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PLAINTIFF'S EXHIBIT

DOW-1634

TABLE 2.—RESPIRATOR CLASSIFICATION

Respirator	General Design Features	Protection Provided
I. Air-Purifying Respirators.	Filter (chemical or mechanical, for removing contaminant or contaminants from inhaled air) and facepiece attached to filter directly or by means of short length of flexible rubber tubing. Entire device is carried by the wearer.	Against specific contaminants or types of contaminants. No protection against atmospheres deficient in oxygen.
A. Chemical-Filter Respirators.....	Canisters or cartridges containing suitable chemicals attached directly or by means of short length of rubber tubing to full face piece or half mask.	Against gaseous contaminants.
1. Gas Mask.....	Canisters with chemicals for individual gases or combinations thereof.	Up to 3% ammonia and 2% most other gases and/or vapors.
2. Chemical - Cartridge respirators	Cartridges with chemicals for individual gases or combinations thereof.	Against very low or nuisance concentration of gases and/or vapors.
B. Mechanical - Filter Respirators (commonly called dust respirators).....	Fibrous filter attached to half mask face piece directly or by means of a short length of flexible rubber tubing.	Against particulate contaminants.
1. Dust.....	Do.	Against dusts of all kinds.
2. Fume.....	Do.	Against fumes of various metals. Since fumes are probably more difficult to remove by mechanical filtration than other kinds of particulate matter with the possible exception of smokes, this respirator will protect against such particulate matter as dusts and mists.

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TABLE 2—*Continued*

Respirator	General Design Features	Protection Provided
3. Mist	Fibrous filter attached to half mask face piece directly or by means of a short length of flexible rubber tubing.	Against mists as produced by spray-coating with paint and vitreous enamels, chromic acid mist as produced in chromium plating, and mists of other materials whose liquid vehicle does not produce harmful gases or vapors.
C. Chemical and Mechanical-Filter Respirator	Chemical and mechanical filter attached to face piece directly or by means of a short length of flexible rubber tubing.	Against combinations of gaseous and particulate contaminants.
II. Supplied-Air Respirators. A. Hose Mask with Blower	Blower (Manual or Power - operated), large diameter hose, harness, and face piece.	Against any atmosphere.
B. Hose Mask without Blower	Large diameter hose, harness, and face piece.	Against any atmosphere, but should not be used in immediately harmful atmosphere.
C. Air-Line Respirators	Air supplied from special system or compressed air line to wearer through small diameter high pressure hose, reducing valve, short piece of flexible rubber tubing and face piece.	Do.
D. Abrasive Blasting	Features same as 1, 2, 3 above (3 is more common) but in addition this device has suitable hood to protect wearer against rebounding abrasive.	Same as 1, 2, or 3 above, depending upon features but in addition has protection against impact and abrasion from rebounding abrasive material.

tion. They are used effectively, however, on jobs such as abrasive blasting, paint chipping, handling used storage battery plates,

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cadmium oxide manufacture, welding operations, spraying of paints and glazes, the manufacture and use of pigments and dyes, and the like. Their most important use is under conditions where protection is required intermittently as in cleaning out operations; sweeping; after blasting; in removing cores from large foundry castings; shoveling, screening, and handling of materials; and the operation and maintenance of processing equipment.

It is the duty of management to decide whether respirators are needed. In no instance should they be selected as the control measure merely because they cost less than the other appropriate control systems. However, they may be used as a temporary expedient until the more satisfactory control measures have been placed in operation. If, after all the pertinent factors have been considered, it is concluded that respirators are needed, good respirators of the proper type should be purchased; they should be given to the workers with adequate instruction as regards the need for and proper wearing thereof, and a satisfactory system of maintenance should be set up.

