liquid or solid with the initial dilution water temperature crosses the boiling point curve, the boiling point of the solution will be exceeded and extreme caution must be exercised. There are some instances where hot water is used to make dilute caustic soda solutions. This can be dangerous if the boiling point of the solution is exceeded and should only be done in equipment and systems specifically designed for these conditions and while wearing the appropriate PPE.

Dilution Calculations

When caustic soda solutions are diluted with water or with weaker solutions, the volumes are not additive. Thus when 10 gallons of 50% caustic soda are added to 10 gallons of water and cooled to room temperature, the final solution occupies 19.0 gallons. The final concentration is 30.3%. Accordingly, simple proportion using volumetric measures cannot be used to calculate dilution ratios.

Table 7 has been designed for use in connection with calculating dilutions of 50% caustic soda. It is a simple, though approximate, means of arriving at the ratio of diluted concentrations and volumes, and is practicable for most purposes.

When greater accuracy is desired, the diluted volumes or concentrations may be calculated as follows:

If dilution is with water. To find the volume of water required to dilute 100 volumes of liquid caustic soda to a given concentration, use the following equation:

$$V = 100\left(\frac{I}{F} - 1\right) SI$$

Where:

V = Volume of water required

I = Initial concentration (wt %)

F = Final concentration (wt %)

SI = Specific gravity of initial solution (at 15 ºC)

Example: How many gallons of water are required to dilute 100 gallons of 50% caustic soda to 35%?

$$V = 100\left(\frac{50}{35} - 1\right) 1.530 = 65.6 \text{ gal.}$$

100 gallons of 50% caustic soda diluted with 65.6 gallons of water will yield a 35% solution.

If dilution is with caustic soda solution. In this calculation, the weight percent and specific gravity of the diluting solution must also be considered. Based on 100 volumes of strong caustic soda the equation is:

$$V = \frac{100(I - F)SI}{(F - L)SL}$$

Where:

V = Volume of diluent

I = Concentration of strong caustic solution (wt %)

F = Final concentration (wt %)

L = Concentration of diluting solution (wt %)

SI = Specific gravity of strong caustic solution (at 15 ºC)

SL = Specific gravity of diluting solution (at 15 ºC)

Example: How many gallons of 20% caustic soda are required to dilute 100 gallons of 50% caustic soda to 35%?

$$V = \frac{100(50 - 35)1.530}{(35 - 20)1.223} = 125.1 \text{ gal.}$$

100 gallons of 50% caustic soda diluted with 125.1 gallons of 20% caustic soda will yield a 35% solution.

If it is desired to calculate a weight ratio, the above equations can be used without considering the specific gravities. The result will be pounds of dilute caustic soda per 100 pounds of strong caustic soda.

Table 7: Dilution of 50% Caustic Soda Solutions

NaOH Concentration Desired (Weight %)	To Obtain Indicated Concentrations Add:		Diluted Volume
	kg water per kg 50% NaOH	vol. water per vol. 50% NaOH	
1	49.00	74.57	75.24
2	24.00	36.52	37.22
3	15.67	23.84	24.55
4	11.50	17.50	18.22
5	9.00	13.70	14.43
6	7.33	11.16	11.90
7	6.14	9.35	10.10
8	5.25	7.99	8.75
9	4.56	6.93	7.70
10	4.00	6.09	6.86
11	3.55	5.40	6.18
12	3.17	4.82	5.61
13	2.85	4.33	5.12
14	2.57	3.91	4.71
15	2.33	3.55	4.36
16	2.13	3.23	4.05
17	1.94	2.95	3.77
18	1.78	2.71	3.53
19	1.63	2.48	3.32
20	1.50	2.28	3.12
21	1.38	2.10	2.95
22	1.27	1.94	2.79
23	1.17	1.79	2.64
24	1.08	1.65	2.51
25	1.00	1.52	2.39
26	0.92	1.40	2.28
27	0.85	1.30	2.18
28	0.79	1.20	2.08
29	0.72	1.10	1.99
30	0.67	1.01	1.91
31	0.61	0.93	1.84
32	0.56	0.86	1.76
33	0.52	0.78	1.70
34	0.47	0.72	1.64
35	0.43	0.65	1.58
36	0.39	0.59	1.52
37	0.35	0.53	1.47
38	0.32	0.48	1.42
39	0.28	0.43	1.38
40	0.25	0.38	1.33
41	0.22	0.33	1.29
42	0.190	0.29	1.25
43	0.163	0.25	1.21
44	0.136	0.21	1.18
45	0.111	0.17	1.15
46	0.087	0.132	1.11
47	0.064	0.097	1.08
48	0.042	0.063	1.05
49	0.020	0.031	1.03
50	0.000	0.000	1.00

Unit Conversions

Converting English to SI units

Table 8: Conversion to SI Units

Quantity	To Convert From	To	Multiply By
Heat	Btu[a]	joule (J)	1054.35
Enthalpy	Btu[a]/pound-mass	joule/kilogram (J/kg)	2324.444
Viscosity	centipoises (cp)	pascal-second (Pa*s)	0.001
Volume	gallon[b]	cubic meter (m^3)	0.0037854
Length	inch (in)	meter (m)	0.0254
Pressure	pound-force/inch^2 (psi)	pascal (Pa)	6894.757
Mass	pound-mass (lbm[c])	kilogram (kg)	0.4536

NOTE: To convert from SI to English system, multiply the SI unit by the reciprocal (1/x) of the factor in Column 4. A more complete table of conversion factors can be found in the Standard Metric Practice Guide (A Guide to the Use of SI – the International System of Units), ASTM E-380.

