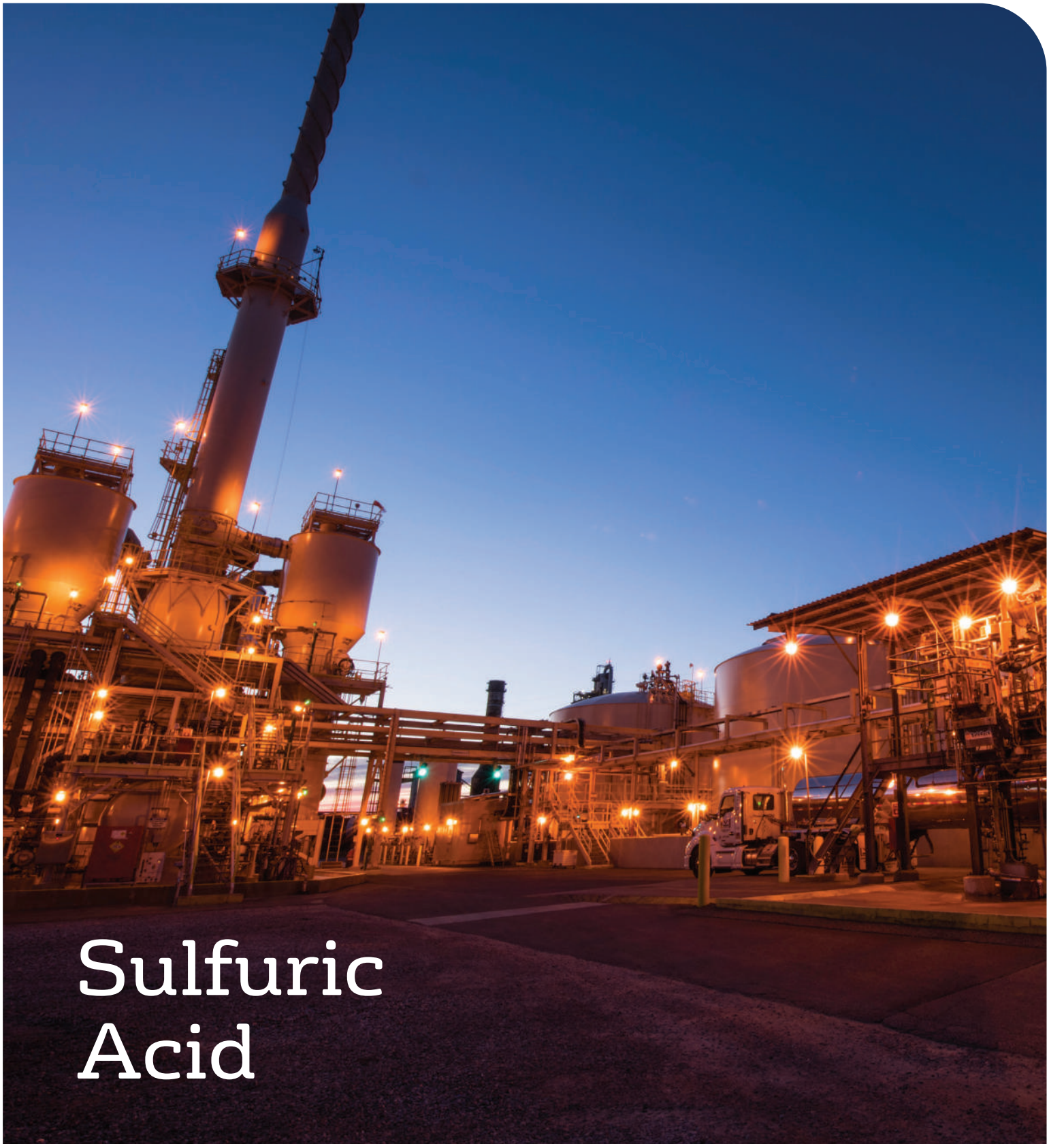

Sulfuric Acid

Properties
Usage
Storage
Handling

VEOLIA

Technical Information

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INTRODUCTION

Sulfuric acid is one of the oldest known industrial chemicals. It is a very strong inorganic acid with qualities that make it very useful for a number of industries. More sulfuric acid is produced and consumed than any other chemical in the world. Some of the industries that find sulfuric acid essential include:

- Fertilizers
- Inorganic chemical manufacturing (including chlorine drying)
- Petroleum refining (principally alkylation)
- Pharmaceuticals (sulfonations/sulfations)
- Soaps and detergents (sulfonations/sulfations)
- Pigments and dyes (sulfonations/sulfations)
- Textiles
- Pulp and paper (chlorine dioxide generation and pulp pH control)
- Metals
- Steel (pickling)
- Car batteries/lead-cell batteries (battery acid)

Some synonyms for sulfuric acid include:

- H_2SO_4
- Oil of Vitriol (OV)
- Vitriolic acid
- Hydrogen sulfate
- Oleum (Fuming sulfuric acid, >100% H_2SO_4)*

*Oleum is a blend of sulfuric acid and sulfur trioxide. A sulfuric acid concentration greater than 100% refers to a mixture of 100% sulfuric acid and sulfur trioxide (SO_3). The concentration represents the amount of sulfuric acid that would be present if all of the free SO_3 were converted to H_2SO_4. For information about Oleum, refer to the Veolia North America Sulfur Trioxide and Oleum "Properties, Uses, Storage and Handling"

Veolia is the global leader in optimized resource management, providing water, waste and energy management solutions that contribute to the sustainable development of communities and industries. Through our complementary business activities, Veolia helps to develop access to resources, preserve available resources and to replenish them. We are committed to providing high-quality services to our customers and operate within a Goal Zero safety culture - focused on continuous improvement toward an overarching goal of zero injuries, zero incidents and zero impacts on the environment.

In July 2016, Veolia North America finalized an agreement with Chemours (formerly DuPont) to purchase the assets of its Sulfur Products division. The asset purchase agreement included 7 operating locations; corporate and functional support teams; and the Acid Technology Center, a dedicated team of engineers who exclusively support the sulfuric acid business. Chemours, and previously DuPont, were widely recognized as global leaders in chemical manufacturing. DuPont had been involved in the sulfuric acid business since 1865, supplying John D. Rockefeller's first oil refinery (Standard Oil of Ohio) with barrels of sulfuric acid on horse-drawn wagons. The business today, under Veolia's ownership, continues to be the benchmark for sulfuric acid plant operations and services.

"We will work with you to ensure you have the training necessary to safely handle and use Veolia's sulfuric acid products. "

Veolia owns and operates seven sulfuric acid plants throughout the United States. Some of these plants are sulfur-burning plants that use a contact process (refer to "Sulfuric Acid Process, page 3). Other plants use Spent Acid Regeneration (SAR) processes, where unreacted sulfuric acid that was used in other processes is regenerated for re-use. We can supply a range of sulfuric acid products, varying in strength and quality requirements.

Besides having a strong product base, we are experts in distribution and logistics. We have a variety of means available to us for transporting sulfuric acid, including barges, rail cars and tank trucks. We partner with highly skilled transportation providers to ensure the product gets to you on time and safely, and we provide them with annual training on the handling and management of sulfuric acid products.

Veolia has joined the American Chemical Council (ACC) and is committed to Product Stewardship and Responsible Care®. Our plant operators and personnel are among the best in the world.

We know how to run a safe and environmentally-friendly plant. And we are willing to share our knowledge on the safe handling, use and storage of sulfuric acid with our customers.

Product Stewardship

Veolia fully endorses American Chemical Council's (ACC) Responsible Care® seven codes of Management Practice. We encourage customers to thoroughly review their safety management practices in the handling of sulfuric acid. In support of product stewardship, Veolia is willing to consultant with our customers in the design of unloading and handling facilities, as well as make recommendations for first aid, medical treatment, personal protective equipment (PPE), emergency response, spill mitigation, and materials of construction selection. We will work with you to ensure you have the training necessary to safely handle and use Veolia's sulfuric acid products. Veolia personnel may visit sites before making the first shipment.

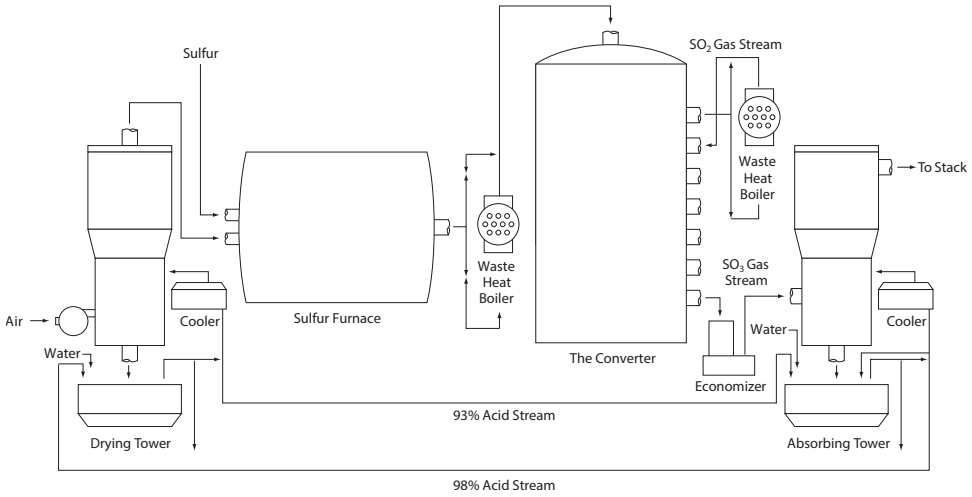


FIGURE 1: Contact Process

Sulfuric Acid Process

Figure 1 above is a typical flow diagram of the contact process for a sulfur-burning plant for sulfuric acid. As you can see, sulfur and air are brought in and burned to make sulfur dioxide (SO_2). The SO_2 goes through a series of gas cooling and heat recovery operations, and then is run through a catalytic converter to make sulfur trioxide (SO_3). The sulfur trioxide is absorbed in sulfuric acid. Water is added to control the sulfuric acid to the desired strength. Chemically, sulfur trioxide (SO_3) reacts with water (H_2O) to make sulfuric acid (H_2SO_4).

Veolia also produces sulfuric acid using the Spent Acid Regeneration process, as shown below in Figure 2. In this process, spent sulfuric acid is combusted in air to produce sulfur dioxide (SO_2). The SO_2 is cooled and cleaned through a series of scrubbers, reheated, and sent to a catalytic converter with more air to make sulfur trioxide (SO_3). The remainder of an SAR plant process is essentially the same as a sulfur-burning sulfuric acid plant. For more information on Spent Acid, refer to Veolia's Spent Sulfuric Acid "Properties, Uses, Storage and Handling" bulletin.

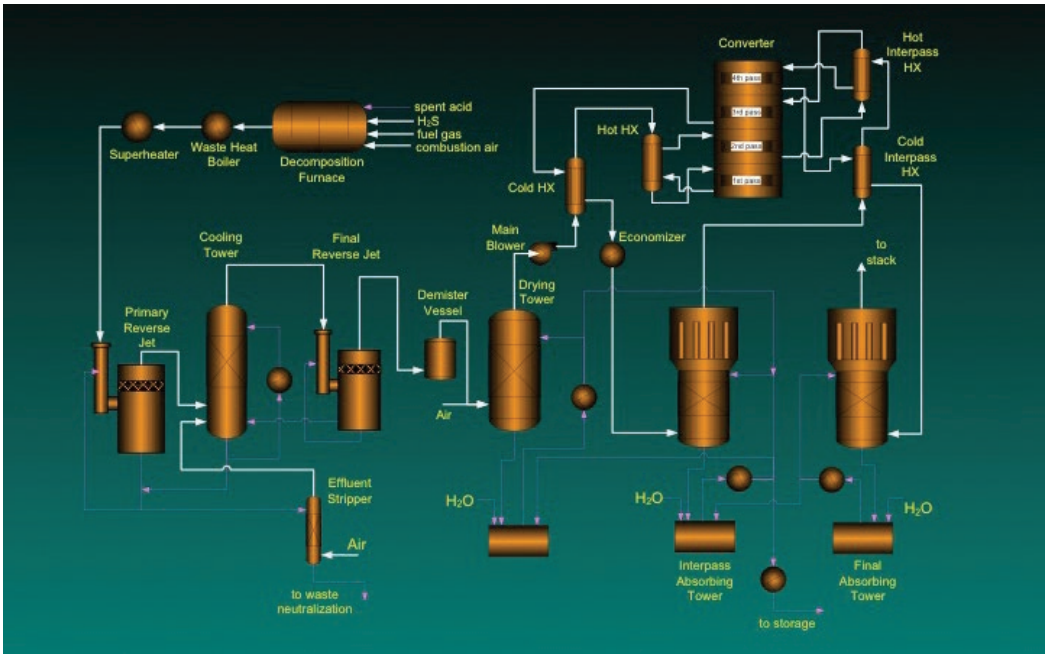


FIGURE 2: SAR Process

TABLE 1: Typical Physical Properties of Sulfuric acid and Oleum

Strength	Equiv. H_2SO_4	Sp. Gr., 15.6°C (60°F)	Density at 15.6°C (60°F), lb/gal	Approximate Freezing Point °C / °F		Approximate Boiling Point °C / °F		Viscosity at 20°C (68°F), cP (mPa·s)	Sp. Heat, cal/g·°C (Btu/lb·°F)
60° Bé	77.67	1.706	14.2	–10	13	19	380	17	0.45
66° Bé	93.19	1.835	15.3	–34	–29	279	535	22	0.38
96%	96	1.843	15.4	–14	6	308	586	23	0.36
98%	98	1.844	15.4	–2	29	327	621	25	0.35
99%	99	1.842	15.4	4	40	310	590	26	0.34
100%	100	1.839	15.3	11	51	274	526	28	0.34
10% oleum	102.25	1.880	15.7	0	32	173	344	31	0.32
20% oleum	104.50	1.915	16.0	–5	23	142	288	39	0.32
25% oleum	105.62	1.934	16.1	9	48	131	268	42	0.32
30% oleum	106.75	1.952	16.3	19	66	121	250	48	0.32
65% oleum	114.63	1.992	16.6	2	36	58	137	55	0.41

Conversion tables for concentrations are given on page 20.

Physical Properties

Sulfuric acid (H_2SO_4, Molecular Weight 98.08) is a heavy, oily, strong, liquid mineral acid with a pH less than 1 and an acrid odor. It is completely soluble in water, and clear and colorless in pure form. Technical grades may be turbid and off-white in appearance. Grades below 100% have a very low vapor pressure of about 0.3 mm Hg at room temperature. Pure sulfuric acid does not have good warning properties, as it looks just like water and has no fumes. As a vapor, sulfuric acid is more than three times as dense as air.