The *selection* of the proper respirator is not an easy task. Some of the important factors which must be considered are: (1) nature of contaminant, that is, whether particulate or gaseous; (2) concentration of contaminant; (3) area of operation of wearer; (4) percentage of time respirator must be worn; (5) possible interference with operation, and (6) other protective devices needed by the wearer such as goggles, shields, or hoods. Table 2 will help in the selection of the appropriate device for a given operation.

Respirators, with the exception of the chemical cartridge type, are approved by the U. S. Bureau of Mines if they pass approval schedules formulated by that agency.[13] A large variety of approved respirators is available today, and only respirators which bear this approval label should be used. Lists of approved respirators are available from the U. S. Bureau of Mines, Department of the Interior, Washington, D. C.

Maintenance, Housekeeping, and the Education of the Worker

Even though these three items are discussed individually in this section, they are interdependent. It is impossible to have good maintenance unless the housekeeping is good and the worker has been informed of the need for the control measures and the proper operation thereof. Any attempt to maintain working

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equipment in good condition and to keep the work place in good order, is doomed to failure unless the worker is given the necessary instruction.

Maintenance.—It is not enough to purchase and install good, carefully designed equipment. Even the best equipment will become ineffective in a relatively short time unless it is maintained in good working condition. Maintenance is a duty of management and the worker. It is the duty of the worker to handle the equipment as intended, to keep it as clean as the nature of the operation will permit, to report to the management all signs of wear or failure and in very small industries to lubricate the moving parts. It is the duty of the management to provide the necessary personnel or instruct the proper personnel to inspect, lubricate, clean out, and repair the equipment routinely. Improper maintenance is evidenced by such indications as badly dented or collapsed hoods or ductwork; torn bags in bag-type collectors; ducts clogged with waste of all kinds, paper, or articles of clothing; collectors not functioning because they are not cleaned; dirty respirator filters; exhalation valves or filters missing from respirators; holes in ductwork; and ductwork badly corroded.

Much equipment such as the component parts of exhaust ventilation systems is expensive and an honest effort is usually made to maintain it in good condition to avoid the need for frequent replacements. However, respirators are relatively inexpensive and it is not unusual to find such equipment in use day in and day out without any provision for the maintenance thereof. Little good will be accomplished by the purchase of good respirators unless a satisfactory system is devised for their maintenance. These devices, even though rugged in construction, require daily inspection and cleaning if they are to function effectively.

The *most satisfactory method* of maintaining respirators in good condition is briefly as follows:[14] (1) mark each worker's respirator with his employment number; (2) collect all used respirators at the end of each shift; (3) distribute the cleaned devices at the beginning of each shift; and (4) assign one employee, either part-time or full-time, if necessary, to the careful cleaning, sterilizing, and repairing of all respirators. The fact that each worker always gets his own respirator in a clean well-kept condition will go a long way toward overcoming the objections usually presented by workers against wearing such devices.

Housekeeping.—As used here, the term "housekeeping" refers principally to the general cleanliness and orderliness of the plant,

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equipment, and machinery. Housekeeping is helped greatly by careful attention to details in the design of the plant so that the equipment and machinery are located in a methodical and systematic manner. In operating plants, housekeeping is a responsibility of the management and worker. It is the responsibility of the management to provide the requisites for good housekeeping, and it is the duty of the worker to use the facilities provided to the best advantage. Some of the *items* which are *essential* to good housekeeping are: (1) covers for containers; (2) vacuum cleaners, brooms, or hoses for cleaning; (3) shelves or compartments for storage of equipment or materials when not in use; (4) lockers for clothing; (5) toilets and wash rooms for personal hygiene; (6) trash and garbage receptacles—and they should be emptied frequently and cleaned routinely; (7) cuspidors, preferably of the disposable type, for workers who use chewing tobacco; and (8) barriers, guards, or baffles to prevent flying materials such as cutting oils, from getting on the floor and other equipment. Having a suitable place for everything and keeping everything in its proper place will go a long way toward keeping the general atmospheric contamination at a minimum.

