Acids and Caustics

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1. Acids, caustics, and alkalis in one form or another are used in many industries. Because their use, however, is frequently incidental to other operations, many employers and workers give little real consideration to the dangers involved.

2. This pamphlet discusses the various hazards encountered in handling the acids and caustics most commonly used in industrial processes, and suggests ways to overcome these hazards. The pamphlet is not intended as a guide for the manufacturers of chemicals, nor does it discuss completely the broad question of occupational diseases. The hazards of the following acids and caustics are first discussed in general in paragraphs 3 to 58:

a) Nitric acid, HNO_3
b) Sulphuric acid, H_2SO_4
c) Mixed acid, HNO_3 and H_2SO_4
d) Hydrochloric acid, HCl
e) Hydrofluoric acid, HF
f) Carbolic acid, C_6H_5OH
g) Oxalic acid, $C_2H_2O_4$
h) Picric acid, $C_6H_2(OH)(NO_2)_3$
i) Acetic acid, $C_2H_4O_2$
j) Hydrocyanic acid, HCN
k) Ammonia, NH_3
l) Caustic soda, NaOH
m) Caustic potash, KOH
n) Soda ash, Na_2CO_3
o) Lime, CaO

A more detailed discussion of each of these chemicals is presented in paragraphs 59 to 73. It is not practicable to discuss in this brief pamphlet all of the acids and caustics used in industry. Users of substances not included in this list should make further investigations before assuming that such substances are harmless.

This pamphlet is one of more than 150 Safe Practices and Health Practices Pamphlets. It is a compilation of experience and accident prevention from many sources. It should not be assumed, however, that it includes every acceptable procedure in the field covered. It must not be confused with American Standard Safety Code; federal laws; insurance requirements; state laws, rules and regulations; and municipal ordinances. *Additional copies of this pamphlet are available. Member price, 35 cents each. Quantity and non-member prices on request.*

Chemical Injuries

3. In general, acids and caustics in concentrated form, and sometimes in milder form, may cause injury in four different ways:

a) Burning, from direct contact with the skin or eyes, or indirectly through the clothing.
b) Fume poisoning or suffocation. Some chemical fumes are poisonous if inhaled, while others tend to exclude oxygen and if in sufficient concentration in the atmosphere, this atmosphere may fail to sustain life.
c) Poisoning when taken internally.
d) Fires or explosions resulting from their improper handling and storage.

Courtesy Western Electric Co.

Figure 1. Acid-dipping operation on which the operator is protected by special gauntlet gloves, wooden soled safety shoes, and special goggles. (See paragraph 4.)

Burns

4. Chemical burns are painful and may be slow to heal. When extending over large areas of the skin surface, they may result in death. Workers cannot be too careful in avoiding accidental splashes, mists, sprays, and dusts, and direct contact with those acids and caustics that produce burns. Suitable clothing and protective devices should be worn by workers exposed to the hazard of burns. A proper selection to fit the conditions may be made from such articles as rubber gloves, rubber boots or wooden clogs, rubber aprons, tight fitting goggles preferably with rubber faced pads, face shields, and acid-proof hoods. Those working with acids should preferably wear woolen clothing, while those working with caustics should wear cotton clothing. It should be understood, however, that neither woolen nor cotton clothing affords complete protection against chemical burns. (See Figures 1, 2 and 3.)

5. The difference in the time element is an important factor in burns caused by acids and those caused by alkalis or caustics. In general acid burns are felt at once or very quickly after contact. Alkali or caustic burns, on the other hand, may gain considerable headway before they are noticed by the workman because, unlike acids, alkalis and caustics do not give immediate warning of their presence on the skin by a stinging sensation.

6. Good floors will help prevent many chemical burns that otherwise may be caused by workers tripping or slipping. Floors should be kept in good repair and should not be slippery nor

Courtesy Calco Chemical Division American Cyanamid Co.

Figure 2. An acid plant worker wearing an acid hood and other personal protective equipment. (See paragraph 4.)

made of material that will wear slippery. They should be properly drained to the sewer or to a catch basin. (For further information on floors, see Safe Practices Pamphlet No. 11.)

7. Good lighting is a paying investment, not a needless luxury. In a properly illuminated working place accidents are less frequent, the employees work more efficiently and make fewer mistakes. Good lighting is especially desirable where steam, fumes, or vapors are likely to limit dangerously the field of vision. The use of vapor-proof electrical equipment prevents sparks and corrosion. Electric lighting and power equipment should be of a type that will resist the corrosive action of acid fumes and that will not cause electric arcs which might ignite an explosive mixture of gas, fumes, vapor, or dust with air. (For details on Shop Lighting, see Safe Practices Pamphlet No. 22.)

8. Men continually handling acids and caustics should be encouraged to change their clothes and take a bath before leaving the job at the end of each shift. In some companies a double compartment locker is assigned to each man; one compartment to contain work clothes, the other street clothes. In locating lunch rooms it is well to have the workers enter through a washroom so they can wash all chemicals from their hands and faces before eating.

9. Many employers consider it important to post signs printed in languages readily understood by the workers, warning them of the dangerous properties of the different substances used. Others publish pamphlets to accomplish this purpose, making sure that new employees read and understand them before starting work.

10. The treatment of chemical injuries should be left wholly to the physician in charge. When the services of a physician are not immediately available a worker's life may depend upon prompt administration of first aid so that first-aid remedies together with instructions for their use, should always be readily available. Some one person should be made responsible for the quality and quantity of remedies kept in work-rooms and first-aid stations, and at least one person trained in rendering first-aid should be immediately available at all times.

11. For all chemical burns, physicians recommend the immediate use of clean water in large quantities, until the chemical has been diluted and washed from the skin surface. It may be advisable to maintain the water supply at comfortable bath temperature. Even substances that are insoluble in water may be mechanically removed from the skin surface by flushing and water helps to reduce the temperature of the chemical action.

