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ACCIDENT PREVENTION MANUAL

for Industrial Operations

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5th EDITION

NATIONAL SAFETY COUNCIL Chicago, Illinois 60611

PREFACE

The dominant theme of this Manual is safety; the pervading purpose is accident prevention. Industrial accident prevention has as its primary objective the prevention of injuries to persons; an auxiliary goal is the prevention of damage to equipment and other property.

The favorable reception of the first four editions of this book by safety engineers and others who have the responsibility for accident prevention has provided the incentive for this revised Fifth Edition.

The object was to update the material and extend its scope while being more specific in both word and illustration to reduce the bulk of the book. For improved readability, a slightly larger and clearer typeface has been used. For easier reference, the index includes as many synonyms as possible, but it has been considerably shortened by including only major references under each subject. If a subject is discussed on successive pages, only the first page is referenced.

Two new chapters have been developed: "Audio-Visual Aids" and "Industrial Noise." Many others have been completely revised. For more logical organization, some chapters have been retitled and material has often been regrouped.

Some duplications will be found among the sections. The Editors think this facilitates the use of a section and avoids the necessity for frequent reference to other parts of the book. Where a significant amount of additional information is in another chapter, cross references are provided.

The preparation of each chapter was directed by a National Safety Council staff specialist in the field. In some cases, new material was developed by recognized authorities who are identified by the footnote on the first page of each chapter. All worked with many collaborators. For all of these men, the most satisfying reward is the knowledge that they have contributed to the more effective performance of the industrial safety men of today, and to the education of future safety men.

To increase the effectiveness of those responsible for industrial accident prevention, much detailed material had to be included, but it is not the purpose of this Manual to serve as a complete handbook of all design, fabrication, operation, inspection, and management principles. Rather, it attempts to set forth the important points to be considered when evaluating an industrial accident prevention program including the safe operation of equipment and processes.

This Manual does not constitute an official code or standard, and it does not obviate prescribed regulations or minimum safe practices. When practices are described, it is not intended that they supplant other practices that have proven satisfactory, nor is their description intended to discourage innovation and originality in contributing to ever-more-effective industrial accident prevention.

No one prescribed safety formula can be superimposed on all accident-prevention programs. As a suggestive guide the Manual necessarily speaks in broad and general terms; its contents must be adapted to the specific circumstances of the particular operation. Ultimate responsibility, therefore, must rest in the *selection* of the technique or method for correcting any given condition or situation.

THE EDITORS

Free silica is uncombined silicon dioxide (SiO_2). Silicates contain silicon and oxygen combined with other elements in more complex molecules. The SiO_2 reported in chemical analyses for mineral and geological reports is the *total* of the silicon dioxide present, both the free silica (if present), and the silica combined in the mineral. Such analyses are not reliable indications of the silicosis potential of the material, because it is the uncombined or free silica that is most important in industrial dust exposure. So that an exposure can be properly evaluated, the percentage of uncombined silica must be determined by petrographic analysis using a polarizing microscope or, preferably, by X-ray diffraction analyses and special analytical chemical procedures.

There has been some experimental evidence that some dusts may tend to inhibit the action of silica on the body, but this inhibiting action is so slight and uncertain that it must be discounted in practice. In fact, there is also evidence that the nonsiliceous components of a dust mixture containing free silica may provoke a disabling condition more severe than that caused by the silica acting alone.

With the exception of asbestos and some talcs, the silicate dusts do not ordinarily cause a serious disabling lung condition such as is produced by free silica. Much higher levels of silicate dusts than of free silica dust can be tolerated. In many industries, men have worked with silicate dusts that contained no free silica without development of disability or of nodulation in the lungs. The X-ray may show shadows indicating dust deposits in the lungs, but the pneumoconiosis is essentially harmless. However, partially disabling pneumoconioses have been reported where men have worked for long periods of time in very high concentrations of certain silicate dusts. Disabling pneumoconioses from exposure to abnormally high concentrations of mica, tremolite talc, and kaolin dusts have been described in the literature. The clinical signs are not the same for these silicate dusts as for free silica, but the symptoms can be marked.

Asbestosis. Several minerals having a fibrous character are classed as "asbestos"—hydrated silicates of magnesium with variable amounts of iron, calcium, sodium, potassium, and aluminum present as impurities. The fine airborne fibers of asbesto[s] pass through the upper respiratory t[ract] the lower parts of the lungs to cause [irri]tion and to form "asbestos bodies" w[here] the fibers are encapsulated. This [dif]fibrosis probably begins as a "collar" [a]t the terminal bronchioles. There is evid[ence] that other minerals having a fibrous [char]ter (except glass fiber) can produce a [reac]tion similar to that of asbestos.