Physical properties of technical grades of sulfuric acid are found in Table 1. Other grades of sulfuric acid and related products are also available from Veolia.

HIGH PURITY GRADES

Water White: Physical properties same as 66º Bé Technical grade, except clarity is “water white”.

Electrolyte 1,835: Physical properties same as 66° Bé Technical grade. Specification available on request.

RELATED PRODUCTS

Sulfur Trioxide: Refer to the Veolia Safety Data Sheet on Sulfur Trioxide and the Properties, Uses, Storage and Handling Bulletin on Sulfur Trioxide and Oleum.

Thermal Properties of H_2SO_4 Solutions

Figures 3, 4, 5, and 6 give physical properties of sulfuric acid solutions, such as freezing points, boiling points and viscosities. If one mixes portions of acid at any two concentrations and temperatures, the temperature of any mixture will lie on the straight line joining the points on Figure 3 corresponding to the initial acids.

EXAMPLE 1
We have 98.0% H_2SO_4 at 28° C and water at 20° C, and we wish to find the temperature if they are mixed to 70.0% H_2SO_4. Mark the 28° curve at 98.0%, and the 20° curve at 0.0% (water). Lay a straight edge between the two points, and mark it at 70.0%. The result is 160° C (320° F).

NOTE: Even though the final temperature of 160° C is not in the boiling region, it is possible to pass through a boiling region.

EXAMPLE 2
We have 93.0% H_2SO_4 at 12° C and water at 10° C, and we wish to find the temperature if they are mixed to 20.0% H_2SO_4. Mark the 12° curve at 93.0%, and the 10-degree curve at 0.0% (water). Lay a straight edge between the two points, and mark it at 20.0%. The result is 41° C (104° F).

Concentrated sulfuric acid is a strongly acidic material that reacts rapidly with water, evolving considerable heat. When mixing or diluting sulfuric acid solutions, it is important to remember the following:

- Always add acid to water to prevent or reduce boiling and spattering.
- Dilute acid solutions slowly to minimize localized heat generation.
- Provide good mixing to dissipate localized heat.
- Provide cooling capabilities as required.
- Make sure the equipment used for mixing and storage will tolerate the amount of heat generated and is compatible with the dilution range and final sulfuric acid solution. (See Equipment section on page 26 for more information on materials of construction.) In general, the weaker the sulfuric acid strength, the more corrosive it is to most metals.

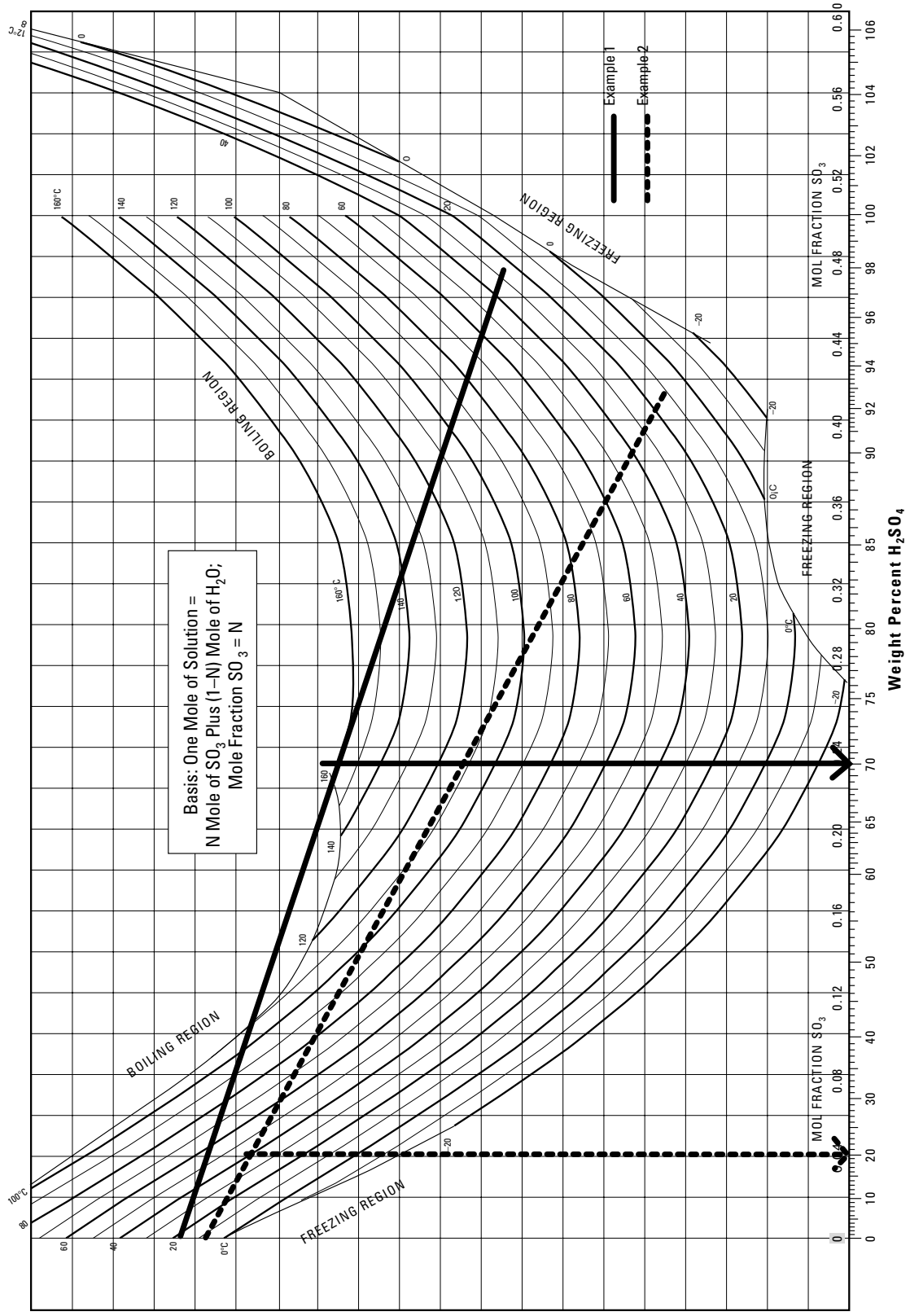


FIGURE 3: Thermal Properties of Sulfuric Acid Solutions from 0 to 106% H2SO4

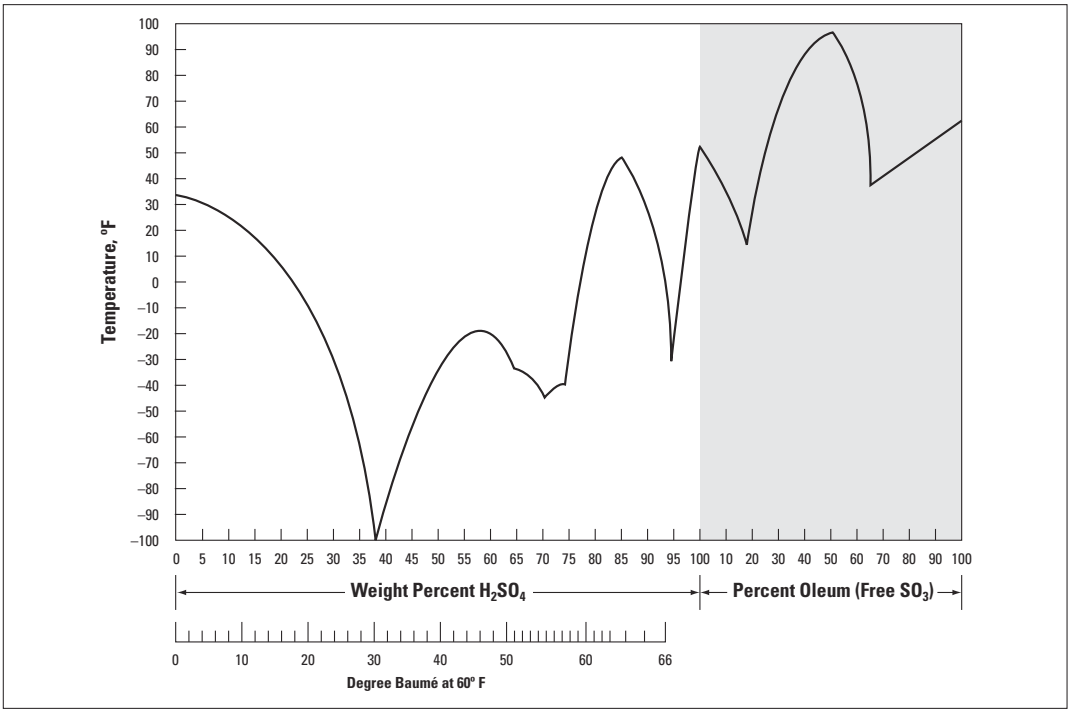


FIGURE 4: Freezing Points of Sulfuric Acid and Oleum

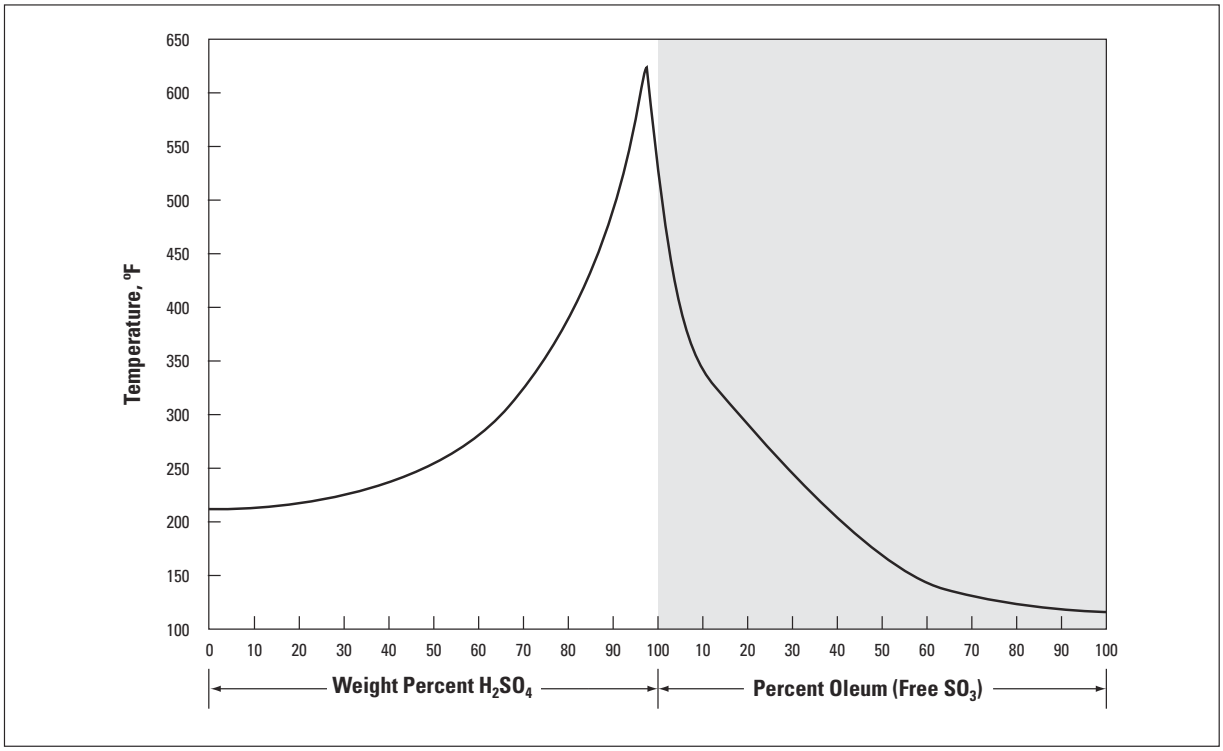


FIGURE 5: Boiling Points of Sulfuric Acid and Oleum

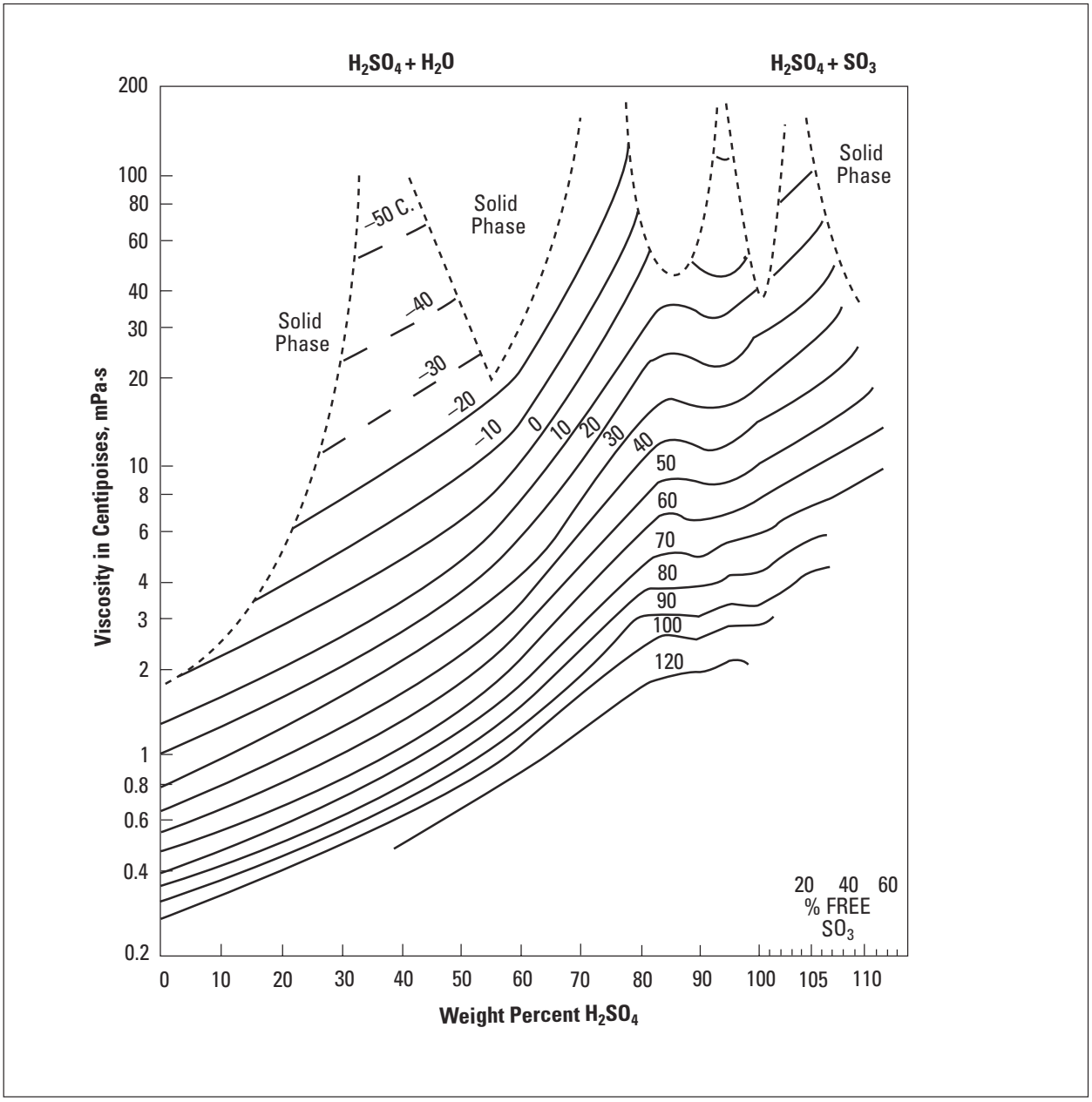


FIGURE 6: Viscosity of Sulfuric Acid Solutions

PERSONAL SAFETY AND FIRST AID

All personnel working with sulfuric acid should be thoroughly familiar with the health and safety precautions, and have the equipment needed to handle this product safely. The current Veolia Safety Data Sheet (SDS) for sulfuric acid should be reviewed prior to using this product.

