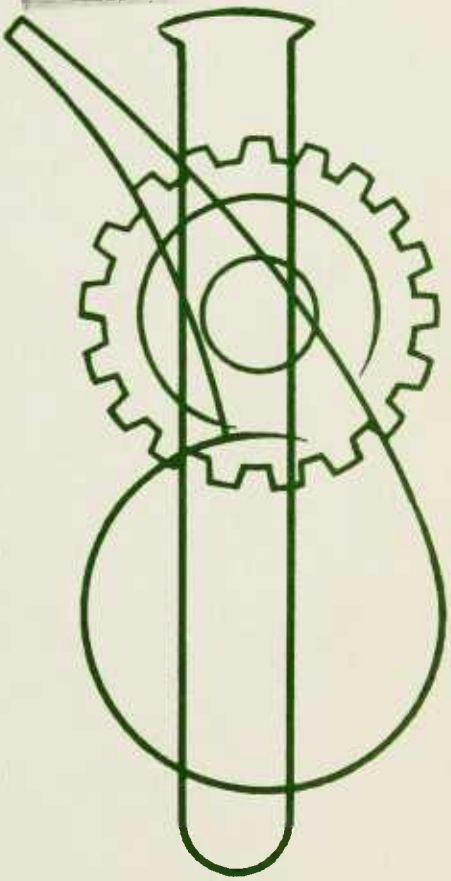
Manual on Safety

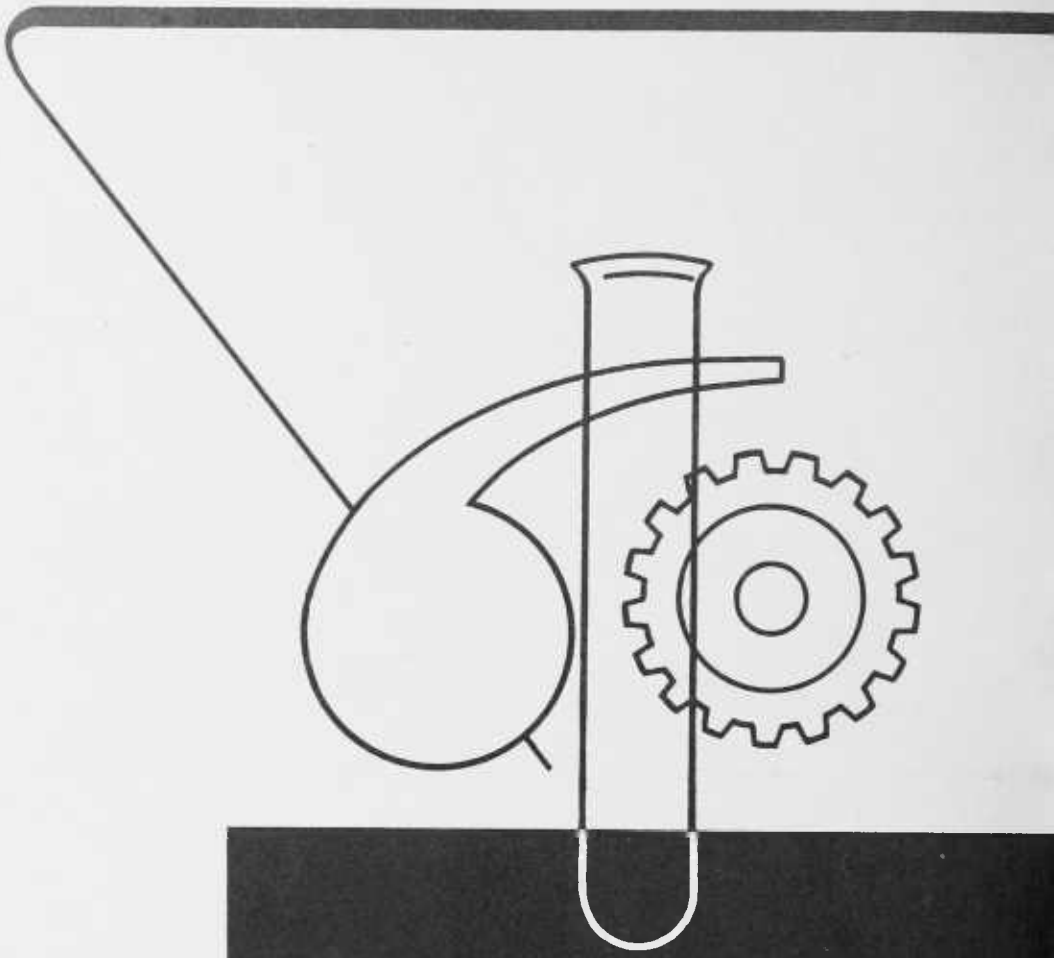
for Workers in...

- Chemical Laboratories
- Pilot Plants
- Chemical Storerooms
- Mechanical Shops



UNITED STATES DEPARTMENT OF AGRICULTURE
U.S. Agricultural Research Service

AGRICULTURE HANDBOOK No. 37



Prepared by the safety committees of Utilization Research Branches of the Agricultural Research Service

UNITED STATES GOVERNMENT PRINTING OFFICE • Washington, D. C., 1954

For sale by the Superintendent of Documents, Washington 25, D. C. — Price 20 cents

Manual on Safety

for Workers in:

Chemical Laboratories
Pilot Plants
Chemical Storerooms
Mechanical Shops

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service
AGRICULTURE HANDBOOK NO. 37

CONTENTS

Issued June 1954

Good Safety Practices

The instructions in this manual are for the protection of you and your fellow employees. By familiarizing yourself with and following them you can prevent many accidents and injuries.

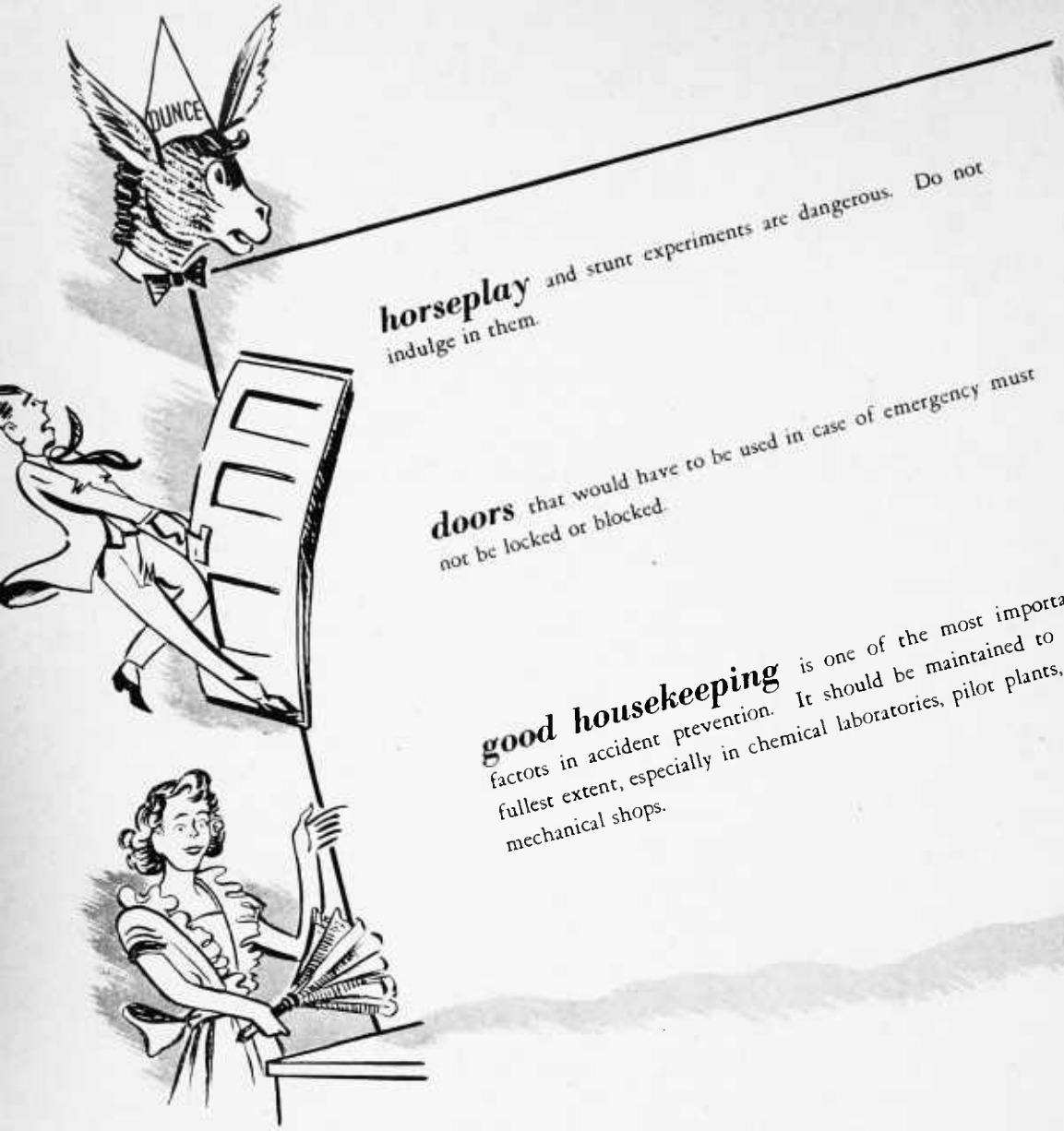
The manual covers not only the usual hazards in the laboratory, the pilot plant, the chemical storeroom, and the shop, but also some less common hazards. Theoretically, it may be said that all accidents are avoidable. Two major types are generally recognized: Those—the most frequent—which would not have happened had adequate care been exercised by the operator; and those caused by unforeseen failure of materials of construction or deviation of reactions from the expected course. Experience shows that in the performance of all laboratory operations there is usually a best way, which is also the safest. Always conduct any potentially hazardous operation with maximum protection. Even though you have conducted it several times without mishap, never relax your vigilance or dispense with any safeguard.

The responsibility for preventing accidents extends from the top of the organization all the way down to the individual worker. Section or group leaders must see that workers under their supervision are informed of hazards which they may encounter and of the safety precautions and proper techniques to be used. No person or group should be entrusted with an operation beyond his or their capabilities. It is the obligation of each worker, who is the chief loser if hurt, to follow the safety instructions that have been prepared and are pertinent to his work. Nature provided us with only one pair of eyes, hands, and feet, and they were meant to last a lifetime.

In case of doubt on any operation, a person carrying it out for the first time, or having but little laboratory experience, should first consult more experienced employees. Under no circumstances, except in emergencies, should he ever use apparatus or equipment in laboratories other than his own without the knowledge and consent of the person immediately in charge. The most simple equipment may be a serious hazard in the hands of an inexperienced worker.

Be familiar with and use, whenever necessary, personal protective equipment, such as gloves, face shields, goggles, aprons, respirators, gas masks, fire blankets, and safety showers. You should also receive instruction, including demonstration, on the correct use and operation of portable fire extinguishers that have been provided for the area in which you are working.

Where unusual risk is involved, the number of individuals present should be kept at a minimum, but never less than two persons. Both must be familiar with the processes and necessary safety measures.



Although a continuous concerted and organized effort is essential to prevent accidents, procedures and means for prompt and effective action when a fire or explosion occurs, or an employee is injured, are also vitally important. This involves the following: Transmission of a fire alarm to the plant fire brigade and, when necessary, to the city fire department; use of fire fighting and safety equipment within the plant; vacating affected areas; rescue of injured persons; administration of first aid; and, in case of serious injury, medical treatment and hospitalization at the earliest possible moment.

All employees should be well organized and properly trained, through the medium of appropriate committees, squads, and designated leaders, to perform prescribed and assigned duties for safeguarding, to the fullest extent possible, persons and property against fires, explosions, and other accidents.