Education of the Worker.—The education of the worker comprises two distinct subjects: (1) why something should be done, and (2) how it should be done. Such information is essential to the proper accomplishment of the workers' regular duties as well as to the proper operation and use of the various control devices. A worker cannot be expected to wear his respirator or goggles, or to turn on an exhaust blower, or open a damper unless he knows why he is doing it. Consequently, his education is of utmost importance and cannot as a rule be left entirely to the foreman. Frequent safety meetings and other meetings are necessary for the education of the worker in the proper use of his various safety and health equipment. Only by incessant instruction will the task of educating the worker be accomplished successfully.

SPECIFIC CONTROL MEASURES BY OPERATION

The present emergency has resulted in the introduction of many new operations and processes into industry and in the tremendous expansion of many operations and processes which were formerly done on a small scale. Consequently, new or increased health hazards are being constantly encountered.

While it is impossible to cover all of the new problems, there is presented herein in alphabetical order a number of new haz-

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ards by operation and recommended control measures for the safe performance of these operations. In certain instances, it is desirable to refer to the chapter on *Occupational Dermatoses.*

Any material potentially toxic should be treated as though it were toxic until it has been shown to be otherwise.

All maximum allowable concentrations given in the following discussions are based on an average eight-hour daily exposure unless otherwise stated.

Abrasive Cleaning

Abrasive cleaning or abrasive blasting may be carried out with sand or steel shot as the abrasive. The health hazard associated with steel shot blasting operations is much less severe than with sand blasting operations; consequently steel shot should be used wherever possible. However, if steel shot is not available or results in an inferior product, sand should be used and can be used safely if the necessary precautions are observed, as given below:

Sandblasting.—The potential health hazard in sandblasting operations is dust of a high free silica content. The maximum allowable concentration of free silica (SiO_2) is five million particles per cubic foot of air (m.p.p.c.f.), as determined by the standard light field technique.

The dust hazard in sandblasting operations may be controlled by the following methods: (1) the use of properly designed mechanically exhaust-ventilated machines, cabinets, or rooms; (2) the use of personal protective devices; and (3) good housekeeping.

As a rule, *production abrasive cleaning operations* can be carried out in mechanical devices such as enclosed tumbling barrels, and rotary tables which are provided with adequate local exhaust ventilation. Wherever possible, devices of this nature should be used and should be maintained in good working condition so that their dust control effectiveness is not impaired. The amount of air which must be exhausted from the various types of automatic abrasive cleaning devices varies tremendously, depending upon a multitude of factors. In no instance, however, should the quantity of air exhausted be less than that required to produce a velocity of about 500 to 1000 f.p.m. at all openings from which dust might escape.

Abrasive cleaning which requires *manual operation* may be carried out in small mechanically exhaust-ventilated cabinets

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which enclose the operation entirely with the exception of several holes in one wall to accommodate the hands and arms of the operator. Where possible, these access openings should be sealed with suitable flexible washers through which the hands may be inserted and which permit free movement of the arms for the operation. The precautions regarding maintenance and ventilation rate given in the previous paragraph apply for these devices also.

Large objects should be cleaned in suitable rooms or chambers which are provided with mechanical exhaust ventilation to prevent the dust from entering the surrounding atmosphere. These operations are usually conducted manually and the operator should be protected by means of a *supplied-air respirator* (*abrasive blasting helmet*) approved by the U. S. Bureau of Mines. The precautions concerning maintenance and the ventilation rate cited in the foregoing paragraphs should be observed for abrasive blasting rooms also.

It is usually economical to collect the abrasive sand from the dust collecting system for reuse. Whether or not this is done, the dust should be collected from the exhausted air before it is discharged to the outside and the discharge outlet should be located at a point which will prevent the reentrance of the contaminated air into the buildings. In no instance should the filtered air be recirculated into the building. The discharge of the dust collector hopper should be provided with a dust-tight flexible sleeve which is attached to the top, or extends to the bottom, of the receptacle for the collected material to prevent the escape of dust when the collector hopper is emptied.