Health Hazards

Concentrated sulfuric acid is a strongly acidic material that reacts rapidly with water, evolving considerable heat. It can rapidly dehydrate body tissues and cause severe chemical and thermal burns. Inhalation of fumes or mists may cause nose, throat and delayed lung injury. Additional effects on inhalation include cough, difficulty in breathing and shortness of breath. Ingestion may cause corrosion of the gastrointestinal tract.

Contact of aqueous solutions of sulfuric acid with the skin and eyes may cause severe irritation or burns. Prolonged skin contact may cause corrosion with pain, ulceration, blisters or peeling of skin. Prolonged eye contact may cause corrosion with pain, redness or swelling. The more concentrated the solution, the faster the damage can occur.

The International Agency for Research on Cancer (IARC) has classified "strong inorganic acid mists containing sulfuric acid" as a Category 1 carcinogen, a substance that is "carcinogenic to humans." This classification is for inorganic acid mists only.

"Concentrated sulfuric acid is a strongly acidic material that reacts rapidly with water, evolving considerable heat. It can rapidly dehydrate body tissues and cause severe chemical and thermal burns."

The U.S. Department of Labor has ruled that an employee's exposure to sulfuric acid mists in any 8-hour work shift of a 40-hour week must not exceed a time-weighted average (TWA) of 1 mg/m3 (29 CFR 1910.1000 Air Contaminants). The American Conference of Governmental Industrial Hygienists (ACGIH) recommends a TWA exposure limit of 0.2 mg/m3 as a Thoracic fraction. Veolia's Acceptable Exposure Limit (AEL) is a TWA limit of 0.5 mg/m3 for 8 to 12 hour work shifts. For 15 minutes of exposure, the AEL is a TWA limit of 1.5 mg/m3. Note: where governmentally-imposed occupational exposure limits are lower than the AEL, such limits shall take precedence.

Safety Precautions

Use of appropriate personal protective equipment is essential to safely handle sulfuric acid. Do not get sulfuric acid in eyes, on skin or on clothing. Eye protection is particularly important when working around sulfuric acid. Avoid breathing vapor or mist. Use with adequate ventilation. Wash hands thoroughly after handling.

Sulfuric acid by itself is not flammable, but weak sulfuric acid can attack most metals, generating hydrogen gas. Precautions must be taken to avoid ignition sources near sulfuric acid.

Personal Protective Equipment

Personal protective equipment should be used to protect workers whenever contact with acid could be encountered. However, it should not be considered a substitute for safe working conditions and practices. It is the responsibility of the employer to make a PPE assessment per OSHA 29CFR1910.132 requirements.

The following four classes of personal protective equipment (PPE) are used when working with sulfuric acid:

- Class D: for low risk of exposure
- Class C: for moderate risk of exposure
- Class B: for high risk of exposure
- Class A: for maximum risk of exposure, used during an emergency leak/spill situation

The general PPE requirements for Levels A, B, C and D are given to provide guidance in selecting the appropriate level of protection for a given job assignment. Each sulfuric acid handling site may have its own standards with respect to the specific PPE requirements, especially for the lower risk levels of exposure.

Protective clothing should be made of an acid-resistant material suitable for acid exposure, such as treated PVC, butyl rubber or other composite materials. Remember, PPE is only acid-resistant, not acid-proof. Selection of appropriate PPE materials should be based on the following criteria:

- Have a low relative sulfuric acid permeation and long breakthrough times.
- Be composed of materials that have good resistance to tears, rips and chemical degradation.
- Be sufficiently flexible to allow the worker to adequately complete the job at hand.

PPE should be regularly inspected before each use to confirm it is suitable for sulfuric acid handling. Any acid suit with flaws, rips or tears should be discarded. In addition, gloves should be tested for holes by immersing them in water while applying a small amount of air pressure to detect leaks. PPE must also be washed and decontaminated between uses.

CLASS D

The minimum PPE required for Class D is:

- Hard hat
- Steel-toe safety shoes with PVC, neoprene or composite soles
- Pants and sleeved shirt, or coveralls, made of acid-resistant polyester, acrylic or wool
- Safety glasses with side shields

In addition, some sites may choose to add coverall chemical splash goggles and chemical resistant gloves. With Level D clothing, workers may enter a sulfuric acid area, read gauges or visually inspect equipment.

CLASS C
The minimum PPE required for Class C protection is the same as that for Class D plus the following:

- Coverall splash goggles
  (a face shield can be added over the goggles if desired, but is not a replacement for goggles)
- Acid-resistant gauntlet gloves
- Optional, acid-resistant jacket
- Optional, face shield

With Level C clothing, personnel may operate valves and switch on pumps.

CLASS B
To provide protection for a high-risk exposure to sulfuric acid, the following Class B PPE is required:

- Head Protection: splash hood and hard hat
  (limit duration of tasks to avoid oxygen deficiency in hood)
- Eye Protection: chemical splash goggles
- Respiratory: not required for non-fuming sulfuric acid
- Hand Protection: acid-resistant gauntlet length gloves with sleeves over gloves
- Body Protection: acid suit, 1 piece or 2 piece
  (fabric must pass ASTM testing for ≥ 93% sulfuric acid)
- Foot Protection: acid-resitsant boots with pant legs over boots

With Class B clothing, personnel can make line breaks into a sulfuric acid system, sample or connect/disconnect hoses from tank cars, tank trucks or portable tanks.

CLASS A
Class A is the most complete protection and is used in the event of a large leak or spill, or other emergency situation. For Class A the following PPE is required:

- Head Protection: hard hat
- Eye Protection: full face mask
- Respiratory: NIOSH approved respiratory protection
- Body Protection: acid-resistant, fully-encapsulated suit
  (Fabric must pass a 45 min breakthrough ASTM F739 chemical permeation test for ≥ 93% Sulfuric Acid)
- Foot Protection: acid-resitsant boots with pant legs over boots

Class A protection is for extreme conditions, where it is necessary to enter areas having a high sulfuric acid mist concentration, or where there is a liquid acid mist spray. Class A suits, like other protective clothing, should be considered a "last-line-of-defense." The limitations of the suits must be recognized. Under no circumstances should personnel enter a situation where they may be sprayed with a stream of liquid sulfuric acid or step into puddles of liquid sulfuric acid.

Working in Class A or B suits for long periods of time in warm climates may produce heat stress for the wearer. Provisions should be made to provide rest periods and/or use of devices for heat removal, such as ice vests or cooling air.

Standby and backup personnel should be specified for Class A and Class B jobs. Standby or backup personnel provide prompt response to a job situation where something unexpected has occurred.

PPE should not be worn or carried beyond the operating area. Each item should be decontaminated with water and removed according to a written sequential procedure, to avoid possible sulfuric acid contact with any part of the body. For Level A and B activities, decontamination procedures should be established for all personnel before removing the acid-suits, such as safety shower for 5 minutes and decontamination brushes available for cleaning bottom of boots, etc.

Site Facilities

The following safety equipment should be easily accessible in all areas where sulfuric acid is handled (unloading stations, storage areas):

SAFETY SHOWERS
Water should be supplied to the shower by a 2-inch line (minimum pressure 30 psig) through a quick-opening valve that will stay open. Per OSHA, 30 gallons per minute (gpm) is the minimum recommended flow. Both the valve (actuated by a push/pull handle at hip level) and a 0.25-inch weep hole directly above the valve should be located below the frost line and surrounded by crushed rock or gravel to provide drainage. Shower locations should be appropriately identified by color (usually green) lights and/or signs, and access to showers must not be obstructed in any manner. Safety showers should be tested on a periodic basis and the results recorded.

WATER HYDRANT AND HOSE
Some means of flushing spills with large volumes of water under adequate pressure should be provided.

EYEWASH FOUNTAIN
An eyewash fountain or a hose with a gentle flow of cool tap water is suitable means for flushing the eyes. Eyewash stations are usually part of a safety shower station.

First Aid

Speed is of utmost importance when removing exposed personnel from a contaminated area and removing sulfuric acid from the skin and eyes. First aid must be started immediately (within seconds) in all cases of contact with sulfuric acid in any form. All workers and supervisors that could be potentially exposed should be trained in first aid care for sulfuric acid burns/exposure.

Medical assistance should be promptly obtained for all affected persons. The physician should be informed in detail of the incident. Joint training sessions between the users of sulfuric acid and the neighboring medical emergency response groups (hospital emergency room, paramedics, etc.) should be done annually.

IN CASE OF EYE OR SKIN CONTACT
Immediately (within seconds) flush the affected area with plenty of water (preferably cold water) for at least 15 minutes while removing all contaminated clothing and shoes—forget modesty! Call a physician. Do not "scrape" or "wipe" the acid off the skin—scraping or wiping could greatly increase the probability of removing the upper skin layer, exposing the area to infection, and delays the water flushing. Watch for signs of shock.

While the patient is being transported to a medical facility, apply compresses of ice water. If medical treatment must be delayed, immerse the affected area in ice water. If immersion is not practical, compresses soaked in iced water can be applied. For more detailed instructions consult the Veolia Sulfuric Acid First Aid and Medical Treatment Manual, available from Veolia technical service.

NOTE TO PHYSICIAN
Continued washing of the affected area with cold or ice water will be helpful in removing the last traces of sulfuric acid. Creams or ointments should not be applied before or during the washing phase of the treatment.

IF INHALED
Move patient to fresh air immediately and have patient lie down and remain quiet. Apply artificial respiration if breathing has stopped. Give oxygen if breathing is difficult. Call a physician.

IF SWALLOWED
Do not induce vomiting. Immediately give patient large quantities of water. Immediately call a physician. Do not give carbonates. Never give anything by mouth to an unconscious person.

HANDLING PRECAUTIONS

Spills or Leaks

Spillage of sulfuric acid should be given immediate attention to avoid dangers of body contact, corrosion of equipment, and generation of hazardous gases. Review "Fire Fighting" on page 14 and "Waste Disposal" on page 16 before proceeding with cleanup. Comply with federal, state, and local regulations on reporting releases. The CERCLA reportable quantity for sulfuric acid is 1000 pounds (as 100% sulfuric acid). Diluted sulfuric acid has a high rate of corrosion on steel and other metals. Spills on external tank surfaces and other equipment must be washed off immediately.

Use appropriate personal protective equipment during clean-up. Keep people away from the source and upwind of the spill or leak. Evacuate personnel to safe areas. Acid spills should be contained to avoid runoff to sewers. Fine water mist or mid-expansion foam should be applied to large spills of sulfuric acid grades of less than 100% strength. The resulting solution should be neutralized with lime, soda ash or other alkali material prior to disposal.

Small spills and leaks are usually diluted with fine-water spray or mid expansion foam. The spill can then be soaked up with sand, oil dry or other non-combustible absorbent materials. Sodium bicarbonate, a soda ash, slaked lime mixture, or other alkali material can then be used for neutralization. Laboratory supply houses also provide packaged kits containing absorbents and neutralizing agents such as Neutrasorb® or Spill-X-A®. Follow label instructions. Wear personal protective equipment to avoid exposure acid—see section on Safety Precautions on page 9.

When neutralizing acid spills (i.e., in neutralization pits, holds of barges, etc.), care must be taken to assure adequate ventilation of gases that could be toxic or cause suffocation, such as H_2S and CO_2.

Hazardous Chemical Reactions

CAUTION: Water or caustic solutions should not be added directly to sulfuric acid because violent reactions and spattering may occur. When diluting, always add the acid to water. Avoid adding water to the acid unless the situation requires, and then only after careful consideration of potential hazards. If water is added to the acid, use a fine water spray mist wherever possible.

Sulfuric acid is an active acid that reacts with many other compounds. Most of its reactions are well known and have been employed safely for many years. For a compilation of chemical reactions reported to be potentially hazardous, refer to NFPA No. 491 M, "Manual of Hazardous Chemical Reactions."

At strengths below 75%, sulfuric acid reacts readily with iron and other metals. At higher strengths, sulfuric acid is a strong oxidizing agent that reacts with organic and inorganic reducing materials. A considerable amount of heat is generated by the reaction. In addition, when heated, sulfuric acid decomposes to sulfur dioxide and water.

Sulfuric acid reacts with carbonates to generate carbon dioxide gas. Sulfuric acid also reacts with cyanides and sulfides to produce poisonous hydrogen cyanide and hydrogen sulfide gases, respectively. Thus, not only is there the danger of a violent eruption that could result in acid burns, but also the possibility of generating explosive or poisonous atmospheres that could present additional hazards. For these reasons, sulfuric acid should be used strictly in accordance with the directions of a qualified chemist or technically trained person.

"Spillage of sulfuric acid should be given immediate attention to avoid dangers of body contact, corrosion of equipment, and generation of hazardous gases."

Corrosion Hazards

Sulfuric acid attacks cast iron, brass, bronze and most other non-ferrous metals. Mild steel (carbon steel) and stainless steel are resistant to corrosion, and are recommended for storage systems and piping. Teflon® is the only known resistant polymer material. Rubber, neoprene, polyester, PVC, FRP and other elastomers are readily attacked and unsuitable for high strength acid service.

Fire and Explosion Hazards

Sulfuric acid is nonflammable, but is highly reactive and capable of igniting finely divided combustible materials on contact. It reacts violently with water and organic materials with high evolution of heat. It is extremely hazardous in contact with many materials, particularly carbides, chlorates, common metals, cyanides, fulminates, nitrates, perchlorates, picrates, powdered metals, reducing agents, strong oxidizers and sulfides. In higher concentration, ignition may occur on contact with combustible materials such as wood, cardboard, sawdust and oily rags. Sulfuric acid attacks many metals to release flammable hydrogen gas. Therefore, no open flames, open lights, matches or other ignition sources should be allowed in or around acid containers or lines.