Following a study by the U.S. Pub[lic] Health Service of the asbestos textile ind[us]try,* it was recommended that the dust [con]centration be kept at less than 5 mppc[f] prevent asbestosis. Evaluation of an [ex]sure to asbestos dust is based on the [to]amount of dust, since the concentration [of] injurious fibers will be kept within [safe] limits if the fine dust is kept below [the] suggested threshold limit.

Miscellaneous pneumoconioses. Even though a dust is classified as harmful amounts above the TLV can lead to trouble by causing a pneumoconiosis, mechanically irritating the walls of the respiratory system or interfering with ordinary lung processes. Mica dust and kaolin dust are two good examples of dusts that ordinarily are considered benign but amounts above the TLV can cause a troublesome pneumoconiosis. Mica pneumoconiosis has been observed in grinding operations where mica dust, but no free silica was present. There were marked changes in the X-ray pictures of the lungs and some disability. The cases occurred where the dust exposures were massive over many years.

Toxic dusts and fumes

Systemic reactions are caused by toxic dusts and fumes of various elements and their compounds and by certain organic compounds. All metallic fumes are irritating, especially when freshly generated. Industrially important metals and their compounds that can have a toxic effect when the dust or fumes are inhaled include arsenic, antimony, cadmium, chromium, lead, manganese, mercury, selenium, tellurium, thallium, uranium, and a few others.

*U.S. Public health Service, Washington D.C. "A Study of Asbestosis in the Asbestos Textile Industry." Bulletin No. 241. 1938.

The effect of some metals, such as magnesium and zinc, appears to be transient. Only limited data are available on the exotic and rare earth metals.

Although the dusts and fumes from metals with low toxicity do not need as much attention as the dusts and fumes from highly toxic metals, they should not be neglected or disregarded. The metals with low toxicity are more readily controlled because greater amounts can be tolerated, but their dusts and fumes should be kept at reasonable levels since excessive amounts of any of them can be harmful.

Inhalation of the dust of lead compounds is the most common mode of entry of lead into the system, and ingestion of lead compounds can add to the problem if personal hygiene is poor. Workers therefore should be encouraged to wash thoroughly before eating, and lunchrooms should be apart from work areas.

Lead is a normal constituent of plants and animals, and people ingest and excrete it daily even though they are not exposed to lead in their daily work. When intake rates exceed the normal excretion rates, however, lead builds up in the body. When the accumulation reaches a sufficient level, symptoms of *poisoning* or *intoxication* appear. The concentration of airborne lead should therefore be kept below the threshold limit because of lead's high toxicity and its tendency to accumulate in the human system.

Beryllium intoxication is a severe systemic disease that can result from the *inhalation* of the dust or fume of metallic beryllium, beryllium oxide, and soluble beryllium compounds. (There is no evidence of intoxication from the *ingestion* of insoluble compounds.) Only the inhalation of the beryllium-bearing dusts or fumes produces systemic disease. Accordingly, control of such dusts and fumes to keep them below the concentration specified by ACGIH (American Conference of Governmental Industrial Hygienists) threshold limit values is a basic protective measure.

When the soluble salts of beryllium, especially beryllium flouride, contact cuts or abrasions on the skin, deep ulcers may be formed which heal very slowly, and complete surgical excision of the ulcer is sometimes required to effect healing.

Metal fume fever is an acute condition caused by a brief high exposure to the freshly generated fumes of metals such as zinc, magnesium or their oxides. Symptoms appear from 4 to 12 hr after exposure and consist of fever and shaking chills. There is complete recovery usually within one day, and ordinarily the employee can return to the same job without recurrence. However, after a period in which there has been no contact with the fume, for example, after a layoff, resumption of exposure is likely to bring on an attack.

Metal fume fever is caused by heavy concentrations of fumes. Zinc oxide fume is the most common source, but cases caused by the inhalation of fumes from magnesium oxide, copper oxide, and other metallic oxides have also been reported. The condition does not occur from the handling of these oxides in powder form. Apparently, it results only from the inhalation of extremely fine particles freshly formed as fume (called a "nascent fume"). Cadmium, mercury, and other metals may also produce a fever followed by the toxic effects of the element.