Good housekeeping which includes such items as keeping the floor, ledges, and machinery free of sand and dust; emptying the collector hoppers frequently and routinely; maintaining all connections through which dust or dust-laden air are conveyed in a dust-tight condition; and cleaning, sterilizing, and repairing the personal protective devices daily will aid considerably in keeping the dust concentration in the inspired air at a safe level.

Shotblasting.—The potential health hazards in shotblasting operations are metallic dusts and silica dusts in those instances where objects having sand on their surfaces are cleaned. The maximum permissible safe concentration for some metallic dusts is fifty million particles per cubic foot of air; for free silica dust, five million particles, as determined by the standard light field

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technique; and for lead dust, 0.15 milligrams per cubic meter of air (mg./m.^{3}).

Even though the health hazard with shotblasting as a rule is much less severe than with sandblasting, the same general control measures are applicable. However, the various precautions need not be observed as rigidly as is the case with sandblasting.

Acid Pickling (see Pickling)

Acid (Nitric) Tank Filling

The potential health hazard associated with nitric acid tank filling is *oxides of nitrogen*. The currently accepted maximum allowable concentration of nitrogen oxides for an eight-hour daily exposure is 40 parts per million (p.p.m.).

In storage tanks where oxides of nitrogen are discharged while the tanks are being filled, the vents should be connected to an acid recovery plant or extended to a sufficient height to prevent injury to the workers through contact with the concentrated nitrogen oxides. Where necessary, the oxides of nitrogen should be removed from the exhausted air by means of a suitable wet collector.

Airplane Motor Cleaning

The operation of spraying airplane motors with gasoline to clean them after they have been tested presents a potentially serious exposure to gasoline vapor, and sometimes to lead. The maximum allowable concentration for gasoline vapor is 1000 p.p.m. and for lead is 0.15 mg./m.^{3}. In addition, if leaded gasoline is used, the lead tetra-ethyl is absorbed readily through the skin.

Gasoline containing lead tetra-ethyl should never be used for this purpose. The spray cleaning operation should be carried out in a booth, cabinet, or small room provided with mechanical exhaust ventilation at the minimum rate of 150 c.f.m. per square foot of booth opening or room cross-sectional area. In addition, the worker should always remain upstream of the motor, that is, in the clean air.

Alkali Cleaning

The potential health hazards associated with cleaning parts in an alkali bath are high relative humidities and skin contact with the alkali.

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Rooms in which alkali cleaning tanks are located should be provided with general mechanical ventilation with sufficient air removal to keep the relative humidity from attaining a value which would result in very uncomfortable working conditions.

The operator should wear protective clothing to prevent skin contact with the alkali.

Alumiliting (Finishing Aluminum and Aluminum Alloy Products)

The health hazard in this operation is from exposure to the sulfuric acid gases and mists, liberated from the acid dipping tanks. While the maximum allowable concentration for sulfuric acid in the air has not been determined definitely, it is believed to be the same as for hydrochloric acid gas, namely, 10 p.p.m.

The hazard may be controlled by the use of slot-type lateral exhaust hoods along one or both long sides of the dipping tank and exhausting a minimum of 120 c.f.m. of air per square foot of tank area through the hoods.

Amatol Break-Up

The potential health hazard from breaking up solid amatol is the TNT in the amatol dust. The maximum allowable safe concentration for atmospheric TNT is 1.5 mg./m.^{3}.

All amatol or TNT break-up operations should be carried out in an exhaust-ventilated booth with the worker upstream of the operation. The recommended minimum ventilation rate for such booths is 200 c.f.m. per square foot of booth opening.

If the operation is an intermittent one, and particularly if no adequately ventilated booth is available, the work may be done in an isolated location or on the outside so that the dust is not contributed to the air of a room occupied by other workers. The operator will receive adequate protection if he wears a U. S. Bureau of Mines approved mechanical filter respirator.