"Sulfuric acid is nonflammable, but is highly reactive and capable of igniting finely divided combustible materials on contact."

Fire Fighting

In case of fire, evacuate personnel to safe areas. Use extinguishing methods that are appropriate to local circumstances and the environment. Dry chemical or carbon dioxide extinguishing methods are viable options. Water can be used on combustibles burning in the vicinity of sulfuric acid, but care must be exercised not to apply water directly to acid to avoid evolution of heat and violent spattering. Cool the acid storage tank with water if exposed to fire, but do not get water in the tank.

Fine mist water fog or mechanical foam can also be used to keep the tank shell cool if exposed to fire. Do not allow water or water-containing foam to contact sulfuric acid in a confined area or tank, because it might cause violent eruptions or pressure increases that could result in structural damage to the confined space or tank.

Engineering Control of Hazards

Proper design of the storage and handling system from point of delivery to point of consumption is necessary to safeguard against the hazards of sulfuric acid. Factors to consider in design include:

1. Location of storage tank relative to other chemicals and working areas.
2. A tight system that minimizes the chances of sulfuric acid leaking and endangering people.
3. Means of confining accidental leaks as well as proper drainage and cleanup of leaks and spills in a manner consistent with plant and regulatory agency requirements.
4. Provision for more than one escape route in event of fire, explosion or release of H_2SO_4.
5. Easily accessible safety showers, fire fighting and other emergency equipment.
6. Provisions for venting storage and unloading facilities to a recovery or abatement facilities.

Acid should never stand in a line completely sealed between two closed valves such as in gravity-filling operations. Pressure may build between the two valves, resulting in a line rupture or hazardous acid spray when a valve is opened. Relief valves discharging to a safe location should be installed in those line sections where acid could become entrapped between closed valves.

Sulfuric acid storage should be in the open or in a well ventilated area. Tank foundations should be slightly above grade and sloped to facilitate drainage away from the tank. Vertical tanks should be mounted on grillage, not directly on the ground, to minimize potential for external corrosion of the tank bottom. Sulfuric acid storage tank design should follow NACE International (National Association of Corrosion Engineers) SP 0294-2006.

Any liquid leaks or spills that occur in pipes or equipment where sulfuric acid is handled should be considered acid leaks and treated accordingly.

Indoor storage or heated storage tanks should be provided to prevent acid freezing where severely cold weather conditions exist. Under no conditions should storage tanks have internal steam coils.

"Any liquid leaks or spills that occur in pipes or equipment where sulfuric acid is handled should be considered acid leaks and treated accordingly."

All exterior piping that carries acid grades susceptible to freezing should be heat-traced and insulated. Care must be exercised to avoid over-heating.

Localized hot spots and pressure buildup by liquid expansion or vaporization between two closed valves must also be avoided.

Storage tanks should be thickness-tested at least every two to three years, or as required by local ordinances. It is recommended that the tanks be cleaned and an internal inspection be made per NACE International (National Association of Corrosion Engineers) SP 0294-2006 recommendations.

Transportation Emergencies

If a shipment of Veolia sulfuric acid is involved in an accident or emergency anywhere in the continental United States, make a toll-free telephone call to the American Chemical Council's Chemical Transportation Emergency Center ("CHEMTREC") in Washington DC:

(800) 424-9300

If outside of the U.S. make a telephone call to CHEMTREC via the following number:

(703) 527-3887

The information specialist on duty will ask the name and location of the caller, the name of the shipper, the product, the shipping point and destination; what happened, nature of any injuries, weather conditions, proximity to populated areas, etc. He/she will then give the caller recommendations for controlling the emergency situation until the shipper's specialist can relay help. "CHEMTREC" will immediately advise Veolia of the emergency and one of our specialists will get in touch with the caller promptly.

WASTE DISPOSAL

Sulfuric acid may be considered an RCRA hazardous waste due to its pH. Disposal of waste-liquid streams containing sulfuric acid must be accomplished within the regulations and guidelines applicable at the specific location under consideration. Users should check with the appropriate local, state and federal authorities to stay up-to-date on rules in force and changes being considered for the future.

Small quantities of waste acid may be added slowly to a larger volume of agitated soda-ash solution or slaked-lime slurry. The neutralized solution may be added to excess running water prior to final disposal—but be sure to follow local regulations for disposal.

Larger quantities of sulfuric acid wastes are also best disposed of by neutralization, keeping the pH of the effluent in the range of 6 to 9, as required by many regulatory agencies. Sulfuric acid wastes may be neutralized with waste alkali streams, lime, dolomite, ammonia, caustic soda or soda ash. The choice of neutralizing agent usually depends on the volume of the waste acid, the allowable pH and the cost of the neutralizing agent. Lime is often used and requires the separation of suspended solids by filtration and/or sedimentation in settling ponds before discharge of wastes to water courses. Acid wastes should not be discharged to sewer treatment facilities without neutralization treatment because of its:

- corrosive effect on collecting systems
- possible effect on biological treatment systems
- possible interaction with other industrial wastes to produce toxic gases such as H_2S, HCN, etc.

Sulfuric acid wastes generally are diluted to concentrations below 15% before neutralization because of the limited solubility of calcium sulfate. The neutralization reaction is highly exothermic so that cooling or further dilution is necessary to remove liberated heat.

When very large volumes of acid wastes are involved, particularly higher-strength acids, recovery may be more economical than neutralization. Many factors must be considered in evaluating the practicality of acid recovery, such as chemical market conditions, geographical location relative to possible uses, possible reuse within the plant, etc. Practical processes for recovery of acid value or of useful products from waste acid streams have been developed and are commercially available.

SHIPPING CONTAINERS

Veolia ships sulfuric acid in tank cars, tank trucks and barges. Tank cars and tank trucks bear placards as prescribed by the DOT. Its DOT hazard classification is Corrosive Material. Barges are regulated by the U.S. Coast Guard under 46CFR and are not required to be placarded. Smaller packages such as drums are available from chemical distributors.

UNLOADING & TRANSFER

During all unloading and transfer operations be sure to wear personal protective equipment appropriate to the potential exposure of the task.

For safety reasons, pump unloading is preferred over air unloading. This puts the unloading hose under suction so that any leak can be stopped promptly without the need for venting the tank car or truck of padding pressure. It may be necessary to supply a nominal amount of air (1–10 psig) for pump priming or to avoid creating a vacuum in the transportation vehicle being unloaded. In this case, the pressure should be the minimum needed for effective pump operation, with appropriate valving and controls for emergency shut-off of air supply and depressurizing. When pumping from a tank car or tank truck without padding air pressure, ensure that the vessel is adequately vented to prevent tank collapse.

A self-priming pump (1) avoids the hazards to the attendant from air-pressure unloading and (2) provides sufficient discharge pressure for transfer to distant or elevated storage tanks. By proper location of the pump, the lines and valves can be arranged that the same pump can be used in transferring acid from storage to process.

Compressed air may be used to unload tank cars or tank trucks. If dry, compressed air is used in place of pumping, pressure must not exceed 30 psig and air connections must include a pressure regulator and a safety relief valve to ensure that this pressure cannot be exceeded. The supply valve should be remotely located or barricaded to protect the operator against leaks at fittings when the tank car or tank truck is pressurized. Safety shut-off of air supply and remote depressurization of the tank car/tank truck should also be provided for use in the event of a tank or pipeline leak.

Tank Cars

Veolia ships sulfuric acid in tank cars of approximately 100-ton capacities (12,000 gallons).

No bottom outlet is allowed on tank cars carrying sulfuric acid. The discharge pipe is located in the dome on the longitudinal centerline of the car and extends into a well in the bottom of the tank. Tank cars have varied dome arrangements and the user should consult the Customer Service Center (800-441-9362) if not familiar with a particular car. A typical tank car unloading arrangement is shown in Figure 7, and an air supply to a tank car dome in Figure 8.

PLACEMENT OF CAR FOR UNLOADING

1. The unloading platform should be in the open.
2. See that train or engine crew accurately spot the car at the unloading line. Tracks can be marked for proper location to simplify spotting. Unloading track should be level.
3. Brakes should be set and wheels blocked on all cars being unloaded to prevent movement in either direction.
4. Standard derails, blue warning flags and lights should be placed as required by regulations. In addition, caution signs can be placed to give necessary warning to persons approaching from open track or siding end.

“During all unloading and transfer operations be sure to wear personal protective equipment appropriate to the potential exposure of the task.”

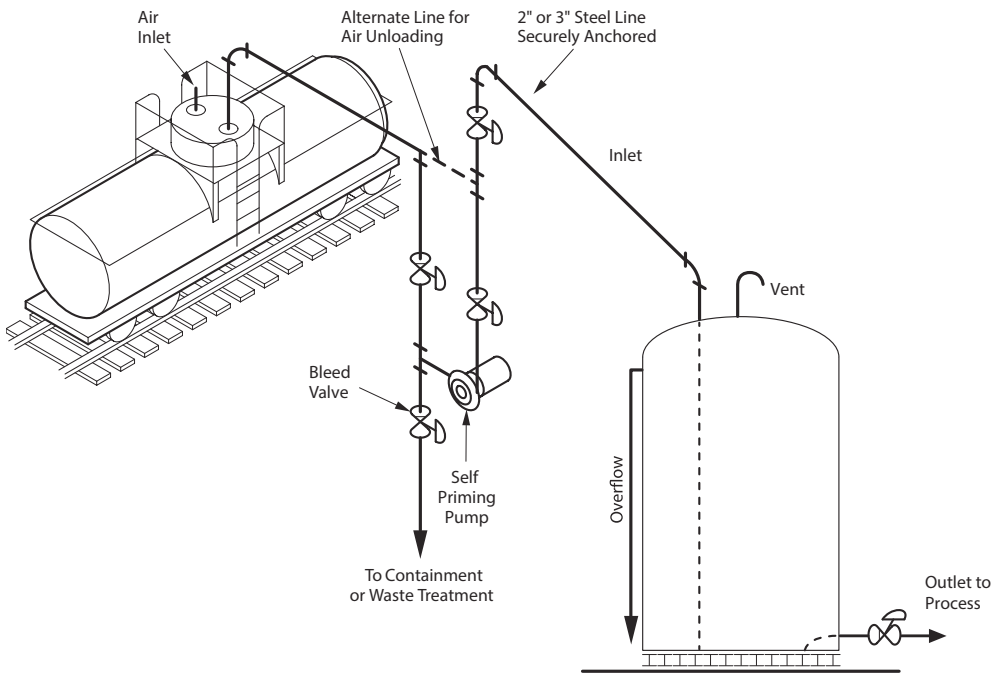


FIGURE 7: Tank Car Delivery

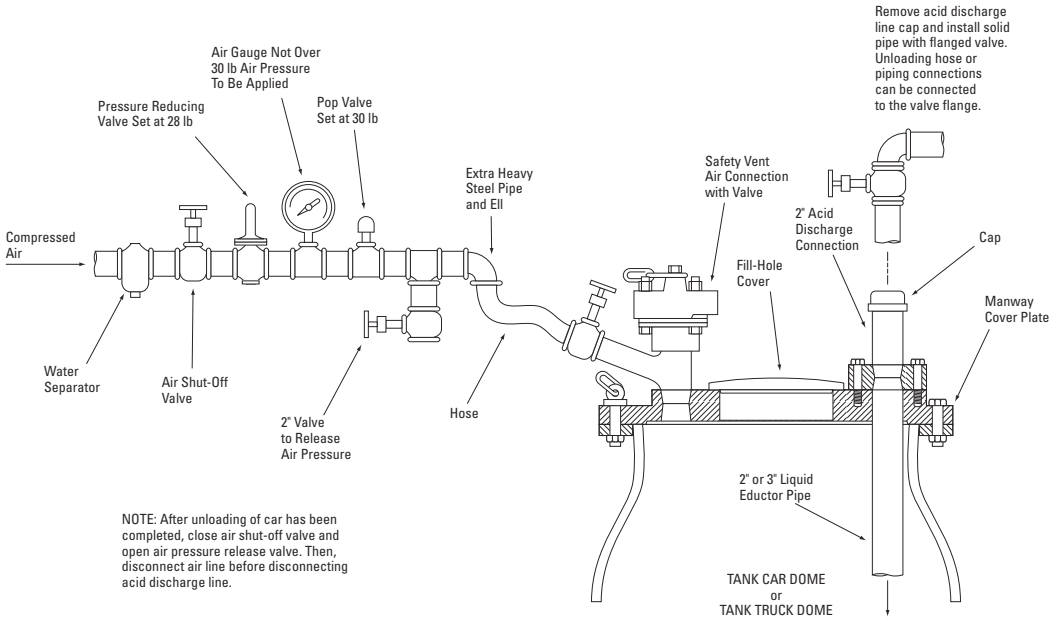


FIGURE 8: Air-Piping Arrangement for Unloading Acid Tank Cars

DOME FITTINGS

1. Dome fittings of tank cars may be of different types. All are designed for unloading through the dome acid connections by means of pump or compressed air. The following fittings and connections are usually identified by name and stenciled for identification:

    - Fill-hole Cover
    - Discharge (or Eductor) Pipe (closed with cap, plug, or valve), usually 2-in or 3-in diameter.
    - Air Connection: A pipe nipple closed with a safety vent, or a separate air connection closed with a cap, valve or plug cock.
    - Safety Vent. A safety device equipped with a frangible disc or pressure relief device, designed to relieve abnormal pressure, which may build up in the tank during transit. All cars are equipped with a safety-vent device.

2. Removal and replacement of connections should be made with a proper tool.

3. If leakage occurs at any of the tank car dome fittings and cannot be stopped by tightening the bolts or fittings, shut off air supply. When pressure in the car has been reduced to atmospheric, remove the leaking fitting and apply a new, approved gasket (Viton® B) and/or fitting. Special gaskets are used. If the wrong type is used as a replacement, contents of the tank may be contaminated.

4. **Do not use a rubber (natural or neoprene) hose for the acid discharge connection.** Veolia recommends Teflon®-lined transfer hoses for sulfuric acid service

UNLOADING PROCEDURES

Under no circumstances should the discharge pipe be opened until all pressure in the tank has been released.

Be sure that the storage tank has enough free capacity to accept the entire contents of the rail car (approximately 12,000 gallons).

Carefully read all caution markings on tank and dome before discharge.

UNLOADING BY PUMP

Be sure that the storage tank has enough free capacity to accept the entire contents of the rail car (approximately 12,000 gallons).