Organic Solvents

The widespread industrial use of organic solvents presents a major problem to the industrial hygienist, the safety engineer, and others charged with the responsibility for maintaining a safe, healthful working environment. Getting the job done without hazard to employees or property is dependent upon the proper selection, application, handling and control of solvents and an understanding of their properties.

Labeling

The labeling of solvents to indicate their properties and health and fire hazards is an extremely important method for recognizing and evaluating the hazards. In fact, if a solvent is not properly labeled, it should not be used. The purchasing department can greatly help the safety department by notifying suppliers that only properly labeled solvents will be accepted in the plant.

Uniformity in language and layout is desirable to simplify understanding of solvent use. The MCA's *Guide to Precautionary Labeling of Hazardous Chemicals*, Manual L-1,* recommends the following subject mat-

*Manufacturing Chemists Assn., 1825 Connecticut Ave. NW., Washington, D.C.

TABLE 39-B
MAJOR CLASSES OF COMMON ORGANIC SOLVENTS

Class	Typical Example	Chemical Formula
Alcohols	Ethyl alcohol	CH_3CH_2OH
Aldehydes and ketones	Acetone	$(CH_3)_2CO$
Glycols and glycol ethers	Cellosolve	$C_2H_5O(CH_2)_2OH$
Aromatic hydrocarbons	Toluene	$C_6H_5CH_3$
Aliphatic hydrocarbons	Mineral spirits	(Mixture of paraffins and cycloparaffins)
Halogenated hydrocarbons	Methyl chloroform	CH_3CCl_3
Esters	Ethyl acetate	$CH_3COOC_2H_5$

ter and organization:

1. Name of product.
2. Signal word designating degree of hazard—DANGER! WARNING! or CAUTION! POISON and the skull-and-crossbones should be used for chemicals defined as poisons or required by law to be labeled as such. POISON should be used in addition to the other signal words.
3. Statement of hazards (EXTREMELY HAZARDOUS, FLAMMABLE).
4. Precautionary measures to be taken or action to be avoided (avoid breathing vapor, keep away from heat or open flame).
5. Instructions in case of contact or exposure (flush eyes or skin with plenty of water for at least 15 min.).
6. POISON legend, followed by first-aid instructions or antidote.

General physiological effects

Physiological effects from industrial organic solvent exposures come principally from skin contact and inhalation of the vapors. Ingestion with resultant absorption into the digestive tract is not normally considered an exposure hazard in industry. If the solvent is present in such amounts that ingestion becomes a hazard, there will always be a much greater inhalation hazard.

Inhalation of excessive amounts of solvent vapors may produce various physiological effects. In some instances, it may result in impairments, such as lack of coordination, drowsiness, and similar symptoms that may lead to increased accident proneness. Other effects may include damage of the blood, lungs, liver, kidney, gastrointestinal system, and other critical organs or tissues.

Some generalizations can be made concerning the physiological effects of each class of organic solvent shown in Table 39-B; however, specific details for individual solvents are given in Chapter 40, "Industrial Toxicology."

Alcohols are generally anesthetic, irritating to the eyes and upper respiratory tract, and may possess other toxic properties. Their toxicity increases and volatility decreases with increasing molecular weight. Toxic concentrations of alcohol vapors and mists have characteristic odors and irritant effects.

Aldehydes and ketones, as a rule, are both irritant and narcotic, with the irritating action predominating in the aldehydes, and the narcotic action being the prime hazard in the ketones. High concentrations of either can be identified by odor and irritant effect.

in the handling of wet dross from a light metals plant, in the cleaning of tank cars which have held sulfuric and hydrochloric acids, in the cleaning of pipes with an acid contaminated with arsenic, in the precipitation of cadmium with metallic zinc, and in other operations.

Arsine rapidly destroys the red cells. After it has been inhaled, the first signs are those of lack of oxygen. After some time the body begins to excrete the damaged red cells, which appear as a dark or bloody urine. The kidneys may then become too clogged to operate at all. Arsine, in very small amounts, is also capable of producing a chronic type of poisoning, but it is more typically a source of acute episodes.

The possibility of arsine formation should always be considered when there is freshly formed hydrogen around ores of the heavy metals, since arsenic is widely distributed in small amounts and only a trace of it is required to produce enough arsine to be troublesome.

One of the more common sources of arsine incidents in recent years has been the handling of dross from the aluminum refining of metals. Probably the most significant observation about these cases, aside from the fact that the moisture in the atmosphere is enough to form arsine, is the fact that the people involved in them have not been aware of the garlic-like odor which is supposed to be a warning of the presence of arsine.