[a] thermochemical
[b] U.S. liquid
[c] avoirdupois

Temperature Conversions

To convert degree Fahrenheit (ºF) to degree Celsius (ºC):

$$ºC = (ºF - 32) \div 1.8$$

To convert degree Fahrenheit (ºF) to degree Kelvin (ºK):

$$ºK = (ºF + 459.67) \div 1.8$$

To convert degree Celsius (ºC) to degree Fahrenheit (ºF):

$$ºF = (ºC \times 1.8) + 32$$

To convert degree Celsius (ºC) to degree Kelvin (ºK):

$$ºK = 273.15 + ºC$$

Hydrometer Conversions

The following formulas can be used to convert hydrometer readings.

$$\text{Sp. Gr.} = \frac{145}{145 - \text{Bé}}$$

$$\text{Bé} = 145 - \frac{145}{\text{Sp. Gr.}}$$

REFERENCES:
[1] Pure Applied Chemistry, 68, 2339-2359 (1996)
[2-6] Chase, M.W., Jr. ed., NIST-JANAF Therochemical Tables, Fourth Edition, J. Phys. Chem. Ref. Data, Monograph 9, 1998, Part II, p. 1293
[7] Perry's Chemical Engineering Handbook, 6th

Caustic Soda Pricing & Billing

Background

The industry standard method of billing caustic soda (NaOH) originated many years ago, when only dry, hydrated caustic soda was commercially available. The many different forms of caustic manufactured at the time each had a tendency to partially convert to sodium carbonate at differing rates during shipping. This made it impossible for the buyer to know how much caustic soda (or, more importantly at that time, how much sodium) had, in fact, been shipped.

This uncertainty led to the establishment of a uniform billing method tied to the sodium content in the product at the time of shipment. The industry agreed to use a standard based on the anhydride of NaOH (i.e., sodium oxide, Na_2O) in the product, even though Na_2O is not physically present. The purest material that could then be produced at the time contained approximately 76% Na_2O. This standard was adopted to bill all shipments of caustic soda.

For liquid caustic soda, the 76% Na_2O standard continues to be used as a basis for invoicing the caustic content of the product. It is referred to as "dry basis" and is based on an actual analysis of the liquid caustic soda loaded into the shipping container.

How to Determine Invoice Cost

The invoice cost is made up of two components: the value of the caustic soda and the shipping or freight cost. First, the value of the caustic soda is determined by the following steps:

1. Determine the amount of sodium hydroxide (total alkalinity, as NaOH) in the shipment by analysis.
2. Calculate the percentage of Na_2O.
3. Divide the calculated percentage by 76, the industry standard percentage, to get a multiplier.
4. Apply the multiplier to the weight of the NaOH shipment to calculate the weight of Na_2O being shipped.
5. Multiply this calculated weight of Na_2O by the price of the caustic on a 76% basis. (Since Na_2O is usually measured in pounds and the price is quoted in tons, conversion to the same weight unit is necessary.)

The calculation of the value of the caustic soda is presented algebraically as:

$$I = \frac{W * N * P}{76 * 2000}$$

Where:

I = Invoice cost for the shipment

W = Weight of liquid (in lbs.) for the shipment

N = Percent of Na_2O (as determined by analysis)

P = Price (per ton) of NaOH on 76% Na_2O basis

In this calculation, 76 is the standard concentration (discussed above) that the pricing is based on and 2,000 is the conversion from pounds to tons. For example, if a 45,000-pound shipment of 39.14% Na_2O (50.5% NaOH) caustic soda is quoted at $900 per ton (dry basis), the invoice cost of the shipment (excluding freight) will be:

$$I = \frac{45{,}000 * 39.14 * 900}{76 * 2000}$$

$$I = \$10{,}428.75$$

Note: Canadian invoices will report weight in metric tons.

Shipping/Freight Cost

The price of a shipment, as determined above, does not include freight costs. The customer typically pays the freight on the net shipping weight of all deliveries, including the weight of water in which the caustic soda is dissolved.

When shipped in tank cars or tank trucks, the net weight of caustic soda in the vehicle is determined at the plant by weighing the tank car/vehicle empty and full.

When shipped in barges, the net weight of caustic soda is determined by volumetric measurements, which are then converted to weight.

The total weight on which freight must be paid appears on the bill of lading as the net weight of the shipment.

Chlorine Institute Information

Chlorine Institute Information

Pamphlet 65, "Personal Protective Equipment for Chlor Alkali Chemicals" – Provides personal protective equipment recommendations for working with caustic soda.

Pamphlet 80, "Recommended Practices for Handling Sodium Hydroxide Solution & Potassium Hydroxide Solution (Caustic) Barges" – Offers recommended practices for handling caustic soda barges.

Pamphlet 87, "Recommended Practices for Handling Sodium Hydroxide Solution & Potassium Hydroxide Solution Tank Cars" – Provides recommended practices for handling caustic soda tank cars.

Pamphlet 88, "Recommended Practices for Handling Sodium Hydroxide Solution & Potassium Hydroxide Solution Cargo Tanks" – Discusses recommended practices for handling caustic soda tank trailers.

Pamphlet 94, "Sodium Hydroxide & Potassium Hydroxide Solution (Caustic): Storage Equipment & Piping Systems" – Provides storage and piping guidance for caustic soda storage and pipelines.

Pamphlet 164, "Reactivity and Compatibility of Chlorine and Sodium Hydroxide with Various Materials" – Provides information concerning the compatibility of these two substances with a variety of materials and their reactivity with other chemicals.

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