The pump should be constructed of suitable materials. A self-priming magnetic-drive centrifugal pump is preferred over the positive displacement type. If the latter is used, it should be provided with an un-valved bypass from outlet to inlet with properly rated rupture disc of suitable material. Also, the car must be vented to prevent a vacuum and to permit air to replace the acid as car is unloaded. All connections to the pump should be made in such a manner as to avoid excessive stresses at the pump. The pump packing (if so equipped) should be checked prior to unloading to avoid the danger of acid leakage. The relief valve (if so equipped) should be connected to discharge to a safe location or may be connected to discharge to the pump suction. In all cases, the relief valve should be large enough to handle the full pump capacity to avoid pressure building up beyond the safe limits for the pump or piping system.

Pump unloading operations should be carried out as follows:

1. First vent the car by cautiously opening the air inlet valve to relieve internal pressure. Care is necessary, for the tank car may be under pressure, particularly during hot weather. If this pressure is not relieved gradually, there is danger of acid spray being carried out with the escaping air. During cold weather, the rail car may actually be under vacuum.

2. The fill-hole cover on the dome may now be safely opened to secure a sample of the product, if needed.

3. Remove pipe cap from top of acid-discharge pipe and make steel-pipe connection with valve to pipe on car (or, from valve on car). Complete the transfer line with either piping or transfer hose to the pump inlet. Check steel-pipe connections and valves from pump outlet to acid storage tank before starting pump.

4. Start pump, with car vented to atmosphere. If priming is required, follow procedure for unloading by air and apply only sufficient pressure to start flow of acid to pump. Do not use more than 30-psig pressure.

5. Storage tank must be vented while acid is being transferred.

6. When the tank car is empty, the pump, operating under less of a burden, may signal the end of the transfer by operating faster at a different sound pitch, and the sound of acid entering the storage tank will cease.

7. Shut off the pump and vent any pressure used for priming. Open drain-line valves.

8. After pressure is vented, and lines have completely drained, close valve on acid line from car-discharge pipe fitting (or valve), disconnect transfer hose or piping, and tightly replace car-pipe cap or plug with wrench. Cap the end of the unloading hose to prevent atmospheric air and/or rain from entering between unloadings. Wear appropriate personal protective equipment to avoid acid contact. Wash any spillage with water.

9. Ensure fill-hole cover on dome is closed and secured. Be sure gasket (Viton® B) is installed properly.

UNLOADING BY AIR PRESSURE

Compressed air used for unloading must be as free as possible from oil, excess moisture and foreign matter. The air supply should be taken from the TOP of the air receiver (reservoir). This receiver should be drained at regular intervals. Dry nitrogen can also be used. The air line leading to the tank car should be thoroughly blown clean before making connection.

Air-pressure unloading operations should be carried out in the same sequence as for pump unloading, except make transfer hose or pipe connection from pipe on car (or from valve on car) to the acid storage tank.

Be sure that the storage tank has enough free capacity to accept the entire contents of the rail car (approximately 12,000 gallons).

1. First vent the car by cautiously opening the air inlet valve to relieve internal pressure. Care is necessary, for the tank car may be under pressure, particularly during hot weather. If this pressure is not relieved gradually, there is danger of acid spray being carried out with the escaping air.

2. The fill-hole cover on the dome may now be safely opened to secure a sample of the product, if needed.

3. Remove pipe cap from top of acid-discharge pipe and make steel-pipe connection with valve to pipe on car (or, from valve on car). Complete the transfer line with either piping or transfer hose to the pump inlet. Check steel-pipe connections and valves from pump outlet to acid storage tank before starting pump.

4. Make connection from plant air line to the air connection on tank car dome. The air line must have a pressure-reducing valve set at no greater than 28 psig, a safety-relief valve set at not over 30 psig, plus an air pressure gauge and a 2-inch valve (See Figure 8) to release car-tank pressure when emptied.

5. **Apply air pressure slowly** until there is normal flow into storage tank; then adjust air pressure and maintain until the tank car is completely empty. **Do not** exceed 30 pgig air pressure. Storage tank must be vented while acid is entering. A drop in pressure and the sound of air rushing through the discharge pipe indicates that the tank car is empty. Continue the flow of air until the discharge line is completely empty, then shut off the air, vent any remaining pressure, and allow the acid pipe to drain.

6. Disconnect plant air fittings from the safety vent or air inlet on car and replace safety vent, or close air inlet.

7. Do not disconnect the acid line from the tank car until the tank car and storage tank are at atmospheric pressure and sufficient time is given to permit complete drainage of line. (Close valve on acid line at car, if so equipped.)

8. Always assuming line still has acid in it, and taking precautions accordingly, carefully disconnect plant acid line from the discharge pipe fitting (or valve) and tightly replace pipe cap or plug with wrench. Cap the end of the unloading hose to prevent atmospheric air and/or rain from entering between unloadings. (Wear appropriate personal protective equipment to avoid contact with acid.) Wash any spillage with water and neutralize.

DISCHARGE LINE BETWEEN TANK CAR AND STORAGE

All pipe and fittings forming the delivery line between the tank car and storage tank should be of stainless steel, steel, or other suitable material.

The minimum air pressure necessary for emptying a car tank depends upon the following:

- Specific gravity of the product
- Design of the delivery line
- Length of delivery line to the storage
- Height from a point on a plane with the bottom of the rail car to top of storage tank

Careful consideration should be given to all new and existing delivery lines and storage tanks. Alterations should be made to ensure unloading of tank cars with air pressure not exceeding 30 psig. This may involve:

- Utilizing an existing railway track
- Extending the present track
- Installing a new track, to permit moving the tank car closer to the storage tank

If more than 30 psig air pressure is necessary to discharge contents to storage, an acid pump should be provided.

SAMPLING OF PRODUCT

A sample may be required to check tank car contents before unloading, or to retain for testing. Wear appropriate personal protective equipment to avoid acid contact during sampling operations.

1. A sample may be taken by filling a bottle of acid-resistant material. This can be lowered into the acid by use of a sampling rod with a slip-hold attachment.

   NOTE: Do not use polyethylene sample bottles on acids of strengths 98% or greater. Plastic-coated glass or TEFLON® is preferable.

2. Alternatively, the introduction of a tee and sampling valve at any desired point in the unloading line to the storage tank will permit easy withdrawal of samples. The sample valve on the unloading line should be flushed to ensure that a representative sample is obtained.

3. Use care when rinsing and cleaning sample bottle–sulfuric acid can react violently with water.

Frozen Cars

Cars of frozen sulfuric acid can be thawed if the car is equipped with insulation and external coils. Low-pressure steam (less than 20 pounds per square inch) can be connected to the heater-coil inlet pipes to thaw the contents.

The discharge pipe should be checked before thawing is attempted. A plugged discharge pipe may be the source of unloading difficulty.

Tank Trucks

Veolia ships sulfuric acid in tank trucks of capacities up to 20–23 tons (2600–3000 gallons). To receive such a truck, the consignee needs:

- An all-weather serviceable road to the unloading station. Railroad sidings having open ties and full-height rails are not suitable for tank truck movements.
- Vertical clearances of at least 11-1/2 feet.
- An open area at the unloading station sufficient to permit normal maneuverability of the tractor and trailer. Tractor and trailer have maximum overall length of 45 feet, and a maximum width of 8-1/2 feet. The turning radius is 50 feet.
- A tractor-trailer spotting area having a good surface capable of supporting about 24,000 pounds per axle (80,000-pound maximum gross weight of vehicle). The surface should be slightly pitched so that any liquid spillage will be contained away from the truck and exposed structures. The spotting area should allow the truck and trailer a 4-foot minimum clearance at each end and 2-foot clearance on each side.
- Securely anchored, free-draining intake lines, the receiving couplings of which are within 6 feet of the rear end of the tank truck trailer spotted in normal unloading position. The carrier usually provides one 20-foot length of unloading hose. All hoses should be labeled with testing expiration date and all hoses must be secured in hose tray with blind flange/end caps prior to empty return.

  NOTE: Veolia requires prior approval by Veolia Product Stewardship for delivering carrier to unload with two lengths of hose – Maximum 40 ft. If approved two hose lengths must be connected in the middle with 4 bolt flange/gasket.
- A functioning safety shower and eyewash station meeting OSHA requirements, readily accessible.
- A running water hose to wash down any minor leaks/spills/drips.
- Containment area for any leaks, spills, drips or wash-downs.

If unloading is to be performed at night, the unloading spot should be well lighted so the truck driver will have no difficulty unloading properly and safely, spotting hazards and moving quickly in case of an emergency.

TANK TRUCK PLACEMENT AND UNLOADING
Plant personnel should:

- Check the shipping papers and verify that the delivery is the correct material and amount.
- Be sure the storage tank can take the entire delivery.
- Make certain the unloading connections are labeled specifically for the product to be received.
- Show the driver the correct unloading line and check that all valves to and from the storage tank are in the correct position for unloading.
- Be sure the storage-tank vent line is open.

Plant personnel and the driver should jointly inspect and test the following site-safety equipment periodically:

- Safety shower
- Eye wash fountain
- Water hydrant or hose for wash-down

If any equipment is not working properly, it should be fixed as soon as possible. Unloading should not proceed if there is no safety water.

"If unloading is to be performed at night, the unloading spot should be well lighted so the truck driver will have no difficulty unloading properly and safely, spotting hazards and moving quickly in case of an emergency."

The driver will:

- Observe DOT regulations spelled out for common carrier shipments in Part 177, Subpart B, Section 177.834.
- Spot the trailer properly and prepare it for unloading.
- Connect the unloading hose to the proper connection on the trailer.
- Open valves on the trailer and unload trailer contents to customer's storage tank.

The discharge pipe is located in the rear of the truck and is generally accessible from the ground. A tank truck unloading arrangement is shown in **Figure 9**.

No platforms are required, provided that the receiving line (and air line, if used) is within easy reach from the ground. The position and type of fittings for the acid-receiving line, and necessity for a flexible hose, must be determined for individual situations.

A self-priming pump located in close proximity to the unloading spot and the storage tank can be used to both unload the tank truck and pump to process.

Some tank trucks carry their own air compressors. In order to receive trucks without compressors, and for greater flexibility, an air supply of 25 cubic feet per minute (cfm) at 30 psig should be provided.

An air-piping arrangement should include a pressure- reducing valve set at 28 psig, a safety relief valve set at not over 30 psig, an air pressure gauge, and a 2-inch valve to release air pressure as shown in Figure 7. In event of a tank or pipeline leak, provision should be made for remote shut-off of air supply and depressurizing of the vessel.

FITTINGS, ETC.
The packing and lubricant for pumps, glands, etc., must be of a material suitable for sulfuric acid. See Equipment section, page 26.

The pump glands, flanged fittings and valve stems should be provided with splash shields or collars in cases where personnel would be exposed to acid leaks or sprays if acid should escape. The use of transparent shields may assist personnel in detecting incipient leaks before they become serious. In areas where there is low or no risk to personnel, the flanges should not be covered to be able to visually inspect the flange for signs of leakage.

Where access to the top of the tank truck is needed, the spot should be provided with stairs and platform. Noncombustible construction is preferred. Overhead unloading lines should be counter-weighted with a pulley and weight system or equivalent. Commercial prebuilt systems are available.

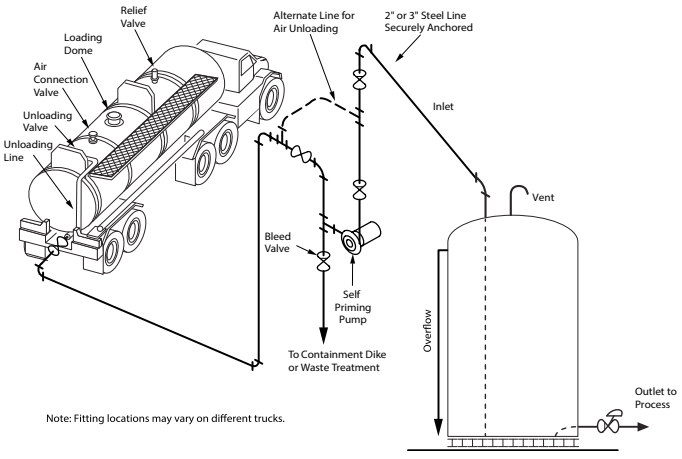


FIGURE 9: Tank Truck Delivery

UNLOADING

DOT Regulations (Section 177.834) require that tank motor vehicles be attended during loading and unloading. If it becomes necessary for the attendant to leave the operation, transfer of the acid must be stopped and the hose disconnected.

Contents of the tank truck should be checked before they are transferred. If a sample is required for testing purposes, the truck driver should open the manhole or filling opening. The person taking the sample should wear appropriate protective equipment.

Before connecting for unloading, the truck engine should be stopped and not started again during the entire unloading operation, unless it is necessary to operate the pump by power take-off, or to use the truck engine to operate compressors as a source of air for air-pressure unloading.

Truck parking brakes should be set and the wheels chocked.

A sign should be placed near truck stating in effect, "Danger—Unloading Acid," to caution others to stay away from the operation. Rope off area to keep others away.

If transfer is by means of air pressure, connect air line and apply air slowly until there is a normal flow of acid into the storage tank. The air pressure must not exceed the safe working pressure of the tank or the start-to-discharge pressure of the relief valve. When the tank truck is empty, shut off the air and vent off the pressure. After pressure has been vented, disconnect the air line. Do not disconnect the acid unloading line until the tank truck is at atmospheric pressure and the tank truck standpipe drained. After disconnecting the acid unloading line, replace blind flanges on standpipe and air line.

"If high freezing grades are shipped in un-insulated trucks, a plugged discharge pipe or sump may be the source of unloading difficulty."

Frozen Trucks

Frozen tank trucks are unlikely even in cold weather because of rapid delivery. If high freezing grades are shipped in un-insulated trucks, a plugged discharge pipe or sump may be the source of unloading difficulty.

External application of steam at the exit valve or sump where freezing has taken place will generally free the blockage.

Pump Transfer to Process

Pumps are used for transfer if the length of the storage discharge line makes gravity flow impractical, or if the point of use is above the level of the storage tank.

It must be recognized that if the end of the line to process is below the level of the acid in the tank, a siphon can be formed.

Consult pump manufacturers for their recommendations for the specific installation advising service conditions, flow rates, line sizes, head considerations, etc. Either self-priming centrifugal, seal-less, or positive displacement pumps may be used.

Measuring Storage

Storage-tank calibration can be obtained from the supplier, calculated from internal measurements, or determined by filling the tank with known weights of water.

Liquid level can be measured by a wide variety of level measurement devices, including bubblers, differential pressure, sonar, radar or electrical conductance, etc.

Operators can also physically check acid depth with a stainless steel or polyvinyl chloride rod or other manual device. Care should be taken not to touch any overhead electrical wires with the measuring rod. Acid contact with skin or clothing during manual measurement can be avoided by proper use of prescribed protective equipment

EQUIPMENT

Corrosion Hazards

Mild steel is generally satisfactory for storage and handling of the concentrated technical grades of sulfuric acid (93 to 99%) H_2SO_4.