12. Many employers have installed safety shower baths in or adjacent to each workroom, under which a man may stand and be deluged with water in cases of chemical burn. (See Figure 4.) The water supply should be ample and positive and all safety showers should be equipped with quick opening valves. Probably the most desirable type of safety shower is one in which the quick opening valve is connected to a platform located directly underneath the shower head. As soon as a man steps on the platform the shower operates, thus leaving the man free to use both hands to quickly remove his clothing. Safety showers should be protected against frost and should be tested daily. In locations where showers cannot be provided a flexible water hose or several buckets of clean water may be substituted.

13. In applying water an effort should be made to remove the clothing from the burned area before or during the application of water. If this is impossible, the water should be quickly directed inside the clothing, for if the skin is being burned by a chemical which reaches it after saturating the clothing, and water is applied on the outside, the resulting heat may be intensified before sufficient water can enter to dilute it or wash it away.

14. Many photo-engravers, electroplaters, and tanners smear their arms with a special ointment made of three-parts petrolatum and one part lanolin. (Lanolin is another name for sheep's-wool grease). This will, to some extent, prevent the corrosive action of the weaker acid and caustic solutions. Another popular ointment contains equal parts of calamine and boric acid. Still another is composed of pine tar and fish oil.

15. The action of most acids and caustics on the eyes is very rapid and may cause blindness unless washing with water is done immediately. Directing a moderate jet of water into the opened eyes from a small flexible hose is very effective. Other methods are to plunge the head into a vessel of clean water and wink the eyes rapidly, or to allow the water from a bubbler drinking fountain to flow into and flush out the eyes.

16. Sometimes large bottles of counteracting solutions are placed on special racks in the workrooms, but the best authorities generally agree that

Courtesy Calco Chemical Division American Cyanamid Co.

Figure 3. A safe type carboy truck with bottom support, top locking fork and pneumatic tires. Also note the goggles, rubber apron, rubber gloves, and rubber boots on worker. (See paragaphs 4 and 47.)

using plenty of clean water is better than trying to use neutralizers. Neutralizers if used at all, should be applied after irrigation with water, and then only under the doctor's orders.

17. *First-aid for chemical burns. (Except eye burns.)* The following procedures are recommended by some doctors:

a) For acid burns—nitric, sulphuric, mixed, hydrochloric, acetic, oxalic and picric (for oleum, first wipe off oleum with a clean cloth) — bathe freely with water and apply a saturated solution of bicarbonate of soda.

b) For alkali burns—caustic potash, caustic soda, ammonia, lime, and soda ash—bathe freely with water and then apply a 2 per cent solution of acetic acid.

c) For hydrofluoric acid burns — bathe freely with water and then with dilute ammonia water.

d) For carbolic acid burns — wash at once with water, then with grain alcohol or sodium sulphate.

e) For hydrocyanic acid burns—wash with water, then immediately drop on the burn either ammonium polysulphide or a solution of potassium permanganate.

Courtesy E. I. du Pont de Nemours Co.

Figure 4. Shower bath for chemical workers. Shower is 6½ feet above standing level. The supply line is equipped with a quick-opening valve below the frost line. This valve is operated by a small rod extending three feet above ground, with the end turned to form a handle. (See paragraphs 11, 12 and 13.)

(For additional data on "Chemical Burns," see the Council's Pamphlet No. Chem. 3.)

Fumes

18. Certain acids give off fumes or vapors that are dangerously poisonous, anaesthetic, or corrosive to respiratory tract and lung tissues. Such fumes may also burn the skin of workers' faces, hands and arms. Precautions should, therefore, be taken to prevent the fume poisoning and burning of operators by removing the fumes at their source or by providing the workers with suitable protective devices.

19. Most dangerous acid fumes give some warning of their presence. One exceedingly serious feature of fume poisoning is that the effects do not always follow promptly upon the exposure, and a man may be in danger of his life without being aware of it. Some workers who are exposed to acid fumes believe themselves to be immune, and attribute their supposed immunity to experience or to a superior constitution. This belief, however, is utterly without foundation. Fatal fume poisoning may follow an exposure that does not appear to be particularly more severe nor worse than the same man has undergone repeatedly on other occasions without apparent ill effects.

20. It is essential to maintain high grade medical supervision in every company where hazardous concentrations of chemicals are used. In such companies it is good practice to examine physically all workers before they are accepted for employment, to make sure they have no pre-disposing defects that will make them especially liable to sickness or injury from acids or caustics. It is also advisable to re-examine the men at regular intervals to determine what effect the work is having upon their health.

21. In an emergency, when a man is caught in an atmosphere charged with chemical fumes, he should try to refrain from breathing until he reaches relatively pure air. If breathing cannot be avoided it should be limited to short shallow breaths. The fumes will then come into contact only with the upper air passages and a comparatively small part of the lung tissues.

22. Special respirators will often afford protection against fume poisoning. Simple mechanical filter respirators containing cotton, flannel, muslin or other similar substances, should not be used for protection against fumes. Respirators with metal fittings are also to be avoided because they can be quickly rendered ineffective due to the corrosive action of acids and alkalis.

Figure 5. For maximum safety while working inside acid tanks, this worker is equipped with a supplied-air respirator, lift belt and line. (See paragraph 24.)

23. Chemical filter respirators are often used to protect against fume poisoning. Care must be exercised, however, to make sure that respirators containing proper chemicals are available, for no one chemical will afford protection against all types of fumes. Furthermore, chemical respirators do not supply oxygen other than that which is filtered through from the atmosphere in which the worker is located. In other words, they furnish no protection where there is a material deficiency of oxygen.

24. Rooms, tanks, or vats that contain or have contained noxious fumes or vapors should be thoroughly cleaned before men are permitted to enter them. In some cases continuous ventilation should be provided. In addition such workers should be provided with supplied-air respirators. Equipped with such respirators the workers breathe fresh air supplied from an outside source. (See Figure 5.) When selecting a man for work in a tank, a thin or medium-built man of light weight should be chosen. He should have a life belt securely fastened about his body. To this should be attached a life line

Figure 6. Although this tank has been cleaned and purged of gas, the workmen are equipped for any emergency. (See paragraphs 24 and 40.)

or rope securely tied outside and attended by two workers who will be able to render assistance in an emergency. (See Figures 5 and 6.) When the work is completed, the man should immediately take a bath and change his clothing. This will minimize the danger of burns that may result from the corrosive action of chemical fumes on the skin. In some companies a light steel chain is used instead of rope, inasmuch as it is more resistant to the corrosive action of various chemicals, although acid-proof belts are available. For detailed data on respirators see Safe Practices Pamphlet No. 64, "Respiratory Protective Equipment."