Amatol Bucket Cleaning (Steam Out)

The potential health hazard associated with amatol bucket cleaning is TNT vapors and fumes. The currently accepted maximum allowable atmospheric concentration for TNT fumes and vapors is 1.5 mg./m.^{3}.

The water baths used to melt the TNT encrusted in the buckets should be enclosed as much as possible and provided with

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a mechanical exhaust ventilation system adequate to give a minimum velocity of 100 f.p.m. across all face openings.

Amatol Cooling (Open Tubs) (see also TNT Cooling)

The potential health hazard associated with amatol cooling is TNT vapors and fumes. The currently accepted maximum allowable atmospheric concentration of TNT vapor and fumes for an eight-hour daily exposure is 1.5 mg./m.^{3}.

This operation should be isolated in an area having good natural ventilation. Covers should be provided for the cooling kettles and all stirring should be done mechanically.

Amatol Pouring and Puddling

The principal potential health hazard associated with amatol pouring is TNT vapors and fumes. The currently accepted maximum allowable atmospheric concentration of TNT for an eight-hour daily exposure is 1.5 mg./m.^{3}.

If this operation is carried out in well ventilated bays or rooms, no health hazard will exist under normal operating conditions. Good ventilation may be obtained by keeping all doors and windows open as much as possible and by supplying or removing an adequate quantity of air by mechanical means. The exact amount of air which must be handled depends upon several conditions and must be determined for each plant.

Frequently several dust-producing operations, such as riser break-out, amatol break-up, and tub cleaning, are conducted in the pouring bays. This contamination in addition to that contributed by the pouring and puddling operations produces a concentration in excess of the safe limit. Therefore such operations should not be done in the pouring bays. Also all workers in these bays should be rotated from job to job.

If the atmospheric TNT concentration is found to exceed the allowable limit, general ventilation should be improved; local exhaust ventilation should be provided at the major sources of air contamination; and for intermittent exposures, respirators approved by the U. S. Bureau of Mines for toxic dusts should be used.

Amatol Preparation

The potential health hazards associated with amatol preparation are TNT vapors and fumes and ammonium nitrate dust. The currently accepted maximum allowable atmospheric concentration of TNT vapor and fumes for an eight-hour daily exposure

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is 1.5 mg./m.^{3}. While ammonium nitrate dust is not considered highly toxic, all reasonable means should be used to keep the atmospheric concentration of this dust low in accordance with good engineering practice.

The mixing kettles should be enclosed and provided with local exhaust ventilation adequate to maintain a minimum face velocity of 100 f.p.m. when the doors of the kettles are open. Due precautions must be observed as regards the safety hazard associated with the collection of explosive dusts in the exhaust ventilation system. A chemical-cartridge respirator for organic vapors should be worn by the operator when he has his head in or near the kettle for cleaning operations.

Ammonia Oxidation (Nitric Acid Manufacture)

The potential health hazards in ammonia oxidation are ammonia and oxides of nitrogen. The maximum permissible safe concentration for ammonia is 100 p.p.m. for an eight-hour daily exposure; and for the oxides of nitrogen it is 40 p.p.m.

Leaks in and about the pump in the pump house are usually a source of constant atmospheric pollution with ammonia. Since the process is automatic and normally requires little attention, the exposure should not be serious if the workers are able to breathe without undue irritation for the short and infrequent periods of exposure. If the concentrations are sufficiently high to cause objectionable irritation, U. S. Bureau of Mines approved gas masks for ammonia should be worn as an emergency measure.

Ammoniacal gas should not be allowed to concentrate near the catalyst in the compressor house. If necessary, suitable local mechanical exhaust ventilation should be installed to keep the atmospheric ammonia concentration below 100 p.p.m.