However, more dilute solutions are highly corrosive and special materials of construction are required. The corrosion resistance of materials to sulfuric acid over different concentration and temperature ranges is illustrated in Figure 10. The supplier should be consulted for materials of construction recommendations based on specific conditions. Unless the process is unique, corrosion data should be readily available to indicate what materials should be selected.

Storage Tanks

Sulfuric acid storage tank design should follow NACE International (National Association of Corrosion Engineers) SP 0294-2006 standard.

The location of storage facilities for tank cars should permit emergency Tank Truck deliveries. For tank car delivery, sufficient storage for 18,000 gallons, or a two-week supply (whichever is larger) is recommended. For tank truck delivery, storage for 4500 gallons is generally sufficient. Where long shipping distances are involved, larger storage is advisable. Storage capacity should be at least 1-1/2 times the maximum quantity normally ordered to ensure against running out of acid between receipts of shipments.

Either horizontal or vertical cylindrical storage tanks can be used. Horizontal tanks of 10,000 to 40,000-gallon capacity should be constructed with standard ASME dished heads of the same thickness. This thickness should include a corrosion allowance of 1/4 inch, which provides a tank life of 15-20 years, depending on acid concentration and handling temperature. Vertical tank thickness depends on size and tank configuration, and addition of up to 1/4-inch corrosion allowance for carbon steel.

Vertical tank designs generally conform to American Petroleum Institute Standards 650 or 620, which provide a rating slightly above atmospheric pressure. Pressure rating must be taken into account in designing the vent system to ensure tank limitations are not exceeded when unloading by air pressure. Vertical tanks should be placed on grillage, not directly on the ground or concrete to minimize potential for external corrosion of the tank bottom.

Welded construction is recommended for tank fabrication per the above applicable codes. At normal service temperatures, stress relieving is not necessary.

The tank should have the following top openings: a 22-inch minimum diameter manhole with cover, a 3-inch vent line, a 2-inch filling line inserted through a 3-inch nozzle, and a suitable opening for measuring acid content.

An opening of 2 to 3 inches for transferring acid to process can be located either on top or bottom, depending on whether pump or gravity transfer is used.

If transfer is from the bottom, no other outlet is needed. Preferably all discharge piping is located on the side of the tank (with appropriate nozzle insert) and not on the tank bottom (floor). On vertical tanks, a 22-inch (minimum) diameter side manhole, fabricated with the upper 180 degrees of the inside of the manhole neck lined with 3/16” stainless steel or Alloy 20 to prevent hydrogen grooving, is recommended. A 1/2-inch thick cover should be provided for the manhole. This manhole, located near the tank bottom, will facilitate cleaning.

Other nozzles should project several inches into the top of the tank, particularly the nozzle for the filling line from the tank car or truck. This prevents acid from running down the side of the tank and forming an acid film. Moisture from the air could dilute the film and cause corrosion (dilute sulfuric acid is more corrosive than concentrated acid). It is desirable to avoid acid impinging on tank surfaces and causing erosion.

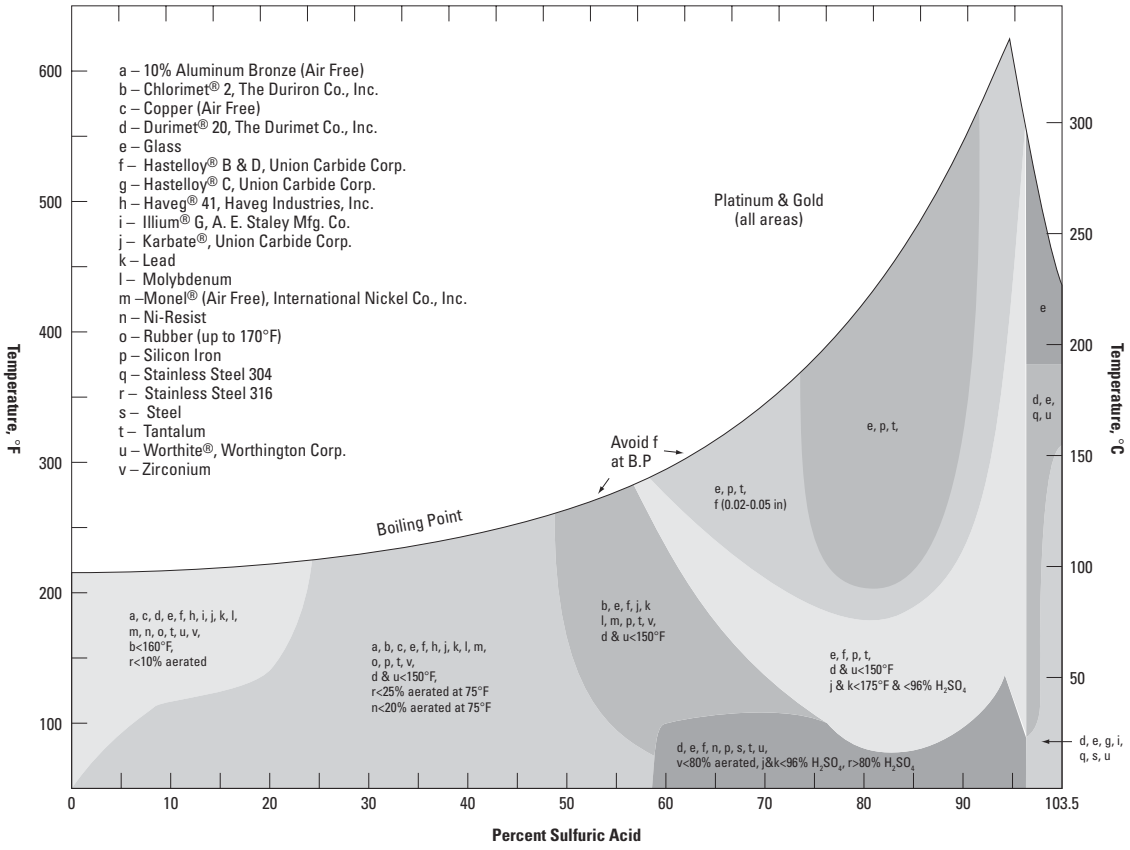


FIGURE 10: Materials of Construction for Use with Sulfuric Acid (Corrosion Rate Less than 0.02 in per yr)

Extending the fill line below the liquid level near the bottom of the tank minimizes fumes. A wear plate should be installed below the fill line, on the tank floor. The fill line should be vented to prevent siphoning the contents from elevated tanks either accidentally or in the case of hose rupture during unloading. A wear plate (1/8-inch thick) should be installed on the tank bottom under the fill line if the line extends to within 2 feet of the tank bottom.

Storage tanks should be placed on supports above the ground. A horizontal tank of 20,000-gallon capacity will normally be grouted in 2 or 4 concrete saddles, each approximately one foot wide. Flashing or mastic can be used between tank and saddle. It is recommended to have the repad plates seal-welded to the tank in the area in which the tank sits in the saddles. Structural steel supports are satisfactory and in some cases may be more economical.

Storage tanks should be sandblasted and painted on the outside with a suitable acid-resisting coating system. Regardless of the coating system selected, sandblasting of commercial quality is required, per Steel Structure Painting Council Specifications SP 6-63. A coating system that gives long-term color and gloss retention uses CORLAR® 825 zinc chromate epoxy primer followed by an intermediate coat of CORLAR® 823-HB epoxy enamel, followed by a topcoat of IMRON® 3.5HG Plus® polyurethane enamel.

The interior of the carbon steel storage tank should be lined whenever the iron content of 66° Bé acid must be maintained at a minimum. Several acid-resistant materials such as glass, Teflon® or a baked-phenolic can be used.

"The entire system should be examined visually annually for external signs of failure."

Some phenolic coatings suitable for sulfuric service are manufactured by “Heresite®”, “Lithcote®”, or “Plasite®” (See manufacturer for latest recommended coating). Phenolic linings can be used for electrolyte acid. Linings are generally spray-applied and are heat-cured to effect bonding. Consult the manufacturers for further information.

Dilution tanks for electrolytic acid may be polypropylene-lined steel, fiber-reinforced plastic or elastomer-lined steel, provided that acid temperatures are kept below 200° F during dilution. If cooling is not provided, tank selection is restricted to steel lined with brick, lead, or glass.

Storage tanks should be examined periodically (every 2-3 years or more frequently if needed) for corrosion-induced weaknesses. Thicknesses should be taken every three years (minimum) until a corrosion rate is established for the particular tank and operating conditions, then follow API 653 guidelines for further testing. The use of an ultrasonic thickness tester or similar device facilitates inspection. The entire system should be examined visually annually for external signs of failure. Acid spills on the tank exterior can be particularly corrosive as acid becomes diluted with atmospheric moisture or rain water, so the use of acid-resistant paint is important. The tanks should be cleaned and internally inspected per NACE SP 0294-2006 standards.

Tanks may need to be diked where release of contents due to broken connections or tank rupture may endanger other facilities. Local authorities may require diking to prevent acid from getting into waterways. Dikes may be of either the impounding or diversion type. Diversion-type dikes are preferred for fuming acids to contain the acid away from the tank to an area where it can be diluted to non-fuming concentration and disposed. This permits better access to repair the leak.

Vents

Sulfuric acid storage tanks must always have an open vent for normal breathing and to prevent dangerous pressure build-up due to hydrogen. Hydrogen gas may be produced from the action of acid on the steel tank and cause an increase in pressure.

Proper venting of storage tanks is essential to dissipate any hydrogen evolved. Potential sources of ignition (such as sparks and flames) should be excluded from the vicinity of the storage tank to minimize the fire or explosion hazard from hydrogen generation.

The vent line must be constructed of acid-resistant material. Polyvinyl chloride (PVC or CPVC) pipe is recommended for sulfuric acid for vent lines ONLY. Iron sulfate can build up in the vent line over a period of time. Periodic documented inspection of the vent line for blockage may prevent tank collapse during acid transfer.

The vent line should be flush with the inner surface at the highest point of the tank to dissipate any hydrogen evolved. This vent can be equipped with a gooseneck bend or point straight up and be protected with a cover to prevent entrance of rainwater.

If the tank is located indoors, the vent line should extend outside the building. Installation of an air dryer is optional. An air dryer may be desirable when there is high humidity and a low turnover rate of the tank contents.

"The line from the unloading point to storage should be equipped with a valve so the acid flow may be stopped at any time. "

Piping

All pipe lines should be installed so they drain toward the storage tank, or toward the point of consumption wherever possible. This will prevent the accumulation of acid in low points, thereby eliminating possible safety hazards when repairs are necessary.

The line from the unloading point to storage should be equipped with a valve so the acid flow may be stopped at any time. The unloading line should also include a drain point with a valve that can be checked prior to disconnecting transfer hose or piping. When unloading with air, this line should be securely anchored to the storage tank, since considerable vibration may occur.

The unloading line can be 2-inch pipe if the distance is short between the unloading spot and storage; otherwise a 3-inch line is recommended. The size of the transfer line from storage to process depends on the required flow, but normally a 1-1/2 to 3-inch-diameter line will be sufficient. Schedule 80 steel pipe is recommended. Steel is velocity-sensitive. Piping should be designed for fluid flow between 1-3 feet per second (fps). At low fluid velocities, hydrogen-grooving failure may occur, while at fluid velocities above about 3 fps, erosion-corrosion will cause failure.

The overflow line (larger in size than acid-inlet line to tank) should drain to containment or approved waste-treatment facilities.

There are two recognized types of fittings for acid-handling lines: welded flanges with a suitable type of gasket and butt-weld fittings. These make a better and more permanent installation and is HIGHLY recommended. Socket-welds and/or screwed piping are strongly discouraged.

Where flanges are used, standard 150 lb.-flange fittings are recommended. Flange guards should be used on all flanged joints where there is significant exposure risk to personnel. Some newer types of rigid PVC (Type I, Grade 1) or PVDV (Type IV, Grade 1) plastic piping may be more economical. However, they are only recommended for vent lines, not liquid lines, due to low mechanical strength and brittleness. Continuous support should be provided for plastic pipe along its entire length.

For severe conditions, steel pipe lined with TEFLON® FEP fluorocarbon resin should be considered. TEFLON®-lined hoses are recommended for strong (>77%) sulfuric acid service for the flexible connection required for unloading tank cars. Hoses must not be flexed beyond the manufacturer's recommended bend radius. Hoses should be inspected for deterioration before each use and tested annually to ensure that they are satisfactory. A swing connection using swivel joints such as OPW® or Chiksan®, with gaskets of TEFLON®, can also be used.

If air is used for unloading, the air line from the plant to the unloading station should be 1/2-inch, minimum. The fittings (trap, pressure reducer, pressure-relief valve, and shut-off valves) should be 3/4-inch nominal pipe size. A 1-inch-diameter rubber hose may be used for attaching to the tank car (see Figure 8). A 2-inch air-release valve should be located sufficiently far from the tank car that in case of a leak in the acid discharge hook-up, the operator can quickly depressurize the car without being sprayed with acid. The air line downstream of this air dump valve should be 2-inch. Ensure the air-to-acid interconnections are properly equipped to prevent backflow of the acid into the air system.

Table 2 on the following page shows limitations in fluid flow velocity for a number of different types of pipes.

"Selection of the proper type of pump for handling sulfuric acid will depend upon the specific requirements of an installation. "

Pumps

Selection of the proper type of pump for handling sulfuric acid will depend upon the specific requirements of an installation. A seal-less magnetic-drive centrifugal pump is usually recommended for handling acids of strength from 60° Bé (77%) to 100% H2SO4.

When a submerged pump is used, it should be mounted in a manhole so the entire pump assembly may be easily removed.

To ensure protection of the top bearing from acid, vertical submerged pumps should be constructed with the top bearing above the packing gland and external to the tank.

In general, horizontal pumps should be self-priming with 50% excess head, and volume characteristics to compensate for the relatively high viscosity of the acid that may be encountered at low temperatures. Special alloys have been developed by pump manufacturers for sulfuric acid handling.

Valves

Experience has shown that for lowest overall cost and minimum maintenance, Alloy 20 or "Durco" ® T-line valves with a TEFLON® liner or equivalent will give the best performance. Plug valves or full-port ball valves are recommended. Valves should be purchased with a stainless steel guard as a safety feature to protect the operator against acid leaking through the packing.

Whenever possible, valves should be mounted in a horizontal pipe with the stem up.

Gaskets and Packing

Viton®B (for H_2SO_4 <100%) or solid TEFLON® TFE are recommended for flange gaskets.

Valve packing should be of TEFLON® fluorocarbon resin; pump packing should be of braided TEFLON®. Alternatively, on pumps, an outside mechanical seal or a double mechanical seal can be used.