A suitable electrical system should also be installed in cold rooms and other hazardous enclosures by means of which an employee, trapped therein or otherwise in distress, can transmit simultaneously both an audible and a visual alarm to a designated receiving station within the plant.

Hazardous Chemicals

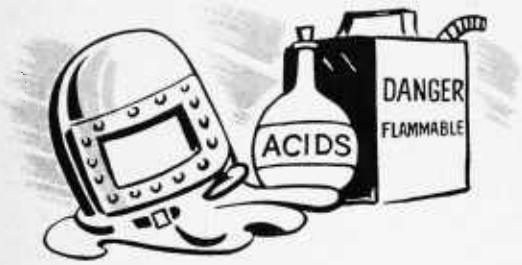
Chemicals that disturb normal physiology may be regarded as toxic. The fact that physiological effects are not immediately apparent is no indication that a chemical is harmless. Your body can absorb toxic materials by inhalation or by contact with the skin. Organic solvents of higher toxicity include the amyl derivatives, most of the chlorinated hydrocarbons, trichloroethylene, the homologues of benzene, chlorobenzene, and the hydrogenated cyclic hydrocarbons. Those that are strongly poisonous include the methyl linkages such as methyl alcohol, methyl chloride, dimethyl sulfate, tetra- and penta-chloroethane, benzene, and carbon disulfide. The vapors of some of these compounds are also highly explosive. Never allow these compounds to evaporate into the laboratory air; never keep them in open containers or heat them without adequate means for condensing or disposing of the vapors.

Do not mix strong oxidizing agents, such as nitric and perchloric acids, nitrates, and perchlorates, with easily oxidizable materials, such as sulfur, sulfides, and organic chemicals, without proper care and realization of the explosion hazard involved.

Have gas masks readily available

Make sure that your gas mask is readily available and properly labeled. Where special gases such as ammonia or sulfur dioxide are a hazard, appropriately marked masks should be provided for the specific service. The all-purpose or all-service gas mask will filter out, adsorb, or neutralize nearly all poisonous smokes or gases. However, it will not provide oxygen in an oxygen-deficient atmosphere. Keep this in mind when using the mask. (A special mask supplies oxygen for a number of hours.) All scientific personnel should be informed as to the use, care, and location of the gas mask. Operating instructions and other pertinent

data are given on a card inside the gas mask box cover. Each person concerned should try on the mask to familiarize himself with the operation. After use, the mask should be sterilized, either as directed on the card with dilute formalin solution, or with 50 percent ethyl alcohol. The alcohol is less irritating when a number of persons are trying on the mask in succession. The mask should be put into the box carefully, to avoid strain or crumpling of the rubber tubing. Periodic inspections of the mask should be made and the canisters should be replaced or returned to the factory for refilling as needed.



Hoods should be used

Use a hood when evaporating acids and flammable liquids and when working with toxic and poisonous vapors or gases. They should also be used for ash tests where fumes are given off, for decomposing chemicals by means of acids, for boiling solutions containing ammonia, hydrogen sulfide, etc., and for experimental work involving explosion hazards. For maximum safety it is essential that hoods be operated with the front windows closed.

Every new chemical prepared in the laboratory should be considered a hazardous material until its properties have been determined. Detailed information on the toxicity of specific chemicals can often be obtained from the National Institutes of Health, Bethesda, Md.

Some hazardous chemicals used in laboratory work

Acetal

Use acetal cautiously when working with old samples because of the possibility of an explosion. Such an explosion (reported in Chemical and Engineering News for June 25, 1944) accompanied the distillation of a specimen of diethylacetal which had been stored for an indeterminate period in amber glass and in complete darkness. After collection of a considerable forerun that appeared to be alcohol, and when acetal was just beginning to come over, an explosion of great violence occurred. It was not accompanied by flame and appeared to take place in the vapor phase, as the stillhead and condenser were shattered, but the flask remained intact.

Acrylates

Store acrylates (methyl and ethyl acrylate monomers) in a cool, dark place. Without an inhibitor the monomers may be destroyed with explosive violence. Table 1 shows the time required for destruction of ethyl acrylate at various storage temperatures with and without an inhibitor. Other acrylate monomers behave similarly.

Table 1

Inhibitor	Temperature	Shelf Life[1]
	°F	
Hydroquinone (¼ percent)	68– 86	12 months
Hydroquinone (¼ percent)	68–122	4 months
Hydroquinone (¼ percent)	68–140	3 months
None	176	7½ hours
None	158	20 hours
None	140	44 hours
None	122	116 hours
None	104	Over 116 hours
None	32	Over 5 months

[1]Not more than a two months' supply of the monomer should be purchased. If enough monomer to last through the summer is in storage, an additional ¼ percent hydroquinone should be added

Allyl chloride

Allyl chloride is toxic. Precautions are always necessary to avoid spillage of allyl halides and accumulation of noticeable concentrations of the vapors in the atmosphere, as repeated exposure to the vapors has serious effects, including damage to the lungs. Keep the liquid off the skin and clothes. Maintain good ventilation. When the odor of allyl halides is at all noticeable, use a gas mask equipped with an organic vapor canister.

Never disregard the warning odor or eye irritation of allyl halides.[1]

Aluminum chloride

Aluminum chloride is potentially dangerous. If moisture is present, sufficient decomposition can build up considerable pressure. If a bottle is to be opened after long standing, enclose it completely in a heavy towel.

Ammonia

Ammonia with silver or mercury forms an explosive. Never place it in contact with these metals. Do not permit an ammoniacal solution containing silver or mercury to dry; acidify and discard it at the first opportunity.

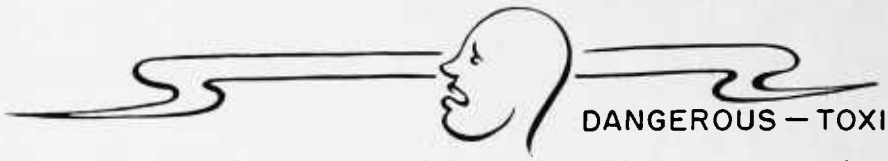
[1] Taken from "Allyl Chloride and Other Halides," Shell Corporation, New York, 1950. For further details see pages 85-87.

Aniline

POISON

Aniline is a poison and its fumes are readily absorbed. Large doses can cause convulsions and death. Observe the following precautions: Use only the minimum amount required at a time. Wash off immediately any spillage: use extreme care to avoid inhaling the fumes. Remove immediately any clothing saturated with aniline to prevent contact with the skin.

Benzene



DANGEROUS — TOXIC

Benzene vapors are very dangerous when inhaled. Great care is essential in working with large quantities of benzene to avoid escape of the vapors into the surrounding atmosphere. Stills used for recovery of benzene should be in a special room or space that is provided with sufficient ventilation to remove all vapors of benzene liberated.

Castor-bean meal

TOXIC

Castor-bean meal or castor pomace and unmilled castor beans contain a violently poisonous protein—ricin—a nitrogenous component—ricinine—also poisonous, and a nontoxic, but exceptionally potent allergenic protein. The physiologic activity of these components warrant suitable precautions to preclude inhalation of dust from the beans or pomace or the contamination of edible products with them. Castor oil, apparently, contains none of these toxic or allergenic components.

Carbon disulfide

FLAMMABLE
EXPLOSIVE

Because carbon disulfide is extremely flammable and its vapors extremely explosive, it is one of the most hazardous flammable solvents used in the laboratory. Use extreme care at all times when handling it. Vapors of carbon disulfide may be ignited by exposed steam pipes. The liquid may be ignited by static electricity when poured from one container into another. For safety, both containers should be grounded.

Carbon tetrachloride

GAS AT ROOM TEMPERATURE

Carbon tetrachloride gives off hydrochloric acid gas at room temperature. It can be absorbed through the skin. Use it only in a well-ventilated room. Never allow it to come in contact with the skin.

Chlorinated hydrocarbons

DERMATITIS

Continual exposure to chlorinated hydrocarbons, even in small amounts, causes dermatitis and other body disorders. They act not only as defatting agents on the skin, but are selectively absorbed by some organs of the body. Avoid continual contact with all such materials either on the skin or by breathing.

Chlorine, bromine, iodine

Chlorine, bromine, and iodine produce very poisonous vapors. Use only in a hood. Don't mix chemicals containing ammonia with chlorine or bromine; those containing iodine or ammonia should not be mixed with chlorides, bromides, or iodides in the presence of oxidizing agents. Extremely sensitive and dangerous nitrogen trichloride, bromide, or iodide may be formed.

Dimethyl sulfate

Dimethyl sulfate is very reactive, especially when it comes in contact with skin or mucous membrane. A very short time of contact results in a painful burn. Extreme caution should be exercised to prevent contact with the eye for on contact the sight could be impaired. Inhalation of the vapors causes a toxic effect which may be delayed but very severe. Never use this compound in the open laboratory but always in a well-ventilated hood.

Dioxane

Dioxane (diethylene dioxide) appears to be a poisonous compound having delayed action. Handle it cautiously; do not inhale it. Condensation of distilled vapors should be done with water above 10° C. to prevent plugging of the condenser. Dioxane, an ether, can form dangerous peroxides in storage. Observe the precautions for old ether stocks in handling it.

Dry ice

Do not handle dry ice with bare hands or store it in a container that can be accidentally stoppered. This compound produces carbon dioxide concentrations in enclosed spaces. Care must be exercised in using it as a refrigerant.

Hydrogen fluoride

Hydrogen fluoride is extremely corrosive to the skin and lungs. It should never be used without adequate protection against any contact with the skin or inhalation of vapors. It also generates hydrogen in contact with certain substances, creating an explosive hazard.

Hydrogen peroxide

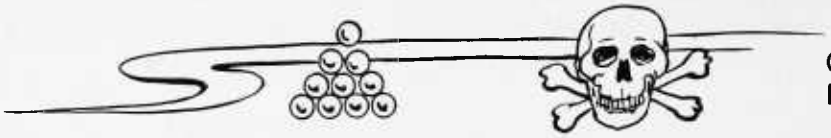
Hydrogen peroxide solutions stronger than 3 percent call for the most careful handling. Contact with the skin may cause severe burns.

210527—54—2

Hydrogen sulfide, hydrogen cyanide

Hydrogen sulfide and hydrogen cynaide are dangerous gases. They should be used only in a well-ventilated hood. Label cyanide solutions prominently. Do not allow them to remain on the laboratory table except when being used. Hydrogen sulfide is also highly flammable. Hydrogen cyanide is moderately flammable.

Mercury



CUMULATIVE POISON

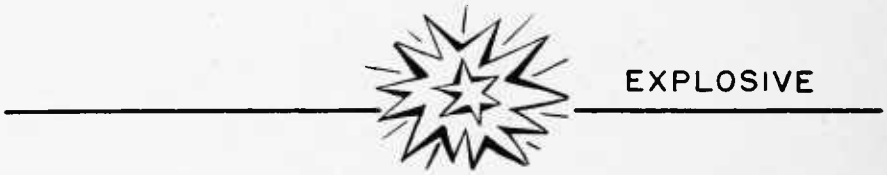
Mercury vapor is a cumulative poison. Vapor pressure of liquid mercury at room temperature is high enough to give vapor concentrations many times greater than the accepted toxic limit. Never keep mercury exposed to the laboratory air in open containers. Clean up all spills at once. Extreme care is necessary to collect all the minute scattered droplets; they evaporate slowly and poison the atmosphere. Spilled mercury can be picked up with a drawn-out glass tube connected to the vacuum line through a filter flask where the mercury is collected. Never pour mercury down sink drains; it destroys the soldered connections. Never draw mercury into pipettes or other tubes by sucking with the mouth. Adequate ventilation should be provided in rooms where mercury is manipulated regularly or in large amounts (vacuum apparatus, gas analyses, etc.).