25. To prevent fume poisoning the first consideration should be to eliminate all fumes by suitable ventilation or through the installation of an adequate exhaust system. In some cases proper ventilation may be secured through vents in the roof so arranged that they can be kept open even when it rains. This may give satisfaction in eliminating fumes that are lighter than air; and it may even be of considerable value in carrying off fumes that are heavier than air. A further precaution is to introduce warm, dry air at the floor level. This rises and tends to take with it many vapors that are heavier than air. Natural draft hoods or fresh-air fans are often successful, but the surest way is to install suction or exhaust fans with suitable hoods, ducts and other necessary accessories. (For additional data see the Safe Practices Pamphlet No. 32, "Exhaust Systems.")

26. In cases where dense fumes may be evolved suddenly it is difficult to insure adequate ventilation. It is then essential that the workers be able to gain quick access to the outer air. To accomplish this, numerous exits may be provided, leading to galleries or platforms constructed on the outside of the building on a level with the floors. Sliding poles may also be installed, similar to those used in fire engine houses, by which workers may quickly descend to another level where the air is clear. In addition one manufacturer has installed a large electric motor fitted with an aeroplane propeller. This fan creates an enormous draft of air, capable of clearing away the heaviest fumes in about one minute.

27. *First-Aid for Fume Poisoning.* The victim of fume poisoning should be taken at once to an atmosphere free from fumes and if breathing has stopped *artificial respiration should be started* without delay. The usual first aid treatment for shock should be given and, if conscious, the patient should be given water to wash out his mouth. He should also be encouraged to drink water. Call a doctor immediately but if one cannot be obtained arrange to get the victim to a hospital as soon as possible. Some doctors authorize the following additional first aid procedures:

a) For persons who have inhaled acid fumes or vapors — nitric, sulphuric, mixed, hydrofluoric, hydrochloric—mix fifteen drops of chloroform in a glass of water with a tablespoon of aromatic spirits of ammonia. This mixture should be administered to the patient a little at a time so that he takes the whole glassful in thirty minutes to an hour.

b) For persons who have inhaled ammonia—frequently add cold compresses and aqueous solutions of boric acid to the eyes.

c) For persons who have inhaled hydrocyanic acid fumes or vapors—allow victim to inhale the contents of one amyl nitrite pearl; repeat in 15 minutes. (See Safe Practices Pamphlet No. Chem-6, "Cyanide Compounds.")

Internal poisoning

28. When acids or caustic alkalis are taken internally antidotes should be taken into the stomach at once. A doctor should be summoned immediately and he should be informed that he will need a stomach pump. The general rule of inducing vomiting in internal poisoning cases should not be followed when acids or alkalis are involved. The following specific first-aid procedures are recommended by some doctors:

First-aid for internal poisoning by acids and alkalis:

a) For persons who have swallowed acids—sulphuric, nitric, hydrochloric, mixed, hydrofluoric, oxalic, picric and acetic—give powdered chalk or magnesia with a large quantity of water, or give baking soda, soap or wood ashes with milk, olive oil, or white of an egg in water.

b) For persons who have swallowed alkalis—caustic potash, soda ash, ammonia, caustic soda, and lime—give water freely, with vinegar, citric acid, cider, orange or lime juice; follow with milk, barely water or white of an egg in water.

c) For persons who have swallowed carbolic acid—give a tablespoonful of Epsom or Glauber's salts in a cup of warm water; follow with the white of egg and water.

d) For persons who have swallowed hydrocyanic acid—make victim vomit by causing him to drink quantities of warm tepid water, or soap and water solution, or mustard and water.

Fires

29. Certain acids and caustics, by their chemical action on animal and vegetable substances, develop sufficient heat to set fire to clothing, straw, wood, and other combustible material. In extinguishing a fire caused by chemical action, it is generally best to cover the fire with loose dirt or sand. If a worker's clothing is afire, wrap him in a

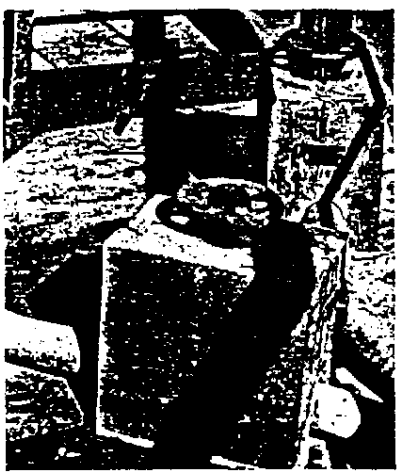


Figure 7. Sheet metal enclosed acid pipe line valves. (See paragraph 34.)

woolen blanket. Water or chemical extinguishers may put out the fire but they may increase the fumes to such an extent that they become more dangerous than the fire. Special instructions should be given company fire brigades and other workers who may be called upon to extinguish fires that involve specific chemicals.

Explosions

30. A frequently overlooked property of strong acids is that they can, under certain conditions, generate explosive gases. In their action on metals, for example, they may liberate hydrogen and thus may produce explosive mixtures which can be ignited by flame or spark. This applies to tanks, drums, pipe lines, spills on the floor or equipment, and vent lines from acid storage tanks.

31. If two different chemicals are mixed, there is always a possibility of trouble. Notable examples are mixtures of strong acids and strong oxidizing agents that may produce reaction products which may explode with considerable violence; also toxic gases may be created if acid is mixed with such chemicals as sulfides, cyanides, ferricyanides, nitrates, and nitrites. Supervisors should make sure that chemicals are so stored and handled that unsafe mixtures will not be created. In diluting an acid with water considerable heat is generated; the acid should always be added to the water, not the water to the acid. The acid should be added slowly, and the mixture should be stirred constantly.