Consult manufacturers for specific grades and style numbers.

TABLE 2.
70-99% H_2SO_4 Fluid Flow Velocity Limitations, Feet per Second (FPS)

Carbon (mild) steel	1-3 fps
304 Stainless Steel	0-6 fps
316 Stainless Steel	0-8 fps
Alloy 20	0-20 fps
Teflon® lined pipe	0-50 fps

SPILL OR LEAK PREVENTION CONTROL

In design of a storage facility, all steps should be taken to minimize the possibility of a major spill or leak. Consideration should be given in design to such items as alarms, interlocks, remote operated valves, relief devices and emergency shutdown buttons. It is important to select proper materials of construction and to include a corrosion allowance. Thickness testing of vessels and piping on a regular basis may indicate potential problems before a major spill or leak occurs.

Written procedures for unloading and transferring acid to process should prescribe a proper procedure and assign responsibility. Thorough training of operating and maintenance personnel is essential to minimize personnel error.

However, spills or leaks may occur regardless of preventive measures. All storage and process areas should have facilities for quick clean-up in case of a spill or leak. Consideration should be given to likely problem areas and where the spill will drain. Drainage pattern and methods of containment should be considered. Personnel should be trained in handling a spill emergency, and such emergency actions should be incorporated into a plant emergency response plan.

Spills and Leaks

A contaminated area should be immediately zoned off to avoid anyone being exposed to the acid spray or stream, and valves closed to stop leakage. Fine water mist or mid-expansion foam should be applied to the contaminated area. The area should then be neutralized with lime, soda ash or other alkaline material.

If fine water mist or mid-expansion foam is not available, the contaminated area should be covered with sand, ashes or gravel and neutralized with soda ash, lime or other alkaline material.

If the acid spill or leak is of sufficient quantity to contaminate the plant sewer system, soda ash, lime or other alkaline material should be added to neutralize the acidity. Sulfuric acid spills, leaks or drainings must not come in contact with any sulfide wastes, such as in sewers, because of the danger of evolving hydrogen sulfide gas. Similarly, other hazardous reactions may occur, depending on sewer contents. Local authorities should be consulted for spill-reporting requirements.

Cleaning Storage Tanks

Over a period of years, steel sulfuric acid storage tanks tend to build up a deposit of iron sulfate sludge, which can cause line blockage. It is recommended that storage tanks be cleaned and inspected per NACE SP 0294-2006 standards before sludge causes line blockage. Sludge that has accumulated over many years can become similar to clay and be extremely difficult to remove.

Any material removed from a storage tank for the purpose of disposal must be handled within RCRA regulations. Before attempting a tank cleaning, become thoroughly familiar with all pertinent federal, state and local regulations, and the permits that may be required, so all cleaning operations are within compliance.

In preparation for tank inspection and cleaning, the acid level should be run as low as possible by postponing deliveries and transferring to process.

PROCEDURE

1. Using proper safety equipment, inspect the inside of the tank through the top manhole cover for the amount of sludge. Determine the amounts of acid and sludge by probing with a wooden pole or steel rod. Sampling and analysis of sludge for heavy metals may be required to determine the correct disposal method.

2. Choose a sludge disposal method. Contractors who specialize in acid-tank cleaning are generally available. Some contractors can neutralize RCRA waste on-site and are knowledgeable in pertinent regulations. RCRA includes the Elementary Neutralization Exemption (ENE), which is a federal provision covered in Section 264.1. This allows neutralization in a "tank," "container," "transport vehicle," or "vessel" without a permit if the waste is considered hazardous only because it is corrosive. States have the option of not accepting this exemption as they administer RCRA. Make certain the ENE applies in the location where cleaning takes place. Make certain that neutralization is performed in a container that meets the specific definition of "tank," "transport vehicle," etc.—a pond, ditch or impoundment is not allowed. Other contractors may remove the RCRA waste by vacuum truck for transport to approved waste treatment facilities.

3. Disconnect or isolate all lines into and out of the tank to avoid getting wash water into them. The tank should be prepared for vessel entry in accordance with local plant procedure.

4. To remove sludge, flush the tank with large quantities of water. A large hose with ample pressure, such as a fire hose, can be used.

   Wash out any acid and sludge as rapidly as possible. Dislodge sludge with an air stick made of a section of steel pipe and attached to a low-pressure air supply. Move the location of the air stick frequently to avoid undue corrosion at the point where air impinges on the tank wall. Once slurried, the sludge can be removed by vacuum or "mud" pumps to an approved RCRA container for transport or neutralization.

   It is important that the tank be washed and drained as quickly as possible to prevent tank damage by contact with the diluted residual acid.

   Weak acid is very corrosive. To minimize corrosion, a commercial corrosion inhibitor can be added to the acid and sludge before dilution.

   If sludge remains after the first wash, the procedure may need to be repeated.

5. After inspection and testing, if the tank is to be reused without repairs, it should be refilled immediately with strong acid to minimize corrosion.

“Use appropriate safety equipment, such as an acid-resistant hood, suit, gloves sealed to the acid jacket sleeve, boots sealed to the acid pant legs, and respiratory protection.”

SAFETY PRECAUTIONS

1. During the tank-cleaning operation, personnel should be protected against acid contact or inhalation. Use appropriate safety equipment, such as an acid-resistant hood, suit, gloves sealed to the acid jacket sleeve, boots sealed to the acid pant legs, and respiratory protection.

2. The tank should not be entered until it is clean and has been checked to determine that there is adequate oxygen and no combustibles/ flammables present. There are hazards from sludge containing strong acid and presence of hydrogen due to the action of dilute acid on steel of the tank.

3. Smoking, welding and sparks must not be permitted in or around the tank until it has been filled with water and neutralized because of the potential explosion hazard of the hydrogen. An explosivity meter should be used to test for concentration of combustible gases prior to performing welding, grinding or drilling work in sulfuric acid storage areas.

4. Before entering any tank, special provisions must be taken to ensure safety of the individuals involved. Be sure to follow all your plant procedures for “Confined Space Entry.”

   Tank entry requires careful planning to outline precisely what tank preparations must be made, what is to be done inside and how it will be accomplished, hazards involved, safety equipment needed, and a plan developed for handling emergencies. Follow all appropriate plant procedures.

PIPELINE REPAIRS

The following procedures are recommended to maintenance personnel for safely repairing sulfuric acid pipelines.

PROCEDURE

1. Obtain release of the line and supplementary equipment from the Operating Department.

2. Check line and equipment for possible inter-connections.

3. Check safety shower.

4. Provide ample source of water to wash tools and repair equipment as necessary.

   Unless release of carbon dioxide gas is objectionable, solutions of soda ash or other carbonate can be used for washing tools. Such solutions should be checked for acidity during prolonged or heavy use, and then replaced as necessary.

5. Smoking should not be allowed in the area where repairs are being performed.

6. Wear personal protective equipment (see recommendations on page 3).

7. Close, tag and lock out the supply valve, and transfer pump. Drain all lines where possible. Provide positive isolation for the equipment to be repaired.

8. Provide for standby assistance.

9. Open all valves at the exit end of the line and allow acid to drain to containment or waste treatment.

10. Physically disconnect the line from the source of acid supply, preferably at a point adjacent to and immediately following the closed supply valve. Appropriate precautions should be taken when breaking flanges to ensure that no acid is sprayed. Assume that all lines are under pressure and dress accordingly.

11. Blow line clean with dry air or nitrogen. Do not flush with water unless absolutely necessary—weak sulfuric acid will greatly accelerate the corrosion rate in the piping.

12. If the pipe has been flushed with water, dry thoroughly by blowing with air or nitrogen. (The air should be as free as is practical of oil, excess moisture, and foreign matter.)

13. Immediately before welding, use an explosion meter to check the atmosphere inside the line for absence of explosive gases. Continue to blow nitrogen through the line while welding or cutting. Check lines at frequent intervals for buildup of explosive gases.

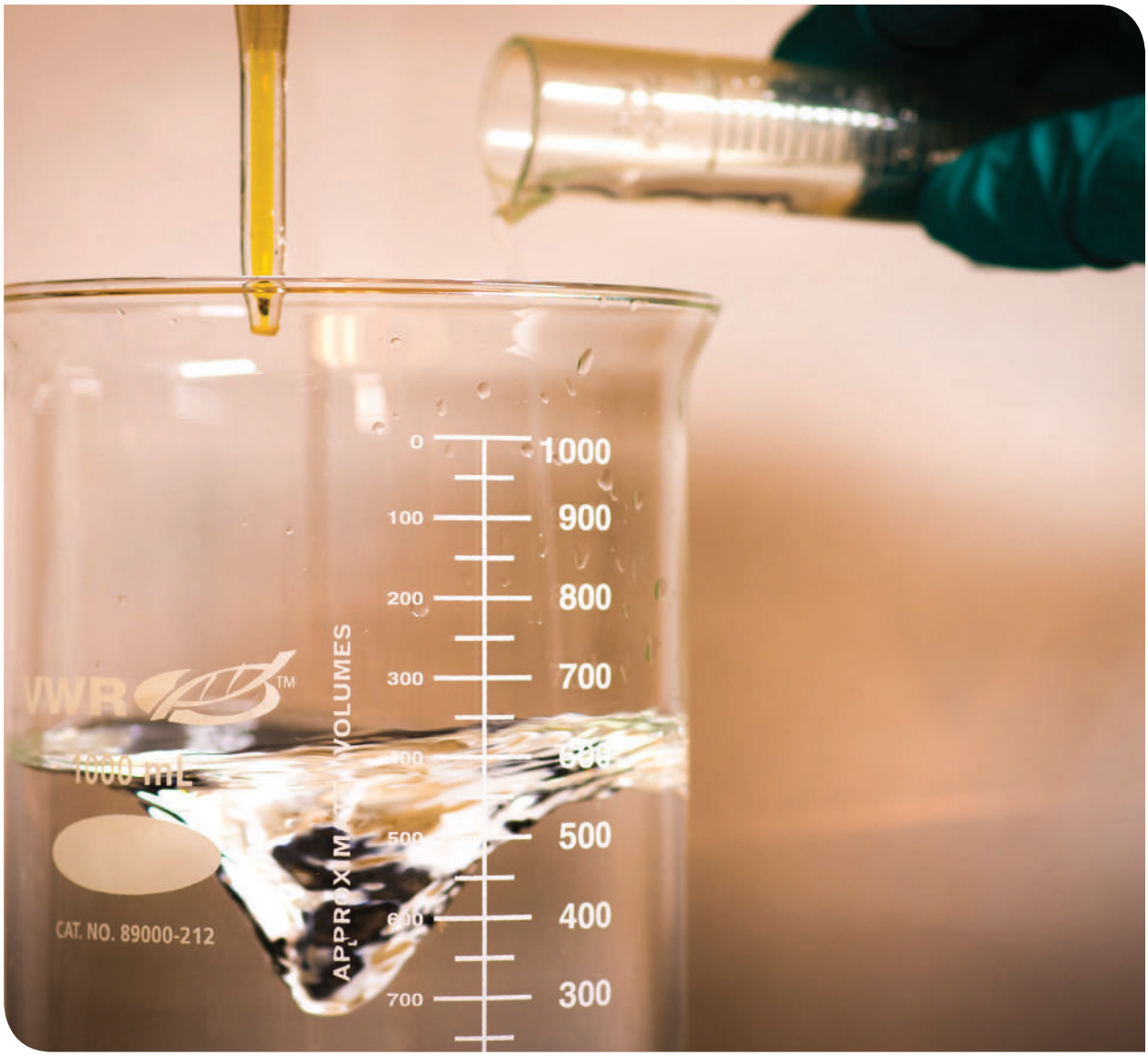
14. Use a gas shielded arc to give a slag-free weld with good fit-up and full (but not excessive) penetration.

15. Test weld for tightness (for example, using air pressure inside and soapsuds outside).

16. Reconnect the pipeline at the source of supply, leaving the supply valve closed and all valves at the exit end of the line open.

17. When operations are ready to resume, open the supply valve and flush acid through the line before closing the exit end of the line. This is to ensure removal of all moisture from the line.

18. Return line and equipment to Operating Department.



CONVERSION TABLES

Specific Gravity determinations were made at 60 degrees F, compared with water at 60 degrees F.

From the Specific Gravities, the corresponding degrees Baumé were calculated by the following formula:

°Baumé = 145 – (145/Specific Gravity)

Baumé Hydrometers for use with Table 3 must be graduated by the above formula, which formula should always be printed on the scale.

66o Baumé = Sp. Gr. 1.8354

1 ft3 water at 60 F weighs 62.37 lbs. avoirdupois

Table 2
Specific Gravity—Sulfuric Acid (0–93.19%)

°Bé	Sp. Gr. $\frac{60}{60}$ F	H_2SO_4 %	lb/gal	Freezes (melting point) °C	°F
0	1.0000	0.00	8.338	0	32.0
1	1.0069	1.02	8.395	–0.4	31.2
2	1.0140	2.08	8.455	–0.4	30.5
3	1.0211	3.13	8.515	–1.2	29.8
4	1.0284	4.21	8.575	–1.7	28.9
5	1.0357	5.28	8.636	–2.1	28.1
6	1.0432	6.37	8.697	–2.6	27.2
7	1.0507	7.45	8.734	–3.1	26.3
8	1.0584	8.55	8.825	–3.8	25.1
9	1.0662	9.66	8.890	–4.4	24.0
10	1.0741	10.77	8.956	–5.1	22.8
11	1.0821	11.89	9.023	–5.8	21.5
12	1.0902	13.01	9.091	–6.6	20.0
13	1.0985	14.13	9.159	–7.6	18.3
14	1.1069	15.25	9.230	–8.5	16.6
15	1.1154	16.38	9.300	–9.6	14.7
16	1.1240	17.53	9.372	–10.7	12.6
17	1.1328	18.71	9.445	–12.1	10.2
18	1.1417	19.89	9.520	–13.5	7.7
19	1.1508	21.07	9.596	–15.1	4.8
20	1.1600	22.25	9.661	–16.8	1.6
21	1.1694	23.43	9.739	–19	–1.8
22	1.1789	24.61	9.818	–21	–6.0
23	1.1885	25.81	9.898	–24	–11.0
24	1.1983	27.03	9.980	–27	–16.0
25	1.2083	28.28	10.063	–31	–23.0
26	1.2185	29.53	10.148	–34	–30.0
27	1.2288	30.79	10.234	–39	–39.0
28	1.2393	32.05	10.321	–45	–49.0
29	1.2500	33.33	10.410	–52	–61.0
30	1.2609	34.63	10.501	–59	–74.0
31	1.2719	35.93	10.593	–63	–82.0
32	1.2832	37.26	10.687	–71	–96.0
33	1.2946	38.58	10.782	–72	–97.0
34	1.3063	39.92	10.879	–68	–91.0
35	1.3182	41.27	10.978	–63	–81.0
36	1.3303	42.63	11.079	–57	–70.0
37	1.3426	43.99	11.181	–51	–60.0
38	1.3551	45.35	11.286	–47	–53.0
39	1.3679	46.72	11.392	–44	–47.0
40.0	1.3810	48.10	11.501	–41	–41.0
.2	1.3836	48.37	11.523		
.4	1.3863	48.65	11.545		
.6	1.3889	48.92	11.567		
.8	1.3916	49.20	11.589		
41.0	1.3942	49.47	11.611	–37	–35.0
.2	1.3969	49.75	11.634		
.4	1.3996	50.03	11.657		
.6	1.4024	50.31	11.679		
.8	1.4051	50.59	11.702		
42.0	1.4078	50.87	11.724	–35	–31.0
.2	1.4106	51.15	11.747		
.4	1.4133	51.43	11.770		
.6	1.4161	51.70	11.793		
.8	1.4188	51.98	11.816		