Nickel carbonyl

LUNG IRRITANT

Nickel carbonyl is an *extremely* toxic lung irritant and asphyxiant with delayed action resembling that of phosgene. Because of its slow action but high potency and the uncertain methods of testing for it, extreme precautions must be taken when working with this chemical. Experiments involving the use of nickel carbonyl must be conducted out of doors with a favorable wind, or in a hood with positive downdraft circulation in an isolated building.

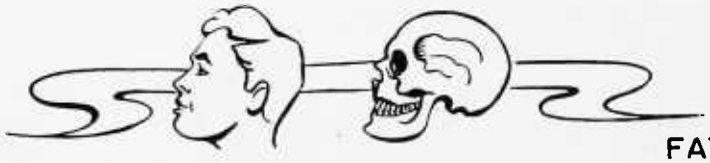
Nitric acid



EXPLOSIVE

Nitric acid may form explosive compounds when used to clean apparatus containing organic residues. It should be used as a cleaning agent only after careful consideration of the hazards involved.

Nitriles



FATAL TO INHALE

Nitriles, especially the lower homologues, react in the same way as hydrogen cyanide. Handle only under a hood. Acrylonitrile is a very active poison; a concentration of 270 parts per million in the air produces fatal results when inhaled. The maximum allowable concentration a human being can breathe is 20 p. p. m.

Old ether stocks

TEST BEFORE USING

Old ether stocks may prove hazardous. All ethers and compounds containing ether linkages—acetals, dioxane, and furane derivatives—tend to undergo auto-oxidation in storage to form peroxides. The peroxides are relatively stable at room temperature and under dilution in the ether, but may *decompose violently* when the ether

is evaporated. While any ether may form peroxides, diethyl and diisopropyl ethers are particularly susceptible to this oxidation. The higher boiling ethers are not so hazardous as the lower boiling members of the series because during evaporation the heat tends to destroy the peroxides.

Test all old ether stocks before use. To test, shake a small portion of the ether with aqueous potassium iodide solution; the release of free iodine (starch test) indicates the presence of peroxides. To destroy the peroxides, add ferrous sulfate solution or sodium bisulfite until the potassium iodide test is negative. To prevent peroxide formation in ether, store in brown bottles or in a dark cabinet. Inhibitors, such as diphenylamine, alpha-naphthol, hydroquinone, or metallic copper, may be added.

Organic peroxides, peracids

Organic peroxides and peracids are capable of *exploding violently,* either spontaneously or as a result of minute shocks, friction, or heating. Peroxides vary in sensitivity, but all are potentially dangerous. As far as possible, work with these compounds should be done on micro quantities or in dilute solution. Do not keep them in bottles having screw tops or ground glass stoppers. Acetyl peroxide is a dangerous explosive and, when pure, can be safely handled only behind a barricade. It appears to be stable when in dilute solutions and should be kept well diluted at all times. It is advisable to prepare this peroxide *in situ,* or to use the commercial 30 percent solution in dimethyl phthalate, where the phthalate can be tolerated. Benzoyl peroxide, when dry, is easily ignited and is sensitive to shock. It decomposes spontaneously at temperatures above 50° C. It is desensitized by adding 20 percent water. Vinylidene chloride, in the presence of air, forms peroxides which are *violently explosive.* Although phenol-type polymerization inhibitors delay or prevent peroxide formation, storage in the absence of air is the positive method of preventing the formation of peroxides.

Perchlorates

Use perchlorates only when absolutely necessary and only then if you are thoroughly familiar with all the hazards involved. With dry alkyl halides, perchlorates react to form free halogen acids and perchloric acid in explosive quantities. Silver perchlorate crystals are highly unstable. Although perchloric acid of 70 percent strength may be boiled safely at approximately 200° C., contact of the boiling undiluted acid or hot vapor of perchloric acid with organic matter or even easily oxidized inorganic matter, such as compounds of trivalent antimony, will lead to serious explosions. Magnesium perchlorate should not be used for drying organic materials.

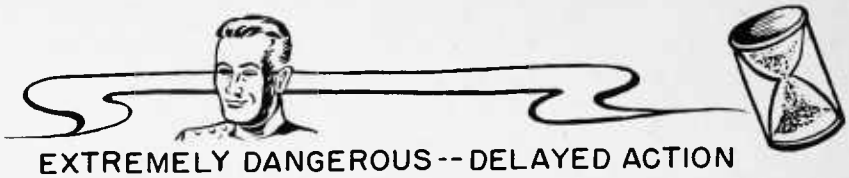
Phenol

Phenol (carbolic acid) dissolved in organic solvents is readily absorbed into the blood stream, with resulting serious or fatal poisoning. The antidote for an accidental spill is to wash all affected parts with ferric chloride in an alcohol solution. Keep the antidote available in the laboratory using phenol.

Phenyl hydrazine

Phenyl hydrazine vapors are poisonous and may cause granular degeneration of the blood corpuscles.

Phosgene

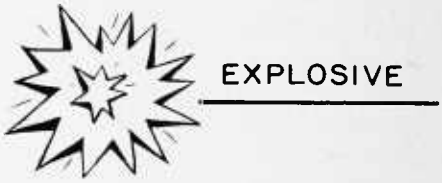


Phosgene is very dangerous since its symptoms are delayed 4 to 8 hours when it is inhaled in small but toxic amounts. A lethal exposure to phosgene can occur before any serious symptoms appear. Phosgene is liberated by a number of chemicals, for instance, carbon tetrachloride.

Phosphorus

Handle phosphorus—white or yellow—with great care because it is poisonous and extremely flammable. Because it ignites upon contact with air and must be stored under water, it is a dangerous material to store in a laboratory. It should not be allowed to come in contact with the skin.

Phosphorus trichloride



Phosphorus trichloride containing moisture may form phosphine when heated, and explode violently.

Pyridine

Pyridine vapors are toxic and highly flammable.

Radioactive materials

Radioactive materials should be used only after consultation with the Safety Committee.

Sulfonyl chlorides

Sulfonyl chlorides are made by chlorination of mercaptans and related compounds. They have been known to explode violently during preparation.

The following publications give further information on hazardous chemicals:

"Toxicology of Gases and Vapors," International Critical Tables, vol 2, pages 318–321.

"Chemical Laboratories," National Safety Council, Inc., Safe Practices Pamphlet 60, pages 11–12.

"Table of Common Hazardous Chemicals," Handbook of Fire Protection, National Fire Protection Association, 10th edition, pages 370–396.

"Controlling Chemical Hazards," U.S. Department of Labor: Series 1–4.

Storage and Handling

Chemicals in heavy containers should be stored on or near the floor and in places where they are protected from colliding and falling objects.

Parts of chemical containers should not extend beyond shelving or cabinets.

Materials that react with dangerous effect should not be stored in close proximity to one another, for example, oxidizing agents should not be placed near combustible materials, and strong acids should not be stored in such a position that an undesirable reaction can occur if the container breaks.

No chemicals in glass bottles should be stored near a source of heat. Allow sufficient space above liquids in bottles to take care of a considerable thermal expansion of the liquid.

Containers in which metallic sodium and potassium are stored under kerosene or similar liquids should be protected against evaporation of liquid.

Fuming nitric and sulfuric acids should be stored in cabinets provided with lead-lined trays.

Special care must be exercised to see that corrosive, deliquescent, and highly reactive chemicals are stored or transported in safe containers.

Special precautions are necessary in the handling and storage of cylinders containing compressed gases and other chemicals.

Always check labels!

All bottles should be labeled distinctly and the labels protected with transparent tape or lacquer.

Always check labels before filling bottles from stock supply.

Identify substances in unlabeled bottles positively before use.

Test chemicals by smelling only with great caution, by wafting a small amount of vapor with the hand toward the nose. Avoid testing by taste.

The use of sulfuric acid or concentrated alkali solutions in gas-washing bottles presents some hazard, as stoppage of the gas exit will build up pressure which may be suddenly released. Preferably, a suitable manometric safety valve is placed in such lines.

Do not use passenger or freight elevators for the transportation of solidified or liquefied gases, such as carbon dioxide, ammonia, and sulfur dioxide, in Dewar flasks or beakers. Use dumb-waiters for transporting such materials.

Do not use sulfuric-acid baths for the determination of melting points or boiling points. The safest practice with concentrated sulfuric acid as a desiccant is

to use only enough liquid to wet some surface such as glass wool or porous tile.

Do not pour or stir corrosive liquids, such as strong acids and alkalies, without proper eye protection.

Carrying materials in large glass vessels is hazardous, especially on stairways. The safe practice is to use a rack, canvas jacket, or other protective device. Move the vessels on the same floor by means of carts or trucks, and utilize the dumb-waiter whenever possible to transport them to different floors. Large bottles should not be carried by their neck.

Special technique is necessary in opening and handling sealed glass ampoules containing corrosive or volatile liquids. Chill the ampoule in an ice bath or in a low-temperature refrigerator. Wrap the ampoule with a towel, leaving the tip of the glass neck exposed; make a scratch near the tip with a fine file or glass knife; rest the surface of the neck opposite the scratch on the edge of a hard support in the hood, with the neck pointing away from the operator; knock off the tip of the neck with a light, but sharp downward blow. For storage of the unused portion, the ampoule can be closed with a loose-fitting glass plug and rubber connector, or the material can be transferred to a small glass-stoppered bottle. Seldom, if ever, is it advisable to attempt to reseal the sample by fusing the glass neck. This can be done safely only with materials known to be nonflammable and nonexplosive.

Disposal

To discard small quantities of acids and alkalies, dilute them highly with water and flush them down the sink. Never put them in refuse containers. When diluting a strong acid or alkali, always pour the acid or alkali slowly into the water—never water into the

acid or alkali. Violent splashing may follow the pouring of water into the strong chemicals. Even putting glassware containing unused chemicals into dishwashers for cleaning has resulted in accidents to the operator. It is the responsibility of those in charge to make certain that glassware to be washed is free from dangerous or irritating chemicals.

Collect flammable liquids not miscible with water in tightly covered metal containers, preferably safety cans, and pour them into an outside solvent-waste can for disposal by burning. Never pour into the drains or sewers. Avoid accumulation of large quantities by frequent collection and disposal. Flammable liquids miscible with water may be poured down the drain if dissolved in at least 20 parts of water or they may be treated in the same manner as the nonmiscible liquids.

Alkali-metal scrap should be placed immediately in benzene, kerosene, or toluene. The containers should be kept tightly closed, and the accumulated deposits should be disposed of at frequent intervals by experienced chemists only. Small quantities of alkali-metal residues should be disposed of by placing them in ethyl alcohol and allowing time for *complete reaction* to take place before discarding. In cleaning an alkali-metal press or other equipment which has been used for handling alkali metal, any material adhering to the equipment should be washed out with alcohol and allowed to react completely with the alcohol before discarding. *Alkali-metal residues should never be disposed of by reacting with water.*

Alkali peroxides should be dissolved carefully by adding a little at a time of the peroxide to a large volume of cold water. The solutions should be reduced or neutralized before being discarded.

Oxidizing chemicals in general should be reduced before being disposed of.