See *Hygienic Guide*.

Asbestos is a hydrated magnesium silicate found in the minerals chrysotile, amianthus, actinolite, and tremolite. Practically all the commercial asbestos is either chrysotile or amianthus, and about 90 per cent of that used in this country is chrysotile. It is used almost exclusively for heat insulation or for textiles which must resist high temperature, such as heat-resistant clothing and brake linings.

Inhalation of excessive quantities of asbestos fiber can produce a fibrosis in the lungs similar to that found in silicosis but somewhat milder and usually not so rapidly progressive. Like silicosis, the condition develops and advances slowly and is equally resistant to treatment. There is also good evidence that inhaled asbestos causes lung cancer.

See *Hygienic Guide*.

Barium, in the form of its soluble salts, is toxic on both ingestion and inhalation and highly caustic when applied to the skin. The carbonate and sulfide are sufficiently soluble to be toxic, although not very caustic. The sulfate, which is used as a contrast medium in X-ray work, is too insoluble to show any toxicity, and soluble sulfates are specific antidotes for ingested barium salts.

Since these salts produce violent stimulation of all muscle, upon ingestion they produce severe disturbances of the digestive system. After absorption, the barium salts increase blood pressure by constriction of the arterial muscle, slow down heart beat by an action similar to that of digitalis, and first excite and then paralyze the central nervous system. In spite of the high inherent toxicity, there are few cases of industrial poisoning with barium.

Barium is a heavy metal, and the dust of the insoluble salts will collect in the lungs and give rise to the condition known as baritosis. Its nodular appearance on X-ray film may be mistaken for that of silicosis. Men showing the sign of baritosis are apparently not disabled or inconvenienced in any way.

See *Hygienic Guide*.

Benzene (benzol) is a colorless, flammable, volatile liquid with a rather pleasant aromatic odor. Its fire hazard is between ethyl alcohol and ethyl ether. The greatest hazard is that of chronic poisoning by inhalation of comparatively small amounts over a long period of time. It is one of the two or three most dangerous organic solvents in commercial use, and acts primarily on the blood-forming organs, producing severe anemia, bleeding under the skin, and great reduction in the ability of the blood to clot.

The most convenient measurement of damage is given by a blood count. People who may be exposed to benzene vapor should have blood counts at regular intervals and significant changes in the count should be closely investigated.

Headaches, dizziness, fatigue, loss of appetite, irritability, nervousness, nosebleed, and other signs of abnormalities of the blood may or may not be present in chronic poisoning.

A single heavy exposure to benzene vapor may produce a serious acute effect, similar

des[illegible] ad installation of the combination system must provide not only a suffic[illegible] or long periods of time and under conditions of poor contrast. The eye protection. As far as possible, it should eliminate direct and reflected glare as well as objectionable shadows. amount of light, but also the proper direction of light, diffusion, and

†The specular surface of the material may necessitate special consideration in selection and placement of lighting equipment, or orientation of the work.

††Special lighting such that (1) the luminous area be large enough to cover the surface which is being inspected and (2) the brightness be within the [illegible]

TABLE 45-H. A GUIDE TO VENTILATION RATES FOR TYPICAL INDUSTRIAL EQUIPMENT

State or Local Regulations Should Be Consulted and Followed Where Higher Ventilation Rates Are Specified

Operation	Ventilation		Usual Transport Velocity (fpm)	Remarks and References
	Type of Hood	Air Flow		
Abrasive blast rooms (sand, grit, or shot)	Tight enclosure with air inlets (usually in roof)	60-100 fpm downdraft (long rooms of tunnel proportions 100 fpm crossdraft)	3,500	Ref. 8. Many codes specify minimum downdraft of 80 fpm
Abrasive blast cabinets	Tight enclosure with access openings	20 air changes per minute but not less than 500 fpm through all openings	3,500	Ref. 14
Asbestos Carding Spool winding	 Enclosure Local hoods	 800 cfm per machine 50 cfm per spool	 3,000 3,000	Ref. 2, 16, 17. See references for details and other operations
Bagging Open bag top	Booth or enclosure (provide spillage hopper)	Paper bags—100 cfm per sq. ft. open area Cloth bags—200 cfm per sq. ft. open area	3,500 3,500	Ref. 18
Barrels—Drums (filling or removing material by scoop)	Local hood Booth	100 cfm/sq. ft. of container cross section 100 fpm at face	3,500 3,500	Ref. 15, 19. Hood with 1-in. slot extending 120 to 180 deg container. Does not confine spillage. Confine spillage—also recommended for container upsetting.
Belt conveyors	Hood at transfer point	Belt speeds less than 200 fpm-350 cfm per foot of belt width, but not less than 150 fpm through open area. Belt speeds over 200 fpm—500 cfm per foot of belt width but not less than 200 fpm through open area	3,500	Ref. 18, 20.
Bins (closed top)	Connect to bin top away from feed point	150-200 fpm through open area at feed points	3,500	Ref. 19, 20
Bucket elevators	Tight casing required	10 cfm per sq. ft. of elevator casing cross-section	3,500	Ref. 19