Shipping and storing

32. Shippers of chemicals should be careful to observe the shipping regulations of the Interstate Commerce Commission and of the Bureau of Explosives. Most acids are shipped or stored in one of four different ways:

a) Tank cars

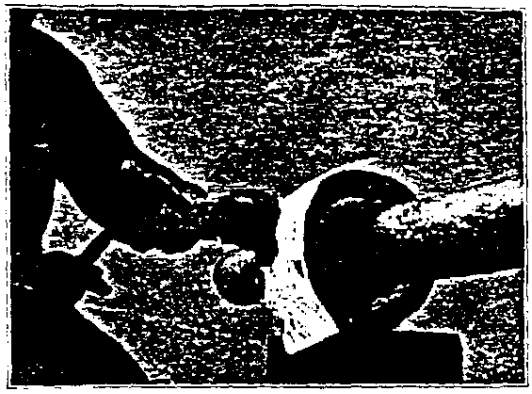
b) Metal drums and rubber lined metal containers

c) Boxed glass and earthenware carboys and unboxed aluminum carboys

d) Small jugs or bottles in wooden boxes

Storage

33. When a new shipment of acids is received, it is well to open the containers at once to relieve any internal pressure which may have developed. The workers who are called on to do this should first equip themselves with the proper personal protective devices, non-sparking tools, and then perform the job with considerable care. These precautions will greatly minimize the danger of burns in case the internal pressure causes some of the liquid to spurt out. If necessary, some of the contents should be removed. This will safely care for ordinary extremes in temperature. After this is done the containers should again be sealed. In many plants it is customary to open each container once a week thereafter. Small containers should not be exposed to the direct rays of the sun for any great length of time; it is best to store them in a cool place. In some plants new incoming shipments are transferred to cool storage rooms without delay and in such cases the containers are not opened until the acid is to be used. Where this is done the decrease in temperature will generally be sufficient to relieve internal pressure in the containers. Except when the contents are being drawn off, all containers should be tightly closed. This will prevent fume leakage and will to some extent stop any corrosive action the chemical may have on the container.



Courtesy E. I. du Pont de Nemours Co.

Figure 8. Lead shield and wedge for opening flange of acid line. (See paragraph 34.)

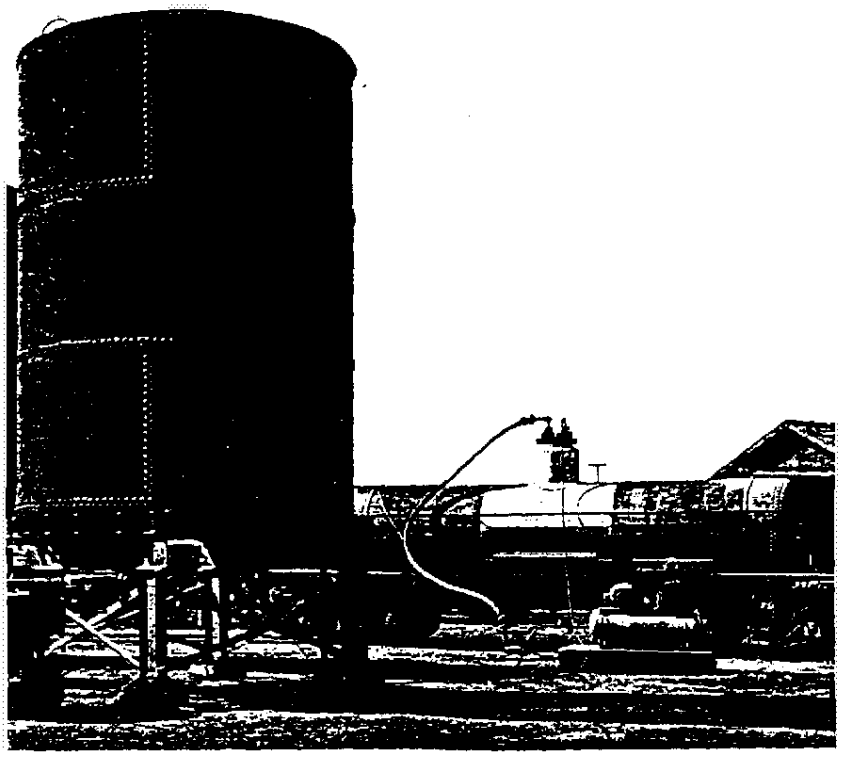
Tanks and vats

34. Acid storage tanks should be placed on concrete foundations and arranged to permit access for complete inspection. The liquid is usually moved to various points in the plant through pipe-lines and centrifugal pumps. All acid-pipe-lines, joints, valves, connections, tanks, and other containers should be regularly inspected and leaks should be repaired at once. In some companies all acid valves are fitted with sheet metal shields. (See Figure 7.) Before starting a repair job, the acid valves (and air valves, if air is used) should be closed and locked, the pipe or container drained, and forced ventilation applied to remove all gases. In some cases, especially if a cutting or welding torch is to be used, the pipe or container may be completely filled with water or with a neutralizing alkali before the repair job is started. Otherwise the flame may cause an explosion. (See Paragraph 30.) In opening an acid line the above directions should be followed and then a lead shield laid over the flanges to protect the operator in case the acid spurts. The two bottom bolts of the flanges are removed and the remaining bolts loosened gently until the acid starts to drip. If the flanges do not part readily, use a small wedge which may be made from a forty-penny wire spike ground to a chisel point. The lead shield has a hole large enough to admit the wedge. (See Figure 8.)

35. Every tank that is used for the storage of chemicals should be so installed as to minimize the danger in case the tank should rupture and the contents escape. The tank should be supported in such a way that leakage from any part of it would be noticed immediately, and it should be covered, externally, with a suitable protective paint that will prevent corrosion from moisture, fumes and other causes. It is also wise to surround the tank with a pit, catch basin or depression of some kind, large enough to hold the entire contents of the tank in case of rupture. This will not prevent the formation of fumes but will at least localize the liquid and prevent it from flowing into workrooms and other places where it would be dangerous.