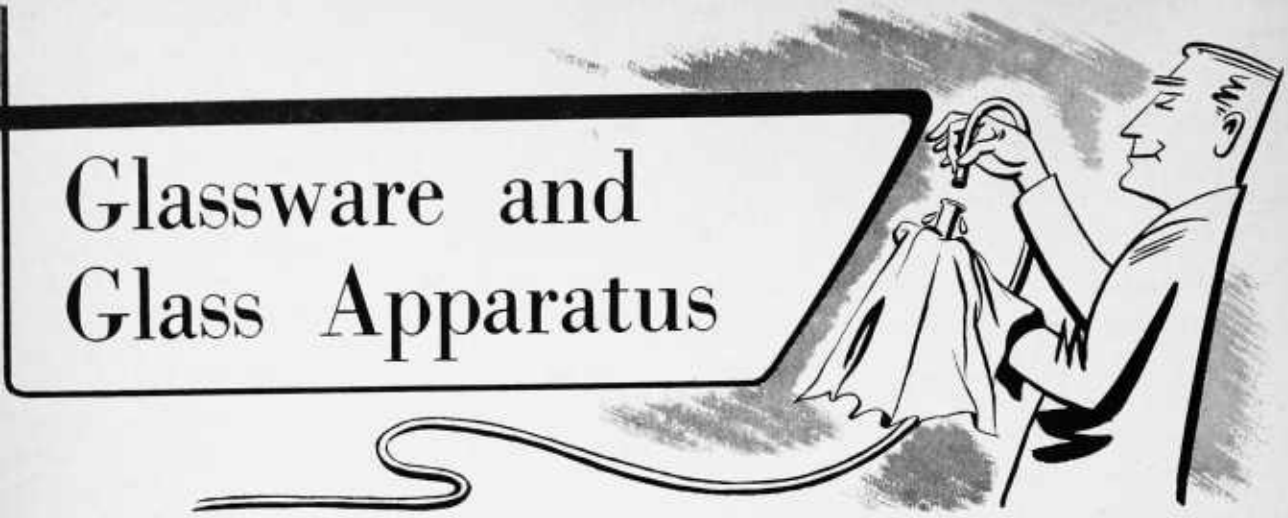
Dangerous chemicals, or those suspected of being dangerous, should be disposed of only by chemists. Cyanids and other materials capable of evolving poisonous gas should not be emptied into drains or sewers. Disposal of such materials should be left to the chemist in charge of the section.

Fumigants

Fumigation is permissible only by persons specifically authorized by the Safety Committee and only with fumigants specifically approved by the Safety Committee.

Appropriate on-the-spot warning signs must be posted, and the building superintendent, the head guard on duty, and other personnel concerned with space in which fumigation is to take place must be given advance notice.

Glassware and Glass Apparatus



Never put large glass bottles under pressure or vacuum, unless they are protected by a shield and a pressure- or a vacuum-limiting device.

Carry long glass tubing or apparatus vertically, instead of horizontally, if possible.

Frozen glass stoppers and stopcocks should be taken to a glass worker or other experienced person for removal. Frozen rubber stoppers or corks should be cut away from glass tubing or thermometers.

Before inserting glass tubing in rubber tubing or in rubber or cork stoppers, fire-polish the ends of the glass tubing or smooth them with a file and then lubricate them with a little water, alcohol, or glycerin. Grasp the glass tubing near the end to be inserted. Always use toweling to protect the hands and avoid the use of excessive pressure when inserting the tubing. This precaution is necessary when removing glass tubing, even if not frozen. Remove rubber tubing or stoppers that have become stuck on glassware by careful cutting with a razor blade or sharp knife, rather than by force.

Glass tubes should always extend well through a rubber stopper, as subsequent swelling of the rubber might close or partially obstruct the opening.

Pick up large beakers by grasping them around the outside, not by their rims. Filled or partly filled beakers of large capacity should be supported on the bottom as well as around the wall when handled.

Beakers or flasks of more than 2-liter capacity should not be heated by direct flame or by direct contact with a hot plate. They can break spontaneously when liquids are heated in them and must be inspected carefully for defects before being used.

A clamp around the neck is not sufficient support for a large flask; a bottom support is also necessary.

Inspect flasks for flaws before using them in the distillation of flammable solvents.

Laboratory clamps of certain alloys have a low melting point and are of low tensile strength. They may fail under a combination of high stress and only moderately high temperature.

Do not seal off glass tubes containing combustible materials unless the vapor pressure in the tube has been sufficiently lowered by freezing in dry ice or a liquid-nitrogen bath. Do not handle or open sealed glass-reaction tubes unless they are contained in metal protecting shells and have been adequately cooled. As a further precaution, in opening the tubes, wear gloves and a face shield. If you have occasion to request such service of the glass shop, keep sealed reaction tubes cool and within metal shells until after the pressure has been released. The pressure may be relieved, after cooling, by causing the tip of the tube to project from the shell, then directing a fine flame at the tip. Any pressure will blow out via the softened glass.

Stopcocks used in systems under slight pressure should be held in place by rubber bands or special clamps.

Compressed air represents a hazard when improperly used. Never dry glassware by blowing compressed air into it. Never connect glass apparatus with the compressed-air line except through an automatic reducing valve set at 5 pounds per square inch or less, and protected with a safety valve or similar safety device.

Use suitable angle clamps, rather than your hand covered with a towel or rag, to hold a piece of glass in which a hole is being cut with a power drill. If the cutting tool sticks, the piece of glass will rotate, unless clamped in place, with possible injury to the operator's hand.

In sealing off solids, such as iron rods and wire, in glass tubes, be sure that the solids have been degassed before making the final seal. After the seal has been made, do not heat it to a temperature higher than that used for degassing.

In performing various operations on glass apparatus, such as freeing frozen joints and sealing side tubes, use a free flame only on clean, dry apparatus that has been flushed free of flammable vapors. Before applying the flame, satisfy yourself that the apparatus is clean and dry.

Immediately discard broken beakers or other glass apparatus in receptacles provided for such waste; do not leave them among other glassware to be washed. This removes the possibility of cuts from washing broken glassware.

In handling or washing laboratory watch glasses or other fragile glassware, avoid using pressure when attempting to remove crayon identification marks or otherwise cleaning them.

When washing microscope slides and cover slips, take care that no broken pieces are left in the sink.

Pick up broken glassware with a broom or brush and a dustpan, never with bare hands.

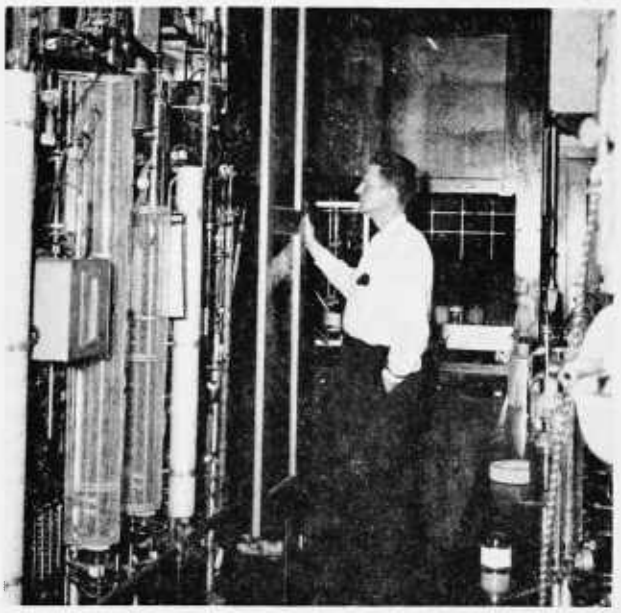
Vacuum systems

Glass vessels under vacuum are capable of collapsing violently, either spontaneously or from an accidental blow. Wear goggles when working near evacuated glass vessels. All vessels of more than 2-liter capacity should be enclosed in a suitable shield before they are evacuated. Never evacuate ordinary soft glass bottles. Never evacuate flat-bottomed flasks unless they are made of heavy-walled Pyrex glass and used cold. It is a common misconception that danger of collapse exists only with a high vacuum obtained with an oil pump. A low vacuum obtained with a water aspirator or the laboratory vacuum line exerts a collapsing force fully 90 percent as great as that caused by a perfect vacuum. The application of pressure exceeding atmospheric to glass vessels is even more dangerous than vacuum. Never apply positive pressures greater than 5 pounds per square inch to glass apparatus.

Goggles or preferably a face shield should be worn when viewing vacuum distillations and similar installations at close range. If possible, safety shields should be placed in front of the apparatus.

Desiccators for vacuum uses should be made of Pyrex or similar glass, and they should be protected by standard metal screens, cages, or wooden boxes.

Dewar flasks containing liquefied gases or solid carbon dioxide must not be tightly stoppered. They must not be placed in electric refrigerators, as these ordinarily have doors which seal airtight on closing. Dewar flasks must be closed in a wooden box or other container or be wrapped with tape to reduce the hazard of flying glass in case of collapse. These flasks are capable of collapsing as a result of thermal shock or a very slight scratch at the neck by a stirring rod.

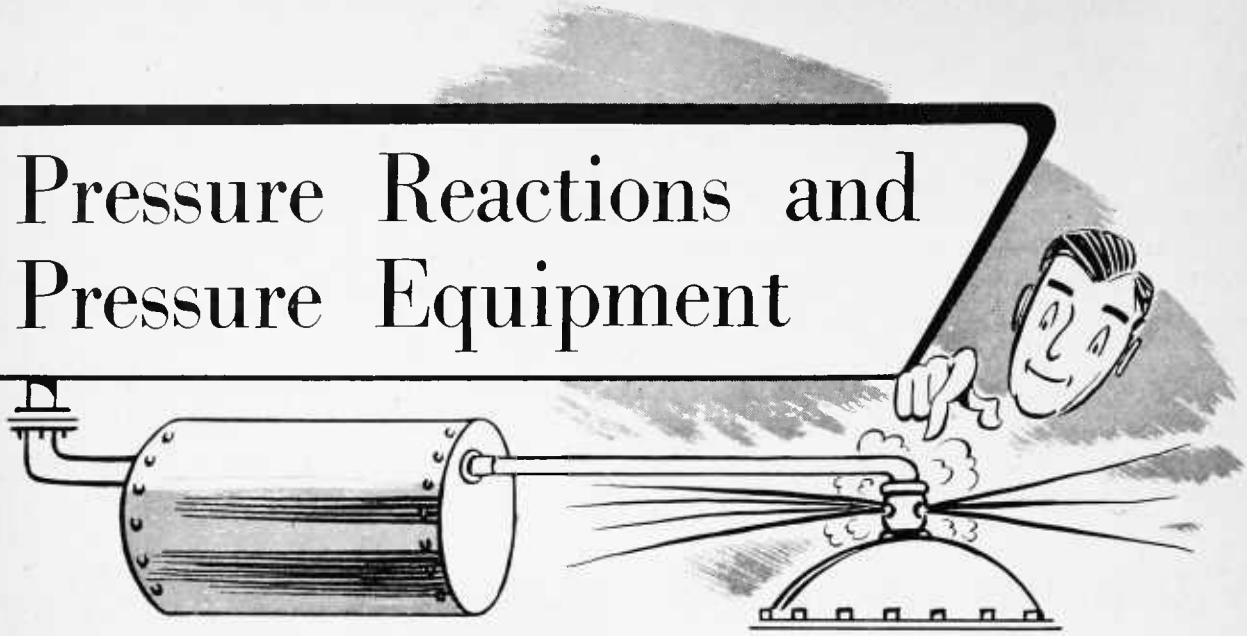


In general, high-vacuum distillation should be conducted with adequate shielding. They should be cooled before venting, or vented with inert gas. Removal of air by means of water pumps must be performed with traps in the line and positive check valves to keep water from backing up into the system.

If, for any reason, the vacuum has to be broken in a system, the heat should also be interrupted to prevent excessive distillation rates on resumption of vacuum.

210527—54—3

Pressure Reactions and Pressure Equipment



Never connect any closed apparatus incapable of withstanding the maximum pressure of the service lines —air, steam, and water—directly to the line.

Install pressure-reducing valve and adequate safety release so that the pressure can never exceed that for which the vessel is rated.