TABLE OF CHEMICAL HAZARDS—*Continued*

Substance	Flash point ° F.	Explosive limits % by volume		Auto-ignition temperature ° F.	Maximum acceptable concentration for 8-hr. exposure	Usual mode of entrance to body	Signs and symptoms of poisoning
		Lower	Upper				
ammonia	gas	16	25	1204	100 p.p.m.[1]	inhalation	Severe irritation of eyes and respiratory passages, cough, caustic action on skin.
amyl acetate–n	77	1.1	...	750	400 p.p.m.[1, 2] 200 p.p.m.[36]	inhalation	Irritation of eyes and respiratory tract, headache and dizziness, cough, nausea.
amyl alcohol–iso	109	1.2	...	650	100 p.p.m.[36]	inhalation	Same as amyl acetate.
amyl alcohol–n	100	1.2	...	700	100 p.p.m.[2]	inhalation	Same as amyl acetate.
aniline	168	...	...	1000	5 to 7 p.p.m.[5]	absorption through skin, inhalation, or ingestion	*Acute:* weakness, dizziness, blueness of lips, fainting, possible death. *Chronic:* disturbances of equilibrium, nausea, vomiting, diarrhea, eczema, sleepiness, and irritability.
antimony (salts)	metal and sulfides flammable				0.5 mg/cu.m.[36]	inhalation of dust, ingestion	*Acute:* vomiting, colic, diarrhea, irritation of mouth and throat. *Chronic:* indigestion, loss of weight and appetite, sometimes severe dermatitis.
arsenic	...	...	...	...	0.15 mg/cu.m.[6] 0.5 mg/cu.m.[38]	inhalation of dust, ingestion and direct action on skin and mucous membrane	Irritation of skin, loss of hair and nails, perforation of nasal septum, hoarse voice, cough, neuralgic pains, diarrhea.
arsine	...	...	...	...	1 p.p.m.[5] 0.05 p.p.m.[30]	inhalation	Headache, nausea, vomiting, chills and shivering, jaundice, dark or bloody urine.
asbestos	non-flammable				5 m.p.p.c.f.[5]	inhalation	*Chronic:* shortness of breath, asbestos corns.

TABLE OF CHEMICAL HAZARDS—*Continued*

	Auto-ignition temperature	Maximum acceptable concentration for	Usual mode of	Signs and symptoms

TABLE OF CHEMICAL HAZARDS (*continued*)

Substance	Flash Point (deg F)	Flammable or Explosive Limits (% by volume)		Auto-ignition Temp. (deg F)	Boiling Point (deg F)	Vapor Volume (cu ft) per gal)	Evaporation Rate (Ether=1)**	References			
		Lower	Upper					NSC Data Sheet	MCA Data Sheet	ACSC Bulletin	AIHA Hygienic Guide†
arsenic	—	—	—	—	1,139	—	—	499	SD-60		12-58
arsine	gas	—	—	—	-67	—	—				6-56
asbestos	—	nonflammable		—	—	—	—				4-58
barium	element ignites spontaneously with moisture, and peroxide, chlorate, and nitrate react violently with flammable materials				—	—	—				12-62
benzene	12	1.4	7.1	1044	176	37	2.8	308	SD-2	C-77	12-61
benzoyl chloride	162	—	—	—	387	28	103				
benzoyl peroxide	—	—	—	—	decomposes at 250 F	—	—		SD-81		
benzyl chloride	153	1.1	—	1085	354	28	47.8		SD-69		
bromine	—	nonflammable		—	138	—	—	313	SD-49	C-49	8-58
bromochloromethane (methylene bromide)	—	nonflammable		—	154	—	—				12-61