36. Several companies have called attention to the need for providing overflow pipes for tanks that are used to store liquid acids and caustics. In some plants a flow indicator is installed in each overflow line and so arranged that it automatically shuts off the pump as soon as any liquid starts to overflow.

37. All open tanks or vats should be installed in such a way as will insure employees from falling into them. It is



Courtesy Western Electric Co.

Figure 9. Acid being pumped from tank car into storage tank. (See paragraph 38.)

advisable to build the top of each vat to a height not less than 30 inches from the floor or standing level; otherwise a double handrail, at least 30 inches high, and (if top of tank or vat is flush with or below the level of the floor) a six-inch toeboard should surround such a vat. Walkways should not cross over open vats or tanks, but where their construction is absolutely necessary, they should be equipped with substantial handrails and toeboards. All handrails and toeboards should be inspected at regular and frequent intervals to make sure that nails and other parts have not been weakened by exposure to chemicals or to chemical fumes.

38. The manufacturers of liquid chemicals specifically warn their customers not to use compressed air in emptying portable acid containers, such as carboys, metal drums, and similar returnable containers. It is essential that this recommendation be followed if accidents due to bursting containers are to be avoided. However, acid tank cars may be emptied by means of compressed air in accordance with I.C.C. regulations 103A and 103B. The air line should be equipped with a pressure gage, a pressure reducing valve and a safety valve set to blow off at a pressure under the specified maximum which, in the case of tank cars, is 30 lbs. per sq. inch. (See Figure 9.)

39. After being emptied, returnable acid containers should never be washed or cleaned by customers unless the manufacturer or shipper makes a request to the contrary. When cleaning is necessary it is not sufficient to merely wash out an empty container with water. To remove fumes and remaining particles of acid the container, after being washed thoroughly with plenty of water, should be cleansed further with high pressure steam introduced by means of a hose. The hose should be directed against every part of the surface of the open tank just as though the metal were being washed with a stream of water. Care should be exercised in handling a steam hose to prevent the scalding of operators and fellow-workers.

40. Some companies prefer to wash out acid containers first with water and then with a neutralizing alkaline solution. In using this method remember to give the container a final washing with water. Furthermore, when workers enter tanks or vats they should be provided with supplied-air respirators, life belts and life lines as suggested in paragraph 24. Special care must be exercised when entering a tank that has been lined or patched. Acid may be trapped back of the patch or lining so even the best cleaning procedure will not remove it. When any possible pocket is opened, it should be cleaned thoroughly; otherwise gas or fumes may be generated as the work progresses.

Drums and carboys

41. Drums of steel, chrome nickel, aluminum, and steel drums with lead and rubber linings of size up to 110 gallons are used for transporting up to 1800 pounds net weight of chemicals. It is recommended that the gross weight of any of these packages be limited to approximately 1000 pounds, and in many instances this would limit the size to 55 gallons. They are best handled by rolling on the hoops. They should be emptied by gravity or siphoned; never emptied by use of air pressure.

42. Carboys are generally glass or earthenware bottles or jugs of 5 to 13 gallons capacity. They weigh from 80 to 270 pounds gross when filled. They should be encased singly in wooden boxes complying with specifications 1A or 1C as prescribed by the Interstate Commerce Commission. They should be carefully cushioned to prevent breakage. Excelsior and similar substances should not be used if the carboy contains nitric acid. Closures for carboys containing chemically pure mineral acids and ammonia consist of unvented ground glass stoppers. All other carboy closures should be porous, earthenware or vented glass stoppers held in place preferably by suitable wires. Containers of similar capacity made of lead are also classed as carboys; cushioning is not required; stoppers should be of rubber or lead carefully secured to prevent leakage. Maintenance of these packages in good condition is essential to safety.

43. The bottom or sides of the box may give way suddenly, due to the corrosion of the nails or weakening of the wood by acid. Some acid manufacturers now use wood preservative and special nails which they claim prolong the life of their boxes from 200 to 300 per cent. To prevent unnecessary corrosion carboys should not be stored in damp places or in open yards exposed to the

weather. It is advisable to use a separate storeroom or building, the walls and floors of which are made of silicate-treated concrete or brick, properly drained to the sewer or to a catch basin.

44. Boxed carboys when placed on the floor should rest on wooden strips; then in case of breakage, the liberated acid will not come in contact with the nails in the boxes containing the carboys.

45. On account of the liability of glass to crack, sudden changes of temperature should be avoided as far as possible. Neither chemicals nor chemical containers should be placed near steam pipes, nor where the direct rays of the sun will strike them.

46. Carboys are fragile, and if broken, fire or explosion may result; also there is always danger that acid will spatter on the hands, face and body of the person handling them. Care should be exercised in handling carboys, that they are not dropped, unduly shaken, nor struck by other objects. They should never be moved unless securely stoppered and wired.

47. Mechanical appliances for handling carboys are nearly all economical and much safer than the simple picking up of a carboy by one or two men. The choice and the successful use of conveyors, roller-skids, derricks with ice tong grips, and various forms of trucks depend upon plant arrangement and the intelligence of the workers. It is impracticable as well as unsafe to use an ordinary warehouse truck because there is no means of securely holding the carboy in place. A better type of truck has a fork attachment, one prong of which passes on each side of the carboy box and beneath the side cleats. Another desirable type supports the container from the bottom and has a locking fork on top. (See Figure 2.) These trucks can be run in between carboys that are placed close together and can be manipulated by one man.

48. Eight methods have been utilized for removing acid from carboys:

a) Mechanical pump
b) Pipette
c) Siphon
d) Ejector
e) Inclinator
f) Pouring by hand (not desirable)
g) Manually-operated air pump (not desirable)
h) Compressed air (should not be used)

49. Mechanical pumps are usually of revolving gear type rather than the reciprocating plunger. Such pumps need frequent priming, and this operation presents the greatest hazard. A small supply of priming acid must be kept on hand in another container which should be safely located, covered, and plainly marked. Furthermore, the operator must be careful not to spill acid when priming the pump. Acid pumps that require priming are not recommended.