A safety valve or a metal rupture diaphragm must be installed wherever the nature of the installation would permit excessive pressures in the event that any pressure-regulating device fails to function. For example, a kettle suitable for 50 pounds per square inch should never be connected through a pressure-reducing valve to the 120-pound steam line unless there is a safety device on the kettle. Similarly, the kettle should not be connected even to a 10-pound line in which the steam is obtained by reduction of 120 pounds steam unless the 10-pound line is protected by a safety device. It is not uncommon for pressure-regulating valves to stick in the open position or to seat improperly.

A free space of 20 percent should be allowed in a high-pressure autoclave, based on the calculated liquid volume at reaction temperature.

Never use cooling water in the jacket of a steam-heated vessel unless (1) the jacket will withstand maximum pressure of the cooling water, (2) the drain is open to the sewer, with no intervening valves, or (3) a safety valve is provided.

The maximum safe operating pressure should be permanently marked on each piece of equipment.

Safety valves must have proper pressure limits and capacity, and should be tested periodically.

All pressure equipment should be equipped with suitable pressure gages. The range or total dial graduation should be about twice the working pressure. For corrosive gases and liquids or viscous fluids that would destroy a steel or bronze Bourdon tube, use a diaphragm gage. Install coil pipe or pigtail siphon before gage on steam connections.

In the design and installation of pressure equipment consult the applicable codes of the American Society of Mechanical Engineers and the American Petroleum Institute. Pressure vessels must pass an approved pressure test before being placed in operation. Thereafter, they must be tested or inspected by a recognized authority at least once a year.

Pressure apparatus should not be tested with oxygen.

Systematic inspection and venting of all pressure tubing, connecting gages, or pressure release devices to the pressure system should be made before each use to make sure that they are not plugged from previous operations. Systems should be so arranged that they may be flushed out.

Never install a pressure relief device where anyone can stand or walk in front of the discharge.

Vessels for vacuum operation should be protected by suitable relief valve (vacuum breaker).

Safety glasses or goggles should be worn when working with pressure reactions.

High-Pressure Technique

Never fill a pressure vessel so full of liquid that external heat would develop pressures in excess of the allowable working pressure.

Never tighten a pressure joint under pressure.

Avoid even traces of oil on equipment to be exposed to oxygen under pressure. Under strong oxidizing conditions special packing or lubricants must be provided.

Escape pipes from safety-release mechanism should be arranged to discharge outside of building.

High-pressure reactions and equipment should be operated only in rooms set aside for that purpose.

Highly hazardous operations should be handled from a distance. Gages may be viewed through a system of mirrors. Gages should be of the safety-back type.

Valves controlling high-pressure liquids or gases should indicate direction of flow to insure proper connection to the shut-off side of the valve with packing- or stuffing-box connection on the low-pressure side.

All pressure vessels should be stamped plainly with the maximum allowable working pressure and the maximum allowable temperature.

When working with poisonous gases, it is desirable to have another person present. Suitable gas masks should be used. Where more than one individual works with pressure apparatus, the extent of individual responsibility should be clearly understood.

Pressure should be relieved and head of pressure vessel unseated before retaining devices (bolts, nuts, etc.) are removed.

Damage through failure and explosion of high-pressure vessels is not confined to direct hits by parts of the exploding bomb or autoclave and spray of autoclave contents. Secondary propelled parts are often as dangerous as the prime movers. Special safeguards, such as an armor-plate shield or a rope mat, should be installed.

Pressure tubing of small diameter should be held down rigidly along its entire length to prevent whipping in case of failure.

The following special precautions must be strictly observed:

Electrical equipment, fixtures, connections, and switches in high-pressure hydrogen laboratories should comply with applicable National and State codes for flammable gases.

No person, except research workers or others who are expressly authorized, may operate or interfere with any bomb apparatus or its accessories, gas compressor, catalytic apparatus, or other high-pressure equipment.

When an individual engaged in high-pressure work has reason to suspect a defect in any of the valves, cylinders, gages, compressors, bombs, or other equipment, he must immediately have the equipment investigated and corrected if found defective.

No high-pressure experiment or operation may be carried out or attempted unless expressly authorized by the individual in charge, and then only under his personal supervision.

No unauthorized person shall be permitted in the room while high-pressure experiments are being prepared for or made.

The individual in charge of the high-pressure work shall be responsible for seeing that all necessary safety precautions are observed.

For further information on this subject, consult "Gaseous Combustion at High Pressures," by Bone, Newitt, and Townend (Longmans, Green, and Company, Inc.).

Compressed Gas Containers

Compressed-gas containers are safe for the purposes for which they are intended. Serious accidents connected with their handling, use, and storage can almost invariably be traced to abuse or mishandling.

Gas cylinders will be tagged with metal tags in the receiving room. On delivery, the recipient must make certain that the cylinder is correctly tagged.

All cylinders over 3 feet tall must be secured, by a chain or strap on the upper part of the cylinder, or supported by a nontipping base. Tank trucks are preferred for the transportation of cylinders, but low bases with wheels may be used. Never move a cylinder by applying force to the cylinder valve.

Cylinders should be protected against excessive rise of temperature. No part of any cylinder containing a compressed gas should ever be subjected to a temperature above 125° F., or allowed to come in contact with a direct flame.

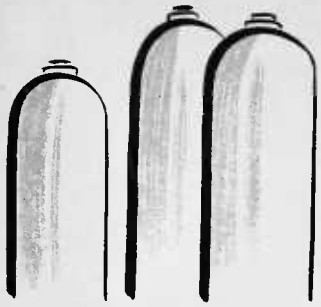
Never store cylinders near highly flammable substances, such as oil, gasoline, or waste, or in the direct rays of the sun.

Do not store cylinders near elevators or gangways, or in other places where heavy moving objects may strike or fall on them. Avoid horizontal storage also.

Valves and safety plugs should always be protected with a cap when cylinders are not in use or are being transported.

Cylinder valves must be kept closed when not in use. When opening a valve, open it slowly. Never hammer the valve wheel in attempting to open or close the valve.

A simple needle valve that is not completely shut off is capable, in time, of transmitting the full pressure of the cylinder to apparatus connected to such a valve. This applies also to single- and double-stage reduction



valves that are not in working order. The proper precaution is a safety release valve or device in the system to which pressure is being applied. If practicable, cylinders should be disconnected from the rest of the apparatus at the close of each day.

Accurate regulation of low rates of gas flow from a high-pressure source should not be attempted with a simple needle valve. A pressure-reducing valve should be used.

Pressure-reducing valves that fit cylinders of water-pumped nitrogen or oxygen must never be used on oil-pumped nitrogen. Oil may enter the valve, rendering it unsafe for future attachment to an oxygen cylinder. Any adapters that might permit inadvertent use of these regulators on oil-pumped nitrogen should be discarded.

Gages used on oxygen tanks are subject to explosions of two types—simple mechanical breakage under pressure of the Bourdon tube within the gage, and actual explosion of oxygen-oil mixtures within the gage tube. All small gages (3 inches or less) used on high-pressure oxygen should be examined for age and design, and replaced by new safety-back gages if they are not provided with this feature. *All* gages used with high-pressure oxygen should bear the following warning in a conspicuous place: *Oxygen—Use No Oil.*

Each oxygen valve must bear a notice naming two persons authorized to connect the valve. It is the responsibility of the safety committee of each laboratory to see that the following precautions are posted and observed:

1. Inspect both tank and reducing valve visually for organic matter.

2. Take all precautions for removing any organic matter, including wiping valve with carbon tetrachloride on a clean cloth if necessary and washing hands with soap and water before handling valve.

3. To dislodge dust and dirt, open the tank valve momentarily before attaching the reducing valve; be sure to point the valve opening away from you. Never hammer the tank valve.

4. Test the reducing valve by turning the tank valve on slowly, and run some oxygen through the reducing valve. Stand so that the cylinder is between your body and the reducing valve while doing this.

For detailed information on the safe handling of compressed gases consult "Safe Handling of Compressed Gases," Compressed Gas Manufacturers' Association, Inc., and "Static Electricity," National Safety Council, Inc., Pamphlet 52.

Flammable Materials

In the storage and handling of flammable liquids not more than a 2-days' supply, limited to a total of 10 gallons of those that are used intermittently or only occasionally, should be stored in any one room at any one time. Any exceptions involving larger quantities of flammable liquids must be approved by the safety committee of the laboratory. All flammable liquids should be stored in tightly sealed containers. The liquids or their vapors should never be exposed to the atmosphere in the presence of flame, sparks, or hot surfaces, such as electric heating elements in operation. As a guide to applying this restriction, a flammable liquid shall be defined as one having a flash point below 75° F. as determined by the closed-cup test. However, quantities of flammable liquids having a flash point of 75° or above should be kept to a practicable minimum and should be stored in tightly sealed containers.

Safety cans should be used wherever possible for flammable liquids.

Ordinarily, electric refrigerators are not adapted to the storage of volatile, flammable solvents, either by themselves or in combination with other materials, owing to the possible ignition of the vapors by the arcing of motor or lamp switches, or the breaking of lamps, within the refrigerator. Unless the necessary safety features have been incorporated in the refrigerators when purchased, *all electric refrigerators shall be properly altered or rewired promptly to eliminate these sources of ignition,* even though there is no intention of placing flammable solvents in them.

In distilling or refluxing volatile, flammable liquids, use a water or steam bath rather than a free flame or a hot plate. Heating mantles or similar systems are also advantageous. Where practical, conduct all distillations in a hood. Pay careful attention to operation of the heating appliance at the proper temperature and to adequate cooling of the condenser. Set up the flask in an empty container, or in a tray containing sand, capable of confining all of the liquid in case the vessel fails. Distillation equipment in operation should not be left unattended.

Vacuum distillations in flasks of more than 500 milliliters should be carried out behind a safety shield or safety glass to protect not only the operator but also others in the vicinity in case the flask collapses. Goggles protect only the wearer.

No open flames should be allowed where flammable gases, vapors, or dusts are present. Gases or vapors heavier than air will seek the lowest level and may float along bench and table tops or the floor for considerable distances. Sources of ignition many feet away, therefore, may cause an explosion or fire. Conspicuous signs warning against smoking and the use of open flames should be displayed prominently.

Use liquid nitrogen in place of liquid air as a refrigerant for cooling flammable liquids in glass vessels.

Do not keep even small bottles of volatile, flammable liquids in the sunshine or where heat from a hot plate, burner, or other device may cause the stopper to blow out and release vapors.

Flame arresters should be installed in vent or vacuum lines connected to processing equipment containing flammable liquids.

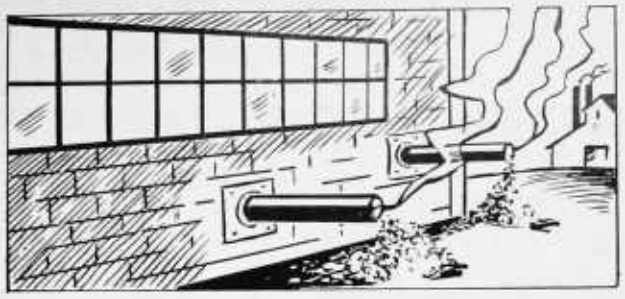
Safety valves must always be vented to the outside if there is a possibility of their discharging flammable gases or liquids.

Gage-glass valves should be of the automatic self-closing type.

Electrical wiring and apparatus for use in hazardous places should be of the type approved for such places. (See "Hazardous Locations," Article 500 of the National Electrical Code.)

Be sure that no electrical apparatus employing a device which may produce sparks, such as an open relay, is operated where flammable vapors are present. Electric refrigerators equipped with outside relays are typical examples.