The vent stacks from the compressors should be made sufficiently high to prevent the nitrogen oxides from contaminating the workroom atmosphere of the compressor house, surrounding buildings, and work area. If it is not practicable to prevent contamination by raising the stacks to a sufficient height, the effluent gases should be collected in a suitable wet collector.

Aniline Distillation

The potential health hazard associated with aniline distillation is aniline vapor. The currently accepted maximum allowable atmospheric concentration of aniline for an eight-hour daily exposure is 5 p.p.m.

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Even though this is an enclosed process, in normal operating conditions, small amounts of aniline are liberated in the general room air. The atmospheric concentration of aniline may be kept below the toxic limit by means of roof ventilators equipped with mechanically driven fans and by keeping all doors and windows open as much as possible. The vents from the aniline water storage tanks should be extended outside the building to a point where the vapors will not reenter the building.

Since aniline is readily absorbed through the skin, direct skin contact should be avoided. Good personal and general cleanliness should be practiced by the workers.

Aniline Manufacture (Nitrobenzene Reduction)

The principal health hazards associated with the reduction of nitrobenzene are aniline vapor and nitrobenzene vapor. The currently accepted maximum allowable atmospheric concentration of each of the above substances for an eight-hour daily exposure is 5 p.p.m.

Since this is an enclosed process, only small amounts of these substances are liberated to the general room atmosphere under normal operating conditions. The atmospheric concentrations of these substances may be kept below their toxic limits by means of roof ventilators equipped with mechanically driven fans and by keeping the doors and windows open as much as possible.

These substances are readily absorbed through the skin. Therefore the necessary precautions should be taken to avoid skin contact with them. In addition, strict personal hygiene and general cleanliness should be enforced by the proper supervisory personnel.

Anodizing (see Electroplating)

Ballistics Testing

In ballistics testing the potential health hazards to the riflemen are oxides of nitrogen, carbon monoxide, lead, and silica dust, and to the observers at the butt ends of the range, lead and possibly silica dust.

The maximum allowable concentrations of these dusts and gases in the atmosphere for an eight-hour daily exposure are:

Oxides of nitrogen	40 p.p.m.
Carbon monoxide	100 p.p.m.
Silica (sand)	5 m.p.p.c.f.
Lead	0.15 mg./m.^{3}

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To prevent atmospheric concentrations in excess of those given above, mechanical ventilation is necessary.

Penetration Ranges.—If the observer does not enter the range directly after test-firing ceases, the lead hazard at the target end of the range may be controlled by exhausting air at or near the target end at a minimum rate of 200 c.f.m. per square foot of cross-sectional area of the range. On the other hand, if the observer enters directly after the test-firing ceases, higher ventilation rates are necessary. Where conditions permit, this same ventilation will serve to control the riflemen's exposure if the air inlet is located at the firing end of the range. Otherwise, a separate exhauster will be necessary for the firing room, in which case the air should be admitted at the center or toward the target end of the range. The supplied air should be heated, if necessary. Propeller-type fans will serve as exhausters if the ductwork is kept at a minimum; otherwise, centrifugal fans will be needed.

Good housekeeping, particularly keeping the walls and floor of the ranges free of dust, will aid considerably in controlling the lead hazard. Daily sweeping or preferably washing with hose and water is suggested.

Velocity Ranges.—Same as *Penetration Ranges* except that lead hazard may be nil.

Function and Casualty, and Hangfire Ranges.—In these tests the rifleman may be exposed to lead and silica as well as to oxides of nitrogen and carbon monoxide. The interposition of a reasonably large room between the muzzle port and the sand butt, requiring the bullet to pass through a wall with a second port before entering the room containing the sand butt, will keep the agitated dust from being blown back to the rifleman. Both the intermediate room and the room containing the sand butt should be mechanically exhaust-ventilated at a rate sufficient to control the hazard. A minimum of 1000 c.f.m. per range is suggested, but greater quantities must be exhausted in some cases, particularly if several rifles are fired simultaneously into the same range.