50. Pipettes and so called glass thiefs are frequently used—particularly by laboratory chemists and samplers—to remove small quantities of acid from carboys. In many plants, drawing acid up into the pipette by mouth suction is prohibited; a suction bottle or hand bulb should be used for this purpose. Care must be exercised to avoid breaking the pipette, and to maintain a good vacuum within the pipette until the chemist empties it.

51. Siphons are operated by removing the air from the exit pipe or hose; then the ordinary pressure of the atmosphere bearing on the surface of the acid forces the liquid through the exit pipe as long as both ends of the exit pipe are lower than the level of acid in the carboy. No one should ever be permitted to apply his lips to the exit pipe to remove air from the line; a suction bottle or rubber hand bulb should be used. (See Figure 10.)

52. Ejectors are operated by blowing compressed air through the exit pipe; this creates a suction which draws acid out of the carboy in a steady stream. The air valve should be of the self-enclosing type, and it should be located as far as practicable from the carboy and the exit pipe. Also, the air hose should be secured to the building structure or to other fixtures, so that in case the hose breaks or becomes disconnected, the escaping air will not strike the surface of the acid and splash it on nearby workers. Ejectors are not considered as safe as many other types of equipment for emptying carboys.

53. The safest types of inclinators are those which hold the carboy boxes on top as well as on all four sides; which operate without the expenditure of undue effort; which automatically return to neutral from the pouring position in case the operator loses control of the device; which permit enough motion so all of the acid may be poured out in a smooth, steady stream; and which can be locked in the neutral position to prevent use by unauthorized persons. A splash shield should be attached to the carboy to protect the worker, who should be instructed to operate the inclinator with a slow, steady motion. When pouring acid from a carboy, the man should be instructed to stand to one side, not in front of the acid stream. (See Figure 11.)

Figure 10. Syphon being used to obtain a small quantity of acid from a carboy. (See paragraphs 51 and 57.)

54. Pouring by hand is unsafe and should be prohibited. A worker may subject himself to severe strain in lifting and balancing a carboy on edge. Furthermore, if the worker were to lose his hold on the carboy, the acid might splash or pour out, possibly causing injury to himself and others.

55. When manually operated air pumps are used, air is forced into the top of the carboy, and this pressure causes acid to flow out of the exit pipe or hose. Pumps are of various types; some operate like a bellows, others like a bicycle pump. If the acid does not start to flow after a few strokes of the pump, the reason should be ascertained and corrected before further attempt is made to remove the acid. The exit pipe should be examined at regular and frequent intervals to make sure it is not clogged. If this pipe were to become

Figure 11. A safe type inclinator being properly used. (See paragraph 53.)

clogged, excessive pressure might be built up in the carboy, resulting in rupture. Air pumps should never be power-operated, as there is too much danger of building up excessive pressure within the carboy. The use of hand-operated air pumps for emptying carboys is not recommended.

56. Air from compressor lines should never be introduced into carboys. Carboys are not constructed to withstand air pressure, and rupture of such containers might have serious results.

57. Workers should be cautioned to drain all acid from siphons, pumps, and other emptying devices before entirely removing them from carboys. Furthermore, such devices frequently leave a small amount of acid in the carboy. As soon as they are emptied, carboys should be washed out by turning them upside down over an upward stream of water.

Small jugs

58. Some operators require only small amounts of acid, sometimes less than a carboy. In such cases, and when carrying samples of liquid chemicals from one department to another, the principal danger lies in accidentally breaking or upsetting the vessel containing the acid. To overcome this hazard a small jug loosely fitted into a fiber or sheet metal cylinder and packed therein with a tar composition or some other pliable material should be used. If a number of bottles are frequently handled together they should be placed in a carrier having individual compartments and a strong carrying handle. (See Figure 12.)

Nitric Acid

59. Nitric acid (HNO_3) is a fuming, corrosive liquid, sometimes called "aqua fortis," varying from colorless to red, according to its purity. It dissolves or attacks practically all metals except gold, aluminum and platinum and is, therefore, usually shipped in glass or aluminum containers. Recently special chrome-iron alloys have been developed which resist the corrosive action of nitric acid, and vessels made of such materials are used extensively in handling and transporting very strong nitric acid. Nitric acid eats through clothing, chars wood, causes serious wounds when in contact with the skin, and may cause blindness if splashed into the eyes. When exposed to the air it gives off nitrous fumes, varying from colorless to orange-yellow, which are extremely poisonous if breathed into the lungs. This liberation of gas is particularly troublesome if the acid happens to spill on wood or other organic matter. Nitric acid is poisonous if taken internally. It is likely to cause a fire if it leaks onto wood, straw, and many other organic materials, and it forms powerful explosives if combined with glycerine, carbolic acid, and many other substances. Nitric acid is used commercially in all nitrating processes, in the manufacture of explosives, and in pickling processes where metal is cleaned, in dyeing, printing, engraving, and electro-plating.

Sulphuric Acid

60. Sulphuric acid (H_2SO_4) is a heavy, oily, corrosive liquid, and is known by a number of commercial names, such as oil of vitriol, fuming acid, glover acid, battery acid, chamber acid, and oleum. It varies from colorless to blackish according to its purity. It dissolves almost all metals. In the weak state it rapidly dissolves steel; therefore, weak sulphuric acid is usually handled and stored in lead or rubber-lined containers. Above 66 degrees Baumé the action of sulphuric acid when cold is extremely slow on steel. Sulphuric acid eats through clothing, chars wood, and causes severe burns when splashed onto the skin or into the eyes. When exposed to the air, oleum and fuming sulphuric acid give off sulphuric acid fumes that have a pungent odor and are suffocating in effect. Sulphuric acid is poisonous if taken internally. It is likely to cause fire when in contact with combustible materials and can generate explosive mixtures as described in paragraph 30. It readily absorbs moisture from the air and from many materials with which it may come in contact. Containers, therefore, should be airtight to prevent dilution in which state the acid mixture is highly corrosive and capable of attacking and rapidly dissolving metal containers. Commercially, sulphuric acid has many uses; in pickling iron, steel, and other metals; in making artificial dyes; in the manufacture of hats, explosives, wood pulp, and paper; in petroleum distillation; in fertilizer plants; in bleaching and tanning; in glue, gelatine and candle-making industries. Sulphuric acid is used in soda-acid chemical fire extinguishers.