The electric breaker switch with which some motors are provided may also be a source of ignition of flammable vapors. Motors so equipped should not be operated where such vapors are present. For stirring volatile solvents use explosionproof electric motors or motors operated with air or water under pressure.



Where flammable gases, vapors, or dusts may be present, use nonsparking tools. Power transmission for equipment should be of the type that will not produce sparking or build up electrostatic charges.

The exposed, noncurrent-carrying metal parts of equipment used in hazardous locations should be grounded in accordance with the requirements of article 250 of the National Electrical Code.

Where unstable substances capable of exploding are dried in electric ovens, all rigid door latches should be removed and the oven surrounded by a suitable protective cage. However, solids containing even small amounts of volatile, flammable liquids should not be dried in electric ovens with exposed heating coils or switch contacts.

Do not solder or use open flames on pipes or vessels that have contained flammable materials unless all of the flammable material has been removed and the pipes or vessels have been cleaned thoroughly. If possible, have them filled with water while the work is being performed.

Provide exhaust systems to remove fumes and dusts.

Where flammable gases may be present, use steam instead of compressed air to clean machinery.

Valves and pipes carrying flammable materials should be prominently identified. (See "Identification of Piping Systems," National Safety Council, Inc., Safe Practices Pamphlet 88.)

Oily rags or waste should be placed in metal containers with close-fitting covers. Containers must be emptied and contents properly disposed of at the end of *each* day.

For detailed information on the fire-hazard properties of flammable liquids, gases, and volatile solids, consult "Handbook of Fire Protection," National Fire Protection Association, 10th edition, pages 233-301.

Electrical Installations

Fluorescent lamps containing beryllium compounds present a poison hazard when broken. Poisoning may result from inhalation of the materials; introduction of the powder into cuts or breaks in the skin causes sores which are difficult to heal. Great care must be taken, therefore, in handling and disposing of broken or burned-out lamps. If a fluorescent lamp breaks while in use, avoid inhaling the air in the space where the breakage occurred until the area has been properly cleared of powder and broken glass. Burned-out lamps should be replaced only by the electrical shop. An individual shall be designated to arrange for the proper disposal of burned-out and broken lamps.

Electrical wiring and equipment for use in hazardous locations should comply with the requirements of Article 500 of the National Electrical Code. (It is suggested that the electrician be consulted before ordering electrical equipment.)

All electrical alterations and repairs should be made by the electrical shop. In case of necessity, however, qualified laboratory workers may perform minor electrical jobs, provided they are authorized to do so and such work is inspected by the electrical shop.

Temporary electrical installations which may be necessary to expedite important research should be made only by an electrician. If it is found later that electrical service is required for an extended period, the temporary installations should be replaced by approved fixtures and appliances as soon as possible. Temporary installations definitely made for a short period should be dismantled and discarded just as soon as the need for them has passed.

For the protection of personnel, the work areas, such as laboratory benches and hoods, are served by a three-wire electrical distribution system, the third wire of which provides a protective ground. All equipment served by these outlets should utilize this safety feature.

Keep the use of extension cords at a minimum. Such cords should be of the approved type and as short as possible, and they should not be used as substitutes for permanent or fixed wiring.

Take care not to overload electric motors, Variacs, and Variatrans.

Before plugging in electrical equipment, be sure that switches on the equipment are turned off.

Do not fasten or block the throw of circuit breakers.

Check the demand on workbench and hood circuits before adding any large load.

Flush-type floor receptacles, when not in use, should have the removable screw top properly inserted.

Adequate precautions must be taken with high-voltage equipment. A conspicuous sign showing operating voltage should also be displayed.

A cutoff switch in the input to high-voltage and machinery circuits should be provided and used.

Process equipment

Gage-glass valves should ordinarily be of the automatic, self-closing type.

Keep hands out of moving conveyors. Means for feeding machines must not endanger the limbs of operators.

Operators around moving machinery should not wear loose neckties, clothing, and coveralls. Women operators should wear hair nets or caps.

Where practical, use color codes and prominent labels on all pipe lines.

Do not lubricate shafting or machinery while in operation.

Do not enter tanks without providing a fresh air supply; also have another person nearby to aid in case of an emergency.

Do not enter a large tank or vessel equipped with an agitator unless the main switch is open and another person is near to prevent starting of the agitator.

If jackets or coils are arranged for alternate steam-heating and water-cooling, constant care is necessary to avoid entry of untreated water into the condensate return lines. A warning sign should be installed.

210527--54—4

In processing vessels heated by direct admission of steam, condensate must be run into the sewer—never into the condensate return lines.

Never open or close any valve or switch without informing all users of the service.

Do not take the word of the previous operator that all valves, pumps, etc. are properly adjusted; check them yourself. Do not leave your shift without thoroughly acquainting your successor with all of the unusual conditions that prevail.

Avoid the use of three-way valves if two ordinary valves will serve the purpose. Three-way valves often cause confusion and may be turned the wrong way in an emergency.

Automatic valves, which will shut off fuel burners when the supply fails, must be provided.

Steam pipes and other hot lines near working levels must be insulated to prevent burns.

Pressure must be removed from pipe lines and vessels before repairs or alterations are made.

Miscellaneous laboratory and pilot-plant technique

Ball-mill grinding is hazardous if iron balls are used in the presence of aqueous liquids because appreciable hydrogen pressure may develop.

Before a centrifuge is operated for the first time, be careful to follow the manufacturer's instructions and to properly secure the basket or head in position. When a centrifuge is provided with a housing having a lid, it should not be operated with the lid open or unlocked. A centrifuge that does not have a protective, stationary housing should not be used without a suitable safeguard to protect the operator. The speed limit recommended by the manufacturer must not be exceeded.

Persons working near an agitator containing corrosive substances should wear a face shield.

Guard against sudden vaporization of liquid because of superheating. Never add a boiling stone or similar device to liquid after heating has begun.

Bottles or other containers made of flint or soda-lime

glass cannot be heated or chilled rapidly without cracking or breaking. Only Pyrex or similar glassware should be used under such conditions.

Be sure that condenser water has been turned on and remains turned on when using volatile, flammable solvents in Abderhalden dryers and distillation apparatus. Make certain that the cooling water is at a sufficiently low temperature.

Never conduct operations over a grating, if spilled material could cause injury to someone below.

A wet place on the floor may be the result of an overhead spill; therefore, do not look directly upward.

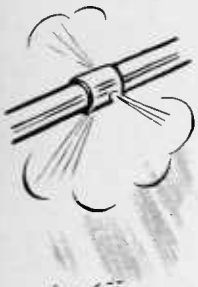
Drink from drinking fountains rather than from beakers or other laboratory utensils.

Pipette and siphon poisonous or corrosive liquids by means of mechanical suction, not by the mouth.

The use of individual wash bottles or bottles equipped with rubber bulbs prevents the spread of colds or other infections.

Do not stand on boxes or swivel stools to work. Use suitable ladders or platforms.

Exposed, noncurrent-carrying metal parts or fixed and portable equipment, which may become electrically energized, should be grounded in accordance with the requirements of article 250, "Grounding," of the National Electrical Code.



Charges of static electricity may be generated by bringing together and separating two substances, one or both of which are nonconductive. Static may also be generated by the separation of a vapor or liquid into particles. Examples are steam leaking from a pipe, or a stream of liquid breaking up into drops, as happens in the pumping of liquid into a tank from above (even within a closed system).

If the static charges build up to a high enough voltage, they jump across gaps, forming sparks which may ignite flammable gases, vapors, or dusts.

One common hazard results from the transfer of a nonconductive liquid from one container to another. This can be controlled by connecting electrically the container and receiver, and grounding the system.

Another hazard may result from the operation of blower systems handling dusts.

Whenever flammable materials are involved, consider possible sources of static generation, and eliminate any hazard by careful grounding.

For more detailed information, consult "Static Electricity," National Safety Council, Inc., Safe Practices Pamphlet 52; and NFPA No. 77 "Static Electricity." National Fire Protection Assoc., Boston, Mass.

Provide handrails on stairs and platforms. Have platforms above shoulder height equiped with toeboards.

Illumination should be adequate everywhere.

Report escaping gas to your supervisor if its source cannot readily be determined. Unsafe conditions, operations, or equipment should also be reported to him.

All gas burners, with the exception of glassblower's burners, Bunsen, and Meker laboratory-type burners, must comply with one of the following conditions: (1) The burner must be connected to the gas supply with rigid metal piping; (2) where rubber tubing is used for conveying the gas, the stopcock on the burner must be fixed in an open position or removed entirely so that it cannot be used to shut off the gas and leave the rubber tubing holding gas under pressure.

In the case of the burners that are excluded from this requirement, the gas must always be turned off at the *bench outlet.*

No apparatus, using heat, which presents a fire or explosion hazard because of the possibility of overheating, or of accidental ignition of flammable materials by the heating medium, shall be operated at night or over the week end without an attendant.

Mechanical and shop equipment

General precautions

No person should operate any machine in the mechanical shops or elsewhere without permission of his supervisor and the man in charge of the machine.

Interrupting a workman who is busy on a power-driven machine, such as a lathe, drill, milling machine, or pipe-threading machine, may cause him to have an accident. The safe thing to do is to wait until he is free or to see his supervisor.

While only one starting button should be provided for each machine, several auxiliary or safety stops may be advisable so that the machine can be conveniently shut down by fellow workers in case of accident to the operator.

Where possible, safeguards should be provided for each point of operation to prevent injury to the operator from dangerous moving parts or from the moving material. This may be accomplished by using one or more of the following devices:

Mechanical feeding device.

Hand-control device at a safe distance from the point of operation.

Tool so designed that it is impossible for the operator to get in the danger zone.

Device that interrupts the movement of the tool or machine while any part of operator's body is in the danger zone.

Device that pulls or pushes the operator's hands away from the danger zone.

Barricade, cover, guard, or enclosure.

Never allow a machine to run unattended. Shut off the power immediately after finishing a job. Someone else may be injured by a machine that is running when he has reason to think it is not.

Never use the hands or feet for braking machines.

Operators of machines in which clothing may become entangled should wear snug-fitting, short-sleeved shirts or jackets and no neckties. Neckties offer a serious hazard, as do rings and wrist watches. Gloves should not be worn.

Floors should be kept in good condition and free from chips or obstructions. Slippery floors around machines are especially hazardous.

Exhaust systems should be provided for collecting vapors, fumes, and objectional dusts at their sources and discharging them outside the building.

Spray painting should be done only in properly designed spray booths, preferably of the water type, or in large spaces, well ventilated.

Exposed belts and pulleys, gears, projecting parts, shaft ends, clutches, and other moving parts present definite accident hazards. Suitable guards should be provided; they can be designed and applied best by the machine builder.

Chip guards (shields) should be available for use on lathes, shapers, and other machines when needed. Also, goggles should be worn when needed. The shields are particularly desirable when brass, cast iron, or tool steel is being machined because chips are most likely to fly from these metals.

Fluorescent lighting can produce a stroboscopic effect on rapidly revolving parts of machinery, thus giving a false impression of true speed. Allow for this effect and take precautions to prevent accidents from it.

Specific machines and equipment

Lathes

Safety lathe dogs, such as those having countersunk setscrews, rather than lathe dogs with protruding setscrews, should be used.

Whenever chucks or faceplates are changed, they should be started on the spindle by hand power, never by machine power.

See that the work is counterbored to sufficient depth to prevent its being torn loose.

Be sure that the lathe spindle fits its bearings and that the carriage is not loose on the ways.

Do not attempt to change or adjust machine tools while the lathe is in motion.

Pipe guards should be installed to prevent a fellow worker from being caught on the projecting revolving stock.

Drill presses

Never attempt to hold the work by hand when using the drill. Make it secure with a clamp.