If considerable sand is contained in the exhausted air, a collector should be included in the exhaust ventilation system to prevent a nuisance in the nearby areas and to reduce the abrasive action on the fan. The collector should be located upstream of the fan. The discharge stack should be so located that the contaminated air will not reenter occupied buildings.

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Balloon Manufacture (see also Rubber Goods Fabrication)

The potential health hazards in the cementing operations in the manufacture of barrage balloons result from the exposure to the cement solvents. The solvents vary as indicated in the section under "Rubber Goods Fabrication" and the health hazards vary accordingly.

The health hazard may be controlled by (1) employing cements containing the less toxic solvents and (2) conducting as much as possible of the cementing on tables with local exhaust ventilation. About 75 per cent of the cementing operations can be performed on tables, leaving only 25 per cent to be done on the floor where adequate control is more difficult. The cementing tables should be provided with slot-type exhaust hoods along both long sides of the table top. The exhaust ventilation rate should be sufficient to maintain the workers' exposure below the maximum allowable concentration for these solvents being used. To accomplish this, an air removal rate of about 50 c.f.m. per square foot of table top is suggested. The exposure for the floor cementing operations may be controlled by providing good general ventilation (about 10 air changes per hour) and by exercising care to keep the cement and solvent containers closed as much as possible and to use only as much solvent as is necessary to soften the fabric surface.

The inspection and final seaming inside the balloon presents a health hazard which should be controlled by general ventilation (air change) in the balloon at the rate given by the following equation $Q = \frac{X}{m}$, which is explained in the earlier part of this chapter.

Barrage Balloon Manufacture (see Balloon Manufacture)

Benzene Nitration

The potential health hazards associated with the nitration of benzene are nitrobenzene and benzene vapors. The maximum allowable concentrations, on the basis of an eight-hour daily exposure, are 5 p.p.m. for nitrobenzene and 100 p.p.m. for benzene.

Since the nitration of benzene is an enclosed process, there should be no appreciable amount of benzene and nitrobenzene vapors liberated into the general room air under proper operating conditions. The small amounts of vapor which may be

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liberated normally may be kept below the toxic limit by means of roof ventilators with mechanically driven fans and by keeping the doors and windows open as much as possible.

If workers repairing benzene nitrators are exposed to nitrobenzene vapors, they should wear chemical-filter respirators (gas masks) or supplied-air respirators (type B hose masks) approved by the U. S. Bureau of Mines for protection against acid gases and organic vapors.

Boat (Rubber) Manufacture (see Rubber Goods Fabrication)

Booster Cavity Drilling

The potential health hazard in booster cavity drilling is TNT dust. The currently accepted maximum allowable concentration for TNT is 1.5 mg./m.^{3} of air for an eight-hour daily exposure.

This operation is usually not a very dusty one and can easily be made almost dust-free by the judicious use of local exhaust ventilation. A small hood will suffice, located near the operation or attached to the drill, through which sufficient air is exhausted to remove all the fine dust. The suggested ventilation rate is such that the velocity at the source of dust production is 200 f.p.m. Consideration should be given to the possible collection of the TNT dust in the exhaust line; to the collection of this dust from the exhausted air; and to the disposition of the collected TNT.

Booster Cup or Tube Loading

The potential health hazard in loading booster cups and tubes with tetryl pellets is tetryl dust. The concentration of tetryl dust in the atmosphere should be kept below 1.5 mg./m.^{3}. (See *Tetryl Blending*.)

The alignment of the pellets for insertion into the tubes as well as the actual insertion of the pellets into the cups or tubes releases considerable dust to the atmosphere. This exposure may be controlled by means of appropriate exhaust ventilation.