Mixed Acid

61. Mixed acid is a mixture of concentrated nitric and strong sulphuric acids. It is similar to nitric acid in appearance and physical properties, in its action on the skin, eyes, and clothing, in giving off poisonous nitrous fumes, and in its ability to start fires and cause explosions. In its action on metals, however, it is similar to sulphuric acid and can be shipped in steel or lined containers. Cast iron containers and fittings are not suitable for mixed acid, because failures occur as a result of the penetration of acid into the pores of the metal where sulphate of iron is formed. This may cause expansion and ultimate failure of the casting. Mixed acid is poisonous if taken internally. It is valuable because of its nitric acid content and because it has many of the commercial uses of nitric acid. It has, however, one advantage over plain nitric acid in many chemical processes, for the sulphuric acid present absorbs much of the water that is formed, and the nitric acid therefore continues its nitrating action efficiently.

Hydrochloric Acid

62. Hydrochloric or muriatic acid (HCl) is a colorless gas of pungent, irritating odor. It is readily dissolved in water, and it is the acid solution that is used commercially. This solution attacks almost all metals except gold and platinum and is, therefore, usually shipped in glass carboys or in tank cars

provided with acid-proof lining. It is neither combustible nor a supporter of combustion although by its action on metals it can create explosive mixtures as described in paragraph 30. It causes severe burns when splashed into the eyes or onto the skin and rapidly eats through clothing. The acid in gaseous form or the fumes given off from an acid solution, are suffocating and irritating when breathed into the lungs. The gas or fumes also produce a caustic effect on the tongue and cause ulcerations of the nasal wall. The acid solution is poisonous if swallowed. Commercially, hydrochloric acid is used in pickling iron, in bleaching, galvanizing, soldering, enameling, in making artificial fertilizers, in cotton print works, and in metal plating operations.

Hydrofluoric Acid

63. Hydrofluoric acid (HF), also called hydrogen fluoride, is a corrosive, colorless gas easily dissolved in water. For industrial use it is usually in the form of a water solution commonly known as etching or fluoric acid. Because of its action on glass and all metals except gold, platinum, and lead, the solution is shipped in containers of rubber, lead, wood, paraffin, wax, gutta percha, or steel. It eats through clothing, causes serious burns when in contact with the skin or eyes, and in vapor form is poisonous if breathed into the lungs. It may cause particularly severe burns around the finger nails. Such burns are not immediately manifested, but later they may become very painful. Hydrofluoric acid is not likely to cause fires, and is explosive only as described in paragraph 30. Because it so rapidly attacks glass, hydrofluoric acid is used principally in the manufacture of etched and cut glass. It is also employed in the manufacture of pottery for cleaning sandstone and marble buildings or monuments and as an insecticide. It is popular for use in pickling processes, for while other acids exert a cleaning effect by eating away a thin outer layer of metal, hydrofluoric acid, at strengths used for this purpose, eats away only the dirt and cleans the outside surface without eating into the metal.

Carbolic Acid

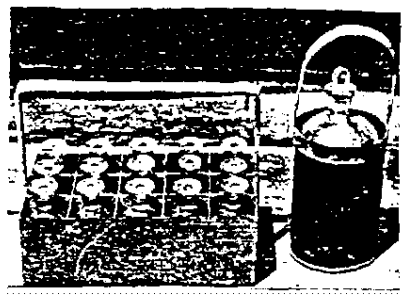
64. Carbolic acid (C_6H_5OH), frequently called phenol, is a crystalline solid of characteristic odor, easily soluble in water and varying from colorless to red, depending upon the amount of impurities present. It has no marked action on metals, but rapidly attacks the flesh and eyes and is highly poisonous if swallowed. The vapor or fumes from carbolic acid are poisonous if breathed into the lungs. The acid is not flammable at ordinary temperatures. It is a disinfectant and unites with animal substances, preserving them from decomposition. It has extensive medicinal and antiseptic uses and is employed in calico printing, in aniline color and other dyeing industries.

Oxalic Acid

65. Oxalic acid ($C_2H_2O_4$) is a colorless and odorless crystalline solid, sometimes mistaken for lump sugar. Crystalline oxalic acid is not dangerous except when swallowed. In solution it has a weak action on metals and slightly corrodes the skin; it turns the finger nails bluish and makes them brittle. It is poisonous if taken internally, and the dust is poisonous if breathed into the lungs. It is neither explosive nor flammable. Its bleaching properties and ability to dissolve metallic oxides or rust make it useful to dyers, cleaners, workers in marble, makers of straw hats and leather workers, and for polishing brass, copper and other metals.

Picric Acid

66. Picric acid C_6H_2 (OH) $(NO_2)_3$, or trinitrophenol, is a pale yellow, bitter-tasting metallic, crystalline solid. It is highly explosive, particularly when it is dry; thus it is usually moistened with at least 10 per cent of water before being handled or stored. Great care must be exercised in handling it. It should never be brought into contact with metal, since it combines to form metallic picrates which are highly explosive. It stains the skin. The dust is poisonous if breathed, and death may result if the acid is swallowed. Commercially, picric acid is mixed with at least 10 per cent water and is usually packed in waterproof wooden boxes or barrels. It is used extensively in chemical works and in dye houses. Any spill of picric acid should be washed down immediately. Furthermore, a definite routine procedure should be established for the safe disposal of empty picric acid containers. Usually they are trucked to a dump and burned the day they are emptied.



Courtesy Calco Chemical Division American Cyanamid Co.

Figure 12. Two types of containers for carrying small quantities of acid. (See paragraph 58.)