Avoid forcing or feeding the drill too fast. Broken or splintered drills have caused serious injuries.

Never use the fingers, cotton waste, or rags to brush chips away from the drill; use a stick or brush.

Never use gloves in operating a drill press except when handling rough materials and then only when the drill is not running.

Keep your hair away from the drill or drill spindle. Wear a cap or keep your hair cut short.

Be careful how you reach around the revolving drill. Keep your sleeves short or they may catch on it.

Milling machines

When setting up jobs or making adjustments, never fail to stop the cutting tools.

Make sure that cutter and arbor are secure.

See that the work is clamped securely.

Avoid cuts and other possible injuries by using a brush to remove chips.

Be careful about your clothing; loose garments are easily caught in machinery.

Keep the floor around the machine clean and free from objects that might cause a fall.

Hacksaws (Power)

Hacksaws should be so placed that the end of the material being cut does not protrude into a passageway.

Be sure that the material is clamped securely and that the piece being cut off will not fall where it may injure someone.

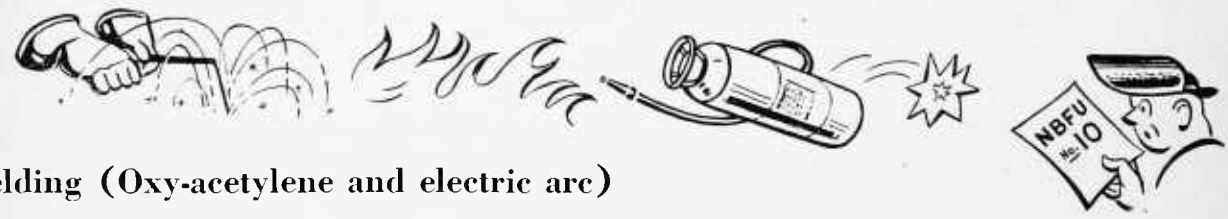
Abrasive wheels

Abrasive wheels are fragile and present exceptional hazards if abused either in handling or in operation. Breaking of the wheel and accidental contact with the wheel while it is in motion are the principal causes of injuries.

See that wheels are properly mounted and equipped with suitable guards. All wheels should be given the "ring" test before they are mounted. After a wheel has been mounted, it should be allowed to develop its rated operating speed for at least one minute, during which time the operator should stand aside and out of danger. Never operate wheels above normal or specified speed. Do not use wheels having uneven or rough surfaces or wheels that make the machine vibrate, indicating that they are out of balance. Have rough wheels dressed by someone who knows how.

The operator should wear goggles.

When using sanders, wear goggles, and be sure that the work is held securely in place *on the bed.* Do not try to sand pieces that are too small to be handled safely. Be especially careful when sanding round pieces.



Welding (Oxy-acetylene and electric arc)

Only properly trained and instructed persons should operate welding apparatus.

Operator should wear a mask protecting eyes and face and suitable clothing for protecting the body from rays of arc or flame and against hot metal sparks.

When welding or cutting, use proper equipment, shields, booths, sheet-metal guards, asbestos paper or curtains to protect other persons from the arc rays and to keep flames, sparks, molten slag, and hot metal from coming in contact with combustible material.

Welding or cutting must *never* be permitted near explosive gases or flammable liquids, regardless of the precautions taken.

Before welding or cutting in a new location for the first time, check with the foreman or person in authority for possible serious explosion or fire hazard.

If feasible, move work to a location where there is no possibility of setting fires.

Remove combustible materials to a safe distance, if possible. Use noncombustible material for supporting work.

Before starting welding or cutting operations on a pipe or vessel which has, or may have, contained flammable materials, be sure that the container is free from explosive vapors. If possible, purge it with steam or an inert gas, or fill it with water while work is being done. Never work on a container that may be sealed or plugged so that the expanding gases cannot escape.

Keep a dry-chemical, or carbon-dioxide, fire extinguisher handy, if possibility of fire exists. On maintenance of carbon-dioxide fire extinguishers consult National Board of Fire Underwriters Pamphlet 10.

Areas in which cutting or welding is being done should be well ventilated.

Wear clear glass goggles when hammering or chipping scale.

For arc welding when changing electrodes, the operator must be kept insulated from the ground and metal objects nearby. Make welding connections direct to the ground whenever possible. When connecting to metal structures, make sure a fire cannot be caused at some distant point. Warning signs or other means should be used to keep people away from power lines to welding machine.

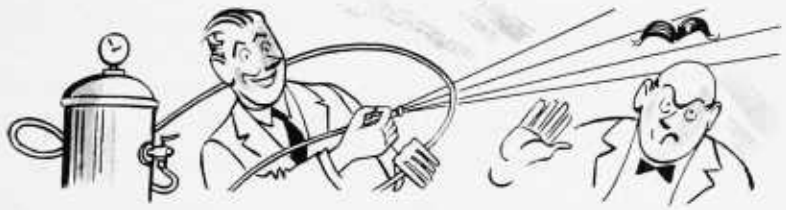
Use only hose made especially for oxy-acetylene welding and cutting. Do not use metal-covered hose. Use only standard hose connections in connecting hose to blowpipes and regulators.

Use regulators or automatic reducing valves *only* with the gas for which they are intended.

Do not store extra gas cylinders within the working area or in the direct rays of the sun.

For information on the safe handling of oxygen and acetylene cylinders, see "Safe Handling of Compressed Gases," Compressed Gas Manufacturers' Association, Inc., bulletin.

Compressed air



Many hazards arise from improperly installing, maintaining, and operating compressed-air equipment. Fatal accidents or serious injuries may result from explosions in air compressors and receivers, and also from the introduction of compressed air into the eyes, ears, or other openings of the body. Compressed air, when misused, can be extremely dangerous. Under no circumstances should a worker aim an air hose at anyone. Air under pressure will pass through clothing, and serious injury is possible. Its use for cleaning clothing, therefore, should be energetically discouraged.

For information on this subject, see "Compressed Air Machinery and Equipment," National Safety Council, Inc., Safe Practices Pamphlet 47.

Jointers

Be sure that the cutters are in good condition, sharpened, and securely held on the arbor.

Do not use jointer on pieces of wood less than 12 inches long.

When working on plywood, joint only the edges.

Power saws (band, bench, and swing)

Be sure that the saw is not defective and that it is firmly held in place and operated at the proper speed.

Saws should be equipped with proper guards and with "kick-back dogs."

Material should be held firmly against the gage while being sawed, with the hands at a safe distance from the saw. Be sure the material contains no nails.

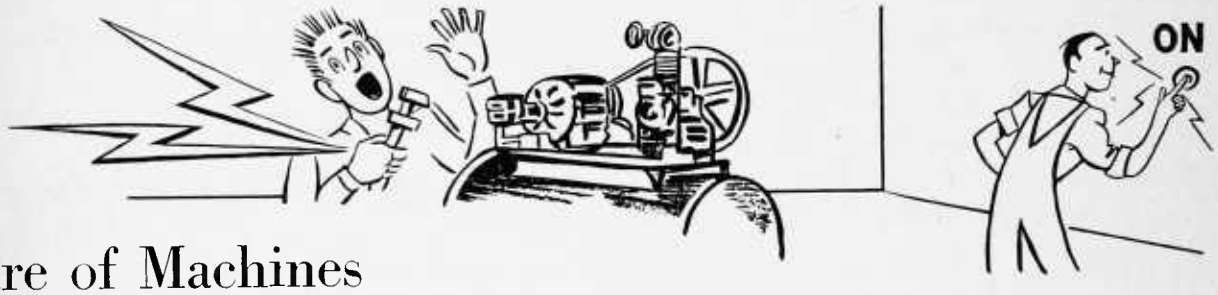
When short pieces are sawed, do not feed the stock with the fingers. Use a stick of hard wood made for the purpose.

Never place the hands back of the saw or pull the work through from the back.

When using the ripsaw, do not try to rip a piece that is too narrow.

Do not allow wood scrap to accumulate on the machine bed.

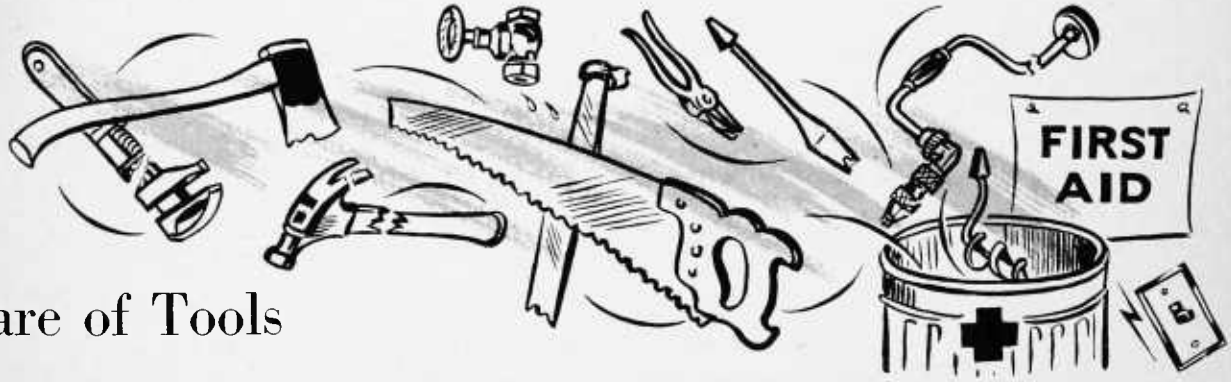
Before attempting to change saws or work on machine in any way, be sure to pull disconnecting switch on starter. Do not rely on the push-button control.



Care of Machines

All machinery should be kept in repair. Failure of a machine to run properly should be reported immediately to the foreman. Repairs or adjustments should not be made while machinery is in operation. The repairman should make sure that power cannot be turned on without his knowledge and permission.

All machines should be cleaned and oiled and their condition checked at regular intervals. Machinery should not be lubricated while in operation.



Care of Tools

The use of tools of poor quality or in poor condition is hazardous. Never use a tool with a faulty handle or a cold chisel, chisel bar, or cutter, or a tool with a mushroomed head. Such heads can readily be corrected by grinding.

Keep the jaws of all wrenches in good condition, and caution workers against misusing them.

Keep sharp-edged tools sharp. This will eliminate strains and slips. The edges should be protected while the tools are in storage.

Portable electric tools and pneumatic tools should be kept in perfect working condition. Special attention should be given to the cable and hose connections and to the control valves and switches.

Handling equipment and material

The hoisting and moving of heavy equipment must be supervised by a qualified individual. The lack of proper supervision or the presence of too many bosses may cause a serious accident.

The use of cranes must be restricted to designated individuals who are fully qualified to operate them and who will be responsible for their proper use. One of the chief dangers of using cranes is failure to properly secure the load to be moved. When a large traveling crane is not in use, the central chain must be secured to a vertical column and the lifting assembly must be left at least 8 feet above the floor. No one should be permitted to ride on the load or the hook.

When installing heavy apparatus, make ample provision for future dismantling when repairs will be required. Provide lifting hooks and supports for heavy parts that must be removed. Before installing or hoisting heavy equipment, consult the building superintendent as to possible overloading of floors or structural members.

Do not overload chain falls, blocks and tackles, or ropes. Know the load limits.

Do not stand beneath loads being lifted.

Limit loads lifted by hand and learn to lift the *right way* to avoid body strain. Bend your knees; keep your body erect; keep your mouth open; then push upward *evenly* and *gradually with* your leg muscles.

Do not use a ladder that is defective or insecurely supported. When a ladder is placed in position, the horizontal distance from the top support to the foot of the ladder should be about one-fourth the length of the ladder. Ladders for use on smooth surfaces should be equipped with safety shoes. Only one person should be on a ladder at one time. Ladders must not be placed in front of doors opening toward them unless the doors are blocked open, locked, or guarded.