For the usual operations, down draft ventilation through the loading and aligning trays or racks is recommended. The trays or racks need perforated or slotted bottoms and may be permanently connected with the exhaust system or may be temporarily placed on an appropriate frame on the work bench through which air is exhausted. The recommended minimum ventilation rate is 100 c.f.m. per square foot of tray or rack area or sufficient to produce a minimum removal velocity of 100 f.p.m. at

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the source of dust production. A dust trap or hopper should be located below the tray or grille to catch large particles and the air borne dust should be removed by a suitable collector (preferably wet) before the air reaches the fan. The dust trap and collector should be cleaned frequently and routinely.

In lieu of the above method, the individual operations may be partially enclosed, with transparent material if necessary, and provided with exhaust ventilation. The enclosure should be open in the front to permit the worker to perform the necessary operations expeditiously. The exhaust ventilation rate should be not less than 100 c.f.m. per square foot of opening in the enclosure. Either down draft through a grille in the table top or lateral ventilation through a connection in the enclosure may be used.

Until the exposure is controlled by means of exhaust ventilation, the workers should wear U. S. Bureau of Mines approved mechanical filter respirators at all times while performing the aligning and loading operations. Clean cloth facelets should be provided on the respirator masks at least daily to prevent dermatitis where the mask touches the face.

Bullet Casting (see Lead Bullet Casting)

Camouflage Paint Manufacture

In the manufacture of some of the camouflage paints, a chlorinated phenol known as "Dowicide F" is used as a wood preservative and mildew preventive. The maximum allowable concentration for this material is not known, but it produces violent coughing and is very irritating to the throats of exposed personnel and consequently requires adequate control measures.

The operation of mixing the Dowicide F with other dry paint ingredients should be done in a completely enclosed area which is exhaust-ventilated at the rate of about five air changes per minute.

Carbide Tool Manufacture

In the manufacture of cemented carbide tools, the finishing operations (grinding to the desired shape and sawing tool tips) are very dusty. These high concentrations of fine dust seem to produce a lung involvement which is under thorough investigation at present. Pending the outcome of this investigation, the dust should be controlled at its source.

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The dust may be controlled by means of local exhaust ventilation at rates suggested under *Grinding* for similar conditions. Collectors in the exhaust systems are advisable owing to the value of the material collected.

Cavity Drilling, Booster (see Booster Cavity Drilling)

Cold Tinning Process

The health hazard associated with this operation is the exposure to high concentrations of atmospheric mercury and potentially to high concentrations of lead. The maximum allowable concentration for mercury is 0.10 mg./m.^{3} and for lead is 0.15 mg./m.^{3} based on an eight-hour daily exposure.

The cold tinning process may be used locally for finishing metal objects with a protective coat which will protect against rust even in the presence of steam. It is commonly used where hot tinning is impracticable and where paint will not endure. Briefly, the operation consists of (1) cleaning the metal surfaces with acid, (2) applying a bonding or adhesive coat of mercury amalgam (usually by manual rubbing with a compound containing mercury and compounds thereof), and (3) applying a protective coat of about half and half lead and tin by means of a metallizing gun.

The lead exposure is intermittent and usually of short duration and will be controlled adequately if the same precautions are taken as are necessary for applying the bonding coat. The compound containing mercury should be applied in a segregated or enclosed space which is provided with mechanical ventilation at the minimum rate of 20 air changes per hour or 150 c.f.m. per square foot of opening into the enclosing space, whichever is the higher, and the operator should wear a U. S. Bureau of Mines approved supplied-air (air-line) respirator at all times while performing this operation.

Colloiding (Nitrocellulose and Ether Mixing and Macerating in the Manufacture of Smokeless Powder) (Mix Houses)

The potential health hazards in the colloiding operations are alcohol and ether vapors.

Although the maximum permissible safe concentrations are controversial at present, an attempt should be made to keep these concentrations as low as is feasible and it is suggested that they should never exceed a total of 1000 p.p.m.

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Adequate control of the vapors liberated in colloiding operations may be