Acetic Acid

67. Acetic acid ($C_2H_4O_2$), or glacial acetic acid, is a clear, colorless liquid, of penetrating odor and sharp taste. It has no marked action on most metals but is usually shipped in wooden barrels, stoneware jugs, aluminum and glass carboys. Strong acetic acid burns the skin quickly, raising blisters, and is injurious to the eyes. When exposed to the air, especially when the acid is heated, vapor is given off that is not only dangerous if breathed into the lungs, but may also be flammable and explosive. It is poisonous when swallowed in concentrated form. It is used principally in calico printing and dyeing, in varnish mixing, and in vinegar plants.

Hydrocyanic Acid

68. Hydrocyanic acid (HCN), or prussic acid, is a colorless, transparent liquid of penetrating odor resembling that of peach kernels. It is volatile and boils at 80 degrees F. It is used extensively in industry, particularly in combination with such bodies as potassium, sodium, zinc, silver or ammonium. These combinations or salts, called cyanides, give off hydrocyanic acid vapor which, unlike most acid vapors does not irritate the breathing organs, but if inhaled, is absorbed into the blood and may cause instant death. Cyanides are poisonous if swallowed, or if allowed to come into contact with the skin. One way to prevent absorption into the skin of the hands is to bathe the hands in a hot solution of concentrated salt water once or twice a day. Hydrocyanic acid vapor is explosive if mixed with air in certain proportions. Cyanides are used in photography and electro-plating, in the gilding of metal, in recovering gold

from its ores, in making dyes, in fumigation work, and in tempering and hardening metals.

Ammonia

69. Ammonia (NH_3) is a colorless gas of pungent, characteristic odor. It liquefies under pressure and is soluble in water. Both the liquefied gas and the water solution are used in industry. The liquefied gas is usually shipped in steel cylinders under a pressure of about 150 pounds per square inch. Ammonia gas is explosive at ordinary temperatures and pressures when mixed with air in concentrations of 16 to 27 per cent by volume, but its explosive properties, under these conditions, are mild as compared, for example, with gasoline vapor and air. At higher temperatures and pressures it can explode with great violence. It is employed in refrigerating systems, in the manufacture of soda and artificial ice, and in the preparation of indigo, lacquers, and colors. The solution of the gas in water is the most common industrial form. It is then known as ammonium hydroxide, aqua ammonia, or ammonia water. In this form it is usually shipped in carboys or drums. It has many household uses and is employed in laundries and in bleaching and dyeing plants. When liquid ammonia solution is exposed to the air suffocating fumes are given off that are harmful to the eyes and breathing organs. Ammonia rapidly attacks the skin and is poisonous if swallowed in solution. Suitable respiratory protection is needed if even small concentrations of ammonia fumes are to be encountered. (See Safe Practices Pamphlet No. 64 "Respiratory Protective Equipment.")

Caustic Soda

70. Caustic soda (NaOH) — called sodium hydrate, sodium hydroxide, or concentrated lye—is a brittle white solid which, if exposed to the air, first liquefies, then absorbs carbonic acid gas from the atmosphere, and finally solidifies in a whitish powder. It dissolves freely in water with the evolution of great heat. When making a solution, add the caustic soda to the water slowly and stir continuously while doing so. It is best not to apply heat until all of the caustic has dissolved. Caustic soda is the most dangerous of all alkalis to handle, for in any form it quickly attacks the flesh and eyes, and also clothing and leather. It does not give off fumes but is deadly if swallowed. In solid form it has no marked action on metals and is therefore shipped in thin sheet-iron drums about two feet in diameter and three feet high. Large quantities are shipped in liquid form in tank cars having special linings. These linings, consisting of special paints, resins or metallic nickel, are necessary because caustic soda solutions attack iron and steel. Sometimes caustic soda can be purchased in granulated form, but usually the drums are filled with molten caustic soda which soon hardens into a solid mass. Unpacking or emptying containers is dangerous and difficult. As there is danger of exposure to flying particles or to caustic soda dust, workmen should wear goggles and respirators or caustic-proof hoods. Rubber gloves, rubber aprons, wooden clogs, and rubber puttees complete the personal equipment. Many consumers use large hammers on the iron drums and break the contents while still in the container. After this the drums are opened and the pieces handled with a shovel. If the entire contents of the drum can be used at one time, it is often desirable to use a sharp chisel to cut rough gashes into the sides and ends of the drum. It may then be lowered into the solution tank, and when the caustic soda has been dissolved, the empty drum is removed. Caustic soda is neither flammable nor explosive. It is used extensively in the manufacture of soap, in tanning leather, in the rayon and petroleum industries and in many metal cleaning processes.

Caustic Potash

71. Caustic potash, potassium hydrate, or potassium hydroxide (KOH) is a brittle grayish-white solid. When exposed to the air, it rapidly becomes liquid by the absorption of moisture. It is similar in most respects to caustic soda. For further particulars see paragraph 70.

Soda Ash

72. Soda ash (Na_2CO_3)—the basic material for making sal soda, washing soda, sodium carbonate—is a white finely crystallized powder. It has no marked action on the flesh or clothing, or on metals, and is usually shipped in barrels, burlap bags or paper boxes. It is slightly caustic to the eye, or if swallowed, or if the dust is breathed into the lungs. It is used extensively to soften water, in washing and cleaning, and in the manufacture of glass, soap and paper. Workers exposed to soda ash dust should wear goggles and suitable respiratory protection.

Lime

73. Lime (quicklime, caustic lime or calcium oxide)—CaO—is a white solid formed by burning limestone. It should be stored in a dry room, preferably above ground, for if exposed to dampness or moistened with water, it forms slaked lime—calcium hydrate $Ca(OH)_2$—and may evolve sufficient heat to ignite combustible material in contact with it. Neither lime nor slaked lime has any marked action on iron, but both burn the flesh and the eyes and are caustic if swallowed. Lime is used in making mortar, fertilizers, and candles, in tanning leather and in many bleaching processes. Properly fitting goggles should be worn by workers when handling lime.

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