Sharp edges and burrs on iron and steel stocks and splintered edges of lumber stocks may cause painful scratches and cuts. The use of hand-leathers and gloves in handling material will prevent many injuries of this nature.

When material is heavy or bulky, obtain help in handling or moving it. Select one individual to supervise or direct operations and abide by his instructions.

Metal and lumber stocks should be kept in racks provided for that purpose. They should not be allowed to lie scattered on the floor or to project into aisles or passageways, where they may cause injury.

See also "Machine Shops," National Safety Council, Inc., Safe Practices Pamphlet 39.

Housekeeping

Keep the plant clean; allow no trash or dust to accumulate.

Supply receptacles for waste materials. Place oily rags and other combustible wastes in metal containers with close-fitting covers.

Keep passageways and exits clear of obstructions.

Leave no lumber with protruding nails on the floor. Pick up all discarded material.

Never leave tools on a ladder or stairway.

Provide guards for openings in the floor, such as those caused by temporary removal of gratings and drain covers.

Do not leave broken glass in towels.

210527—54—5

Office and miscellaneous hazards

Falls may occur in all types of work, but they can easily be prevented. One of the most common causes is undue haste on a slippery floor or running up and down stairs or in corridors. Floors should not be highly polished. Spilled liquids should be removed promptly. Traffic avenues should be kept free of equipment or material which constitutes a tripping or obstruction hazard. Standing on chairs and stools or tilting chairs while sitting in them should be avoided.

Not more than one drawer of a filing cabinet should be pulled out at any one time. Two heavily loaded upper drawers opened at the same time may make the cabinet so top-heavy that it overturns. Desk and filing cabinet drawers should not be left standing open.

Stiff paper, if not handled carefully, may cause serious cuts.

Do not discard cigarette and cigar stubs, pipe ashes, and matches in waste-paper baskets; use ash trays.

Do not throw broken glass or other sharp objects into waste-paper baskets.

There is a collision hazard at every blind corner.

Corridors should be well lighted.

Protective equipment for personnel

Employees handling acids or other corrosive substances should wear rubber gloves, chemical workers' goggles or face shields, and aprons.

Goggles or face shields should also be worn by other employees engaged in work which may result in injury to the eyes. Goggles of the proper type should be used for the particular hazard involved, such as impact, dust, splash, glare, or injurious light rays.

Fitted or prescription spectacle goggles are furnished to all employees who work in areas designated as hazardous. They must be worn at all times in these areas for general work. For specified hazardous operations additional protection is required, as indicated in various places in this manual.

Safety shields constructed of shatterproof glass or heavy wire screening should be placed around all equipment where there is a possibility of rupture or shattering of the apparatus. These enclosures should be used even though the operator is wearing goggles or a face shield; there is always the chance that persons working near him, and not so protected, will be injured.

Employees whose duties bring or may bring them in contact with an atmosphere deficient in oxygen or with poisonous or irritating gases, fumes, vapors, or dusts should wear respirators, gas masks, or other protective breathing equipment approved by the United States Bureau of Mines. A gas mask is not protection against an atmosphere deficient in oxygen. In such situations, ventilation or a hose mask having an air or oxygen supply is required. (See p. 3.)

Protective equipment should be readily available and should be maintained properly. Employees should be trained in its proper use.

Adequate warning signs should be displayed prominently to indicate the nature of the precautions necessary around hazardous work.

Appendix

The following information is taken from "General Industry Safety Orders," Division of Industry Safety, Department of Industrial Relations, San Francisco, Calif.

Concentrations of various substances in which it is considered safe for men to work, whether for brief periods or for full working periods daily for an indefinite time, are given in tables 1 to 4. Most of the figures are tentative and subject to revision in the light of further research and experience. Even for those which are best established, differences of opinion are found among authorities. The figures are given as an indication of current opinion and practice, doubts being resolved on the side of safety.

It cannot be taken for granted that concentrations higher than those given in the table are safe for short and occasional exposure. There is no readily calculable relation between the effects of short, heavy exposures and long, light exposures. It cannot be assumed that a substance safe for 8 hours in a concentration of 100 parts per million will be safe for 1 hour at 800 parts per million; still less at 8,000 parts per million for 6 minutes. Neither can it be assumed that, because two substances are tolerable in the same concentration for long, light exposures, their action will be the same for short, heavy exposures, or vice versa.

The absence of a substance from the tables does not necessarily mean that it is less toxic than some of the substances listed. Many substances which it would have been desirable to include have been omitted for lack of data.

It is not implied that because two substances have the same or nearly the same maximum acceptable concentrations, the hazards connected with their use are necessarily of the same order of severity. In some cases, maximum acceptable concentrations are set up with a view to preventing systematic damage, and exceeding such concentrations may result in severe injury. In other cases, maximum acceptable concentrations are set up with a view to avoiding relatively slight, though still harmful, effects, such as dizziness or irritations of eyes, nose, or throat.

Substances which have the same maximum acceptable concentration expressed in parts per million do not necessarily present an equal hazard on a weight-for-weight basis. Other things being equal, the weight of a given volume of vapor is a function of the molecular weight of the substance, and a stated concentration in parts per million may represent for one substance several times the weight of the same concentration of another substance.

Table I. — Mineral Dusts

	Million particles per cubic foot
Total dust	50
Asbestos	5
Silica (free or uncombined)	
Less than 5 percent	50
5 percent to 25 percent	20
25 to 50 percent	10
Over 50 percent	5
Talc (commercial or industrial)	20
Talc (chemically pure steatite)	50

NOTE. The maximum acceptable concentrations for dusts in this Appendix contemplate the estimate of dust exposures by the method recognized by the U.S. Public Health Service.

Table II. — Metallic Dusts, Fumes and Vapors

	Milligrams per cubic meter
Antimony	0.5
Arsenic and compounds (except volatile hydrides)	0.5
Barium	0.5
Cadmium	0.1
Chromium, chromic acid and chromates (as CrO_3)	0.1
Lead	0.15
Manganese	6.0
Mercury	0.1
Selenium	0.1
Tellurium	0.1
Zinc oxide	15.0
Total metal fumes	30.0

Table III. — Miscellaneous Dusts, Fumes and Mists

	Milligrams per cubic meter
Chlorinated diphenyls	1.0
Chlorinated diphenyl oxide	1.0
Chlorinated naphthalenes:	
Tri- and mixtures of tri- and tetra-	5.0
Tetra-, penta- and mixtures of tetra- and penta-	1.0
Hexa- and mixtures of penta- and hexa-	0.5
Fluorides	2.5
Tetryl, TNT, DNT	1.5

Table IV. — Gases and Vapors

	Parts per million
Acetaldehyde	200
Acetic Acid	10
Acetic Anhydride	5
Acetone	500
Acetylene tetrachloride—See 1, 1, 2, 2-Tetrachloroethane.	
Acrolein	0.5
Acrylonitrile	20
Allyl alcohol	15
Allyl chloride	50
Ammonia	100
Amyl acetate	200
Iso-amyl alcohol	100
Aniline	5
Arsine	0.10
Benzene (benzol)	50
Benzine (gasoline)	500
Bromine	1
1, 3-Butadiene	1,000
n-Butanol (butyl alcohol)	50
2-Butanone	250
n-Butyl acetate	200
Carbon dioxide	5,000
Carbon disulfide	20
Carbon monoxide	100
Carbon tetrachloride	50
Chlorine	1

Table IV. — Gases and Vapors (Continued)

	Parts per million
Chlorobenzene	75
2-Chlorobutadiene (chloroprene)	25
Chloroform	100
1-Chloro-1-nitropropane	20
Chlorophenols *	5
Cresol	5
Cyanogen and compounds as CN †	20
Cyclohexane	400
Cyclohexanol	100
Cyclohexanone	100
Cyclohexene	400
o-Dichlorobenzene	50
1, 1-Dichloroethane (ethylidene dichloride)	100
1, 2-Dichloroethane (ethylene dichloride)	75
1, 2-Dichloroethylene	200
Dichloroethyl ether	15
Dichloromethane	500
Dimethylaniline	5
Dimethyl sulfate	1
Dioxane	100
Ethyl acetate	400
Ethyl alcohol	1,000
Ethyl benzene	200
Ethyl bromide	200
Ethyl chloride	1,000
Ethylene chlorohydrin	5
Ethylene dichloride. See 1, 2-dichloroethane.	
Ethylene oxide	100
Ethyl ether	400
Ethyl formate	100
Ethylidene dichloride. See 1, 1-dichloroethane.	
Ethyl methacrylate	400
Ethyl silicate	100
Formaldehyde	5
Gasoline	1,000
Glycol ethers:	
Diethylene glycol monoethyl ether (carbitol)	200
Ethylene glycol monoethyl ether (cellosolve)	200
Ethylene glycol monoethyl ether acetate (cellosolve acetate)	100
Ethylene glycol monomethyl ether (methyl cellosolve)	25
Ethylene glycol monomethyl ether acetate (methyl cellosolve acetate)	25
Ethylene glycol monobutyl ether (butyl cellosolve)	200
Heptane	1,000
Hexane	1,000
Hexanone. See methyl butanone.	
Hexone. See methyl iso-butanone.	
Hydrogen chloride (hydrochloric acid)	5
Hydrogen cyanide (hydrocyanic acid)	10
Hydrogen fluoride (hydrofluoric acid)	3
Hydrogen selenide	0.05
Hydrogen sulfide	20
Iodine	1
Isophorone	25
Mesityl oxide	50
Methanol (methyl alcohol)	200

See footnotes at end of table.

Table IV. — Gases and Vapors (Continued)

	Parts per million
Methyl acetate	200
Methyl bromide	20
Methyl butanone	100
Methyl chloride	100
Methyl cyclohexane	500
Methyl cyclohexanol	100
Methyl cyclohexanone	100
Methyl ethyl ketone. See 2-butanone.	
Methyl formate	100
Methyl iso-butyl ketone	100
Methyl methacrylate	500
Methylene dichloride. See dichloromethane.	
Monochlorobenzene. See chlorobenzene.	
Mononitrotoluene	5
Naphtha, coal tar	100-200
Naphtha, petroleum	1,000
Nitrobenzene	1
Nitroethane	100
Nitrogen oxides—NO_2	25
Nitroglycerine	0.5
Nitromethane	100
2-Nitropropane	50
Octane	1,000
Ozone	1
Pentane	1,000
Pentanone (methyl propanone)	200
Phenol	5
Phosgene	1
Phosphine	0.05
Phosphorus trichloride	0.5
Iso-propanol (iso-propyl alcohol)	400
Propyl acetate	200
Iso-propyl ether	500
Stibine	0.1
Stoddard solvent	1,000
Styrene monomer	200
Sulfur chloride	1
Sulfur dioxide	10
Sulfur trioxide	10
1, 1, 2, 2-Tetrachloroethane	5
Tetrachloroethylene	100
Toluene (toluol)	200
Toluidine	5
Trichloroethane	50
Trichloroethylene	100
Turpentine	100
Vinyl chloride	500
Vinyl cyanide. See acrylonitrile.	
Xylene (xylol)	200
Xylidine. See dimethylaniline.	

*For monochlorophenol. The mg-per-cubic meter values for other chlorophenols depend on their molecular weights.

†For cyanogen, C_2N_2. The mg-per-cubic meter values for cyanogen compounds depend on their molecular weight.

☆U. S. GOVERNMENT PRINTING OFFICE: 1954—210527


SAFETY
AWARD


UNITED STATES DEPARTMENT OF AGRICULTURE
1862
1889
AGRICULTURE IS THE
AND COMMERCE
FOUNDATION OF MANUFACTURE