Table 2
Specific Gravity—Sulfuric Acid (0–93.19%)

°Bé	Sp. Gr. $\frac{60}{60}$ F	H_2SO_4 %	lb/gal	Freezes (melting point) °C	°F
43.0	1.4216	52.26	11.839	–33	–27
.2	1.4244	52.54	11.863		
.4	1.4272	52.82	11.886		
.6	1.4300	53.10	11.909		
.8	1.4328	53.38	11.933		
44.0	1.4356	53.66	11.956	–31	–24
.2	1.4385	53.94	11.980		
.4	1.4414	54.22	12.004		
.6	1.4442	54.51	12.028		
.8	1.4471	54.79	12.052		
45.0	1.4500	55.07	12.076	–29	–20
.2	1.4529	55.35	12.100		
.4	1.4558	55.63	12.125		
.6	1.4588	55.92	12.149		
.8	1.4617	56.20	12.173		
46.0	1.4646	56.48	12.198	–26	–15
.2	1.4676	56.76	12.223		
.4	1.4706	57.05	12.248		
.6	1.4736	57.33	12.272		
.8	1.4766	57.62	12.297		
47.0	1.4796	57.90	12.322	–26	–15
.2	1.4826	58.18	12.348		
.4	1.4857	58.47	12.373		
.6	1.4887	58.75	12.398		
.8	1.4918	59.04	12.424		
48.0	1.4948	59.32	12.449	–28	–18
.2	1.4979	59.61	12.475		
.4	1.5010	59.89	12.501		
.6	1.5042	60.18	12.527		
.8	1.5073	60.46	12.553		
49.0	1.5104	60.75	12.579	–30	–22
.2	1.5136	61.04	12.605		
.4	1.5168	61.32	12.632		
.6	1.5199	61.61	12.658		
.8	1.5231	61.89	12.685		
50.0	1.5263	62.18	12.711	–33	–27
.2	1.5296	62.48	12.739		
.4	1.5328	62.77	12.766		
.6	1.5361	63.07	12.793		
.8	1.5393	63.36	12.820		
51.0	1.5426	63.66	12.847	–36	–33
.2	1.5459	63.95	12.875		
.4	1.5492	64.25	12.902		
.6	1.5525	64.54	12.930		
.8	1.5558	64.84	12.957		
52.0	1.5591	65.13	12.985	–39	–38
.2	1.5625	65.43	13.013		
.4	1.5659	65.73	13.041		
.6	1.5693	66.03	13.070		
.8	1.5727	66.33	13.098		
53.0	1.5761	66.63	13.126	–45	–49
.2	1.5796	66.93	13.155		
.4	1.5830	67.23	13.184		
.6	1.5865	67.53	13.213		
.8	1.5899	67.83	13.241		

(continued)

Table 2 *(continued)*
Specific Gravity—Sulfuric Acid (0–93.19%)

°Bé	Sp. Gr. 60/60 °F	H_2SO_4 %	lb/gal	Freezes (melting point) °C	°F
54.0	1.5934	68.13	13.271	–50.5	–59.0
.2	1.5969	68.43	13.300		
.4	1.6005	68.74	13.329		
.6	1.6040	69.04	13.359		
.8	1.6076	69.35	13.388		
55.0	1.6111	69.65	13.418	Below –40°F	
.2	1.6147	69.95	13.448	Below –40°F	
.4	1.6183	70.26	13.478		
.6	1.6220	70.56	13.508		
.8	1.6256	70.87	13.538		
56.0	1.6292	71.17	13.568	Below –40°F	
.2	1.6329	71.49	13.599		
.4	1.6366	71.80	13.630		
.6	1.6403	72.12	13.661		
.8	1.6440	72.43	13.692		
57.0	1.6477	72.75	13.722	Below –40°F	
.2	1.6515	73.07	13.754		
.4	1.6553	73.39	13.786		
.6	1.6591	73.72	13.817		
.8	1.6629	74.04	13.849		
58.0	1.6667	74.36	13.881	Below –40°F	
.2	1.6706	74.69	13.913		
.4	1.6744	75.01	13.945		
.6	1.6783	75.34	13.977		
.8	1.6821	75.66	14.009		
59.0	1.6860	75.99	14.041	Below –7°F	
.1	1.6880	76.16	14.058		
.2	1.6900	76.33	14.075		
.3	1.6919	76.49	14.091		
.4	1.6939	76.66	14.108		
.5	1.6959	76.83	14.124		
.6	1.6979	77.00	14.141		
.7	1.6999	77.17	14.157		
.8	1.7019	77.33	14.174		
.9	1.7039	77.50	14.191		
60.0	1.7059	77.67	14.207	–10.7	+12.6
.1	1.7079	77.85	14.224		
.2	1.7099	78.02	14.241		
.3	1.7119	78.20	14.258		
.4	1.7139	78.37	14.275		
.5	1.7160	78.55	14.292		
.6	1.7180	78.73	14.309		
.7	1.7200	78.90	14.325		
.8	1.7221	79.08	14.342		
.9	1.7241	79.25	14.359		
61.0	1.7262	79.43	14.376	–2.6	27.3
.1	1.7282	79.62	14.393		
.2	1.7303	79.80	14.411		
.3	1.7324	79.99	14.428		
.4	1.7344	80.18	14.445		
.5	1.7365	80.36	14.463		
.6	1.7386	80.55	14.480		
.7	1.7407	80.74	14.497		
.8	1.7428	80.93	14.515		
.9	1.7449	81.11	14.532		

Table 2 *(continued)*
Specific Gravity—Sulfuric Acid (0–93.19%)

°Bé	Sp. Gr. 60/60 °F	H_2SO_4 %	lb/gal	Freezes (melting point) °C	°F
62.0	1.7470	81.30	14.549	3.9	39.1
.1	1.7491	81.50	14.567		
.2	1.7512	81.71	14.585		
.3	1.7533	81.91	14.603		
.4	1.7554	82.12	14.620		
.5	1.7576	82.32	14.638		
.6	1.7597	82.52	14.656		
.7	1.7618	82.73	14.674		
.8	1.7640	82.93	14.691		
.9	1.7661	83.14	14.709		
63.0	1.7683	83.34	14.727	7.8	46.1
.1	1.7705	83.57	14.745		
.2	1.7726	83.80	14.763		
.3	1.7748	84.04	14.781		
.4	1.7770	84.27	14.799		
.5	1.7791	84.50	14.818		
.6	1.7813	84.73	14.836		
.7	1.7835	84.96	14.854		
.8	1.7857	85.20	14.872		
.9	1.7879	85.43	14.890		
64.0	1.7901	85.66	14.908	8.0	46.4
.1	1.7923	85.90	14.927		
.2	1.7946	86.17	14.946		
.3	1.7968	86.43	14.964		
.4	1.7990	86.72	14.983		
.5	1.8012	87.03	15.002	5.0	41.1
.6	1.8035	87.33	15.020		
.7	1.8057	87.65	15.039		
.8	1.8080	88.05	15.058		
.9	1.8102	88.31	15.076		
65.0	1.8125	88.65	15.095	.61	33.1
.1	1.8148	88.98	15.114		
.2	1.8170	89.30	15.133		
.3	1.8193	89.76	15.152		
.4	1.8216	90.17	15.171		
.5	1.8239	90.60	15.190	–10.3	13.4
.6	1.8262	91.06	15.209		
.7	1.8285	91.54	15.228		
.8	1.8308	92.07	15.248		
.9	1.8331	92.60	15.267		
66.0	1.8354	93.19	15.286	–34	–29

Allowance for Temperature

At 10° Bé, 0.029° Bé or 0.00023 Sp. Gr. per 1 F
At 20° Bé, 0.036° Bé or 0.00034 Sp. Gr. per 1 F
At 30° Bé, 0.035° Bé or 0.00039 Sp. Gr. per 1 F
At 40° Bé, 0.031° Bé or 0.00041 Sp. Gr. per 1 F
At 50° Bé, 0.028° Bé or 0.00045 Sp. Gr. per 1 F
At 60° Bé, 0.026° Bé or 0.00053 Sp. Gr. per 1 F
At 63° Bé, 0.026° Bé or 0.00057 Sp. Gr. per 1 F
At 66° Bé, 0.0235° Bé or 0.00054 Sp. Gr. per 1 F

Table 3
Specific Gravity—Sulfuric Acid (94–100%)

H_2SO_4 %	Sp. Gr. $\frac{60}{60}$ F	SO_3 %	Freezing Point °F	Freezing Point °C
94.0	1.8381	76.73	–28.1	–33.4
95.0	1.8407	77.55	–11.7	–24.3
96.0	1.8427	78.37	+5.7	–14.6
97.0	1.8437	79.18	17.1	–8.3
97.5	1.8439	79.59	23.2	–4.9
98.0	1.8437	80.00	28.6	–1.9
99.0	1.8424	80.82	39.9	+4.4
100.0	1.8391	81.63	50.6	10.35

Allowance for Temperature

At 94%, 0.00054 Sp. Gr. per 1 F, 0.00097 Sp. Gr. per 1 C

At 96%, 0.00053 Sp. Gr. per 1 F, 0.00095 Sp. Gr. per 1 C

At 97.5%, 0.00052 Sp. Gr.per 1 F, 0.00094 Sp. Gr. per 1 C

At 100%, 0.00052 Sp. Gr. per 1 F, 0.00094 Sp. Gr. per 1 C

Table 4
Sulfuric Acid Conversion Factors

Initial Concentration	Concentration Desired 50° Bé	60° Bé	66° Bé	100% H_2SO_4
50° Bé	1.000	0.80	0.6672	0.6218
60° Bé	1.25	1.000	0.83	0.7767
66° Bé	1.50	1.20	1.000	0.9319
100% H_2SO_4	1.6080	1.2880	1.0730	1.000

This table is convenient for calculating equivalent weights of acids. To find the weight of any acid listed horizontally that is equivalent to a known weight of acid of a strength listed in the vertical column, follow the line of the known-strength acid to the right until it intersects the column of the acid concentration at which the equivalent weight is desired. Multiply the weight of the known-strength acid by the factor at the intersection just located. The result is the equivalent weight of the different-strength acid.

Example: 100 pounds of 66° Bé acid is equivalent to how many pounds of 60° Bé acid?

Answer: 100 x 1.2 = 120 lb of 60° Bé acid.

Table 5
Specific Gravity—Oleum

% Free SO_3	% Total SO_3	Sp. Gr. $\frac{60}{60}$ F	% Actual H_2SO_4	Eq.% 100% H_2SO_4	Oleum lb/gal
0	81.63	1.839	100	100.00	15.33
1	81.81	1.845	99	100.22	15.38
2	82.00	1.851	98	100.45	15.41
3	82.18	1.855	97	100.67	15.46
4	82.36	1.858	96	100.89	15.49
5	82.55	1.862	95	101.13	15.52
6	82.73	1.865	94	101.35	15.55
7	82.92	1.869	93	191.58	15.58
8	83.10	1.873	92	101.80	15.61
9	83.28	1.877	91	102.02	15.64

(continued)

Table 5
Specific Gravity—Oleum

% Free SO_3	% Total SO_3	Sp. Gr. 60 60	% Actual H_2SO_4	Eq.% 100% H_2SO_4	Oleum lb/gal
10	83.47	1.880	90	102.25	15.67
11	83.65	1.884	89	102.47	15.70
12	83.83	1.887	88	102.71	15.73
13	84.02	1.891	87	102.92	15.76
14	84.20	1.895	86	103.15	15.79
15	84.39	1.899	85	103.38	15.82
16	84.57	1.902	83	103.60	15.86
17	84.75	1.905	82	103.82	15.89
18	84.94	1.909	82	104.05	15.92
19	85.12	1.911	81	104.28	15.95
20	85.30	1.915	80	104.50	15.98
21	85.49	1.920	79	104.73	16.01
22	85.67	1.923	78	104.95	16.04
23	85.86	1.927	77	105.18	16.07
24	86.04	1.931	76	105.40	16.10
25	86.22	1.934	75	105.62	16.12
26	86.41	1.939	74	105.85	16.16
27	86.59	1.943	73	106.08	16.19
28	86.72	1.946	72	106.29	16.22
29	86.96	1.949	71	106.53	16.25
30	87.14	1.952	70	106.75	16.28
31	87.32	1.955	69	106.97	16.30
32	87.51	1.958	68	107.20	16.33
33	87.69	1.961	67	107.42	16.35
34	87.88	1.965	66	107.65	16.38
35	88.06	1.968	65	107.87	16.40
36	88.24	1.972	64	108.10	16.43
37	88.43	1.976	63	108.33	16.46
38	88.61	1.979	62	108.55	16.50
39	88.79	1.981	61	108.77	16.52
40	88.98	1.983	60	109.00	16.54
41	89.16	1.985	59	109.22	16.55
42	89.35	1.987	58	109.45	16.56
43	89.53	1.989	57	109.68	16.58
44	89.71	1.991	56	109.90	16.60
45	89.90	1.993	55	110.13	16.62
50	90.72	2.001	50	111.25	16.68
60	92.65	2.102	40	113.50	17.53
70	94.49	1.982	30	115.75	16.50
80	96.33	1.949	20	118.00	16.25
90	98.16	1.911	10	120.25	15.92
100	100.00	1.857	0	122.50	15.50

Allowance for Temperature

Total % SO_3	Specific Gravity Correction Per °C	Per °F
82	0.00100	0.00056
83	0.00105	0.00058
84	0.00110	0.00061
85	0.00110	0.00061
86	0.00115	0.00064
87	0.00120	0.00067
88	0.00125	0.00069

Reference: Sulfuric Acid Handbook by T. J. Sullivan
Courtesy of Chemical Construction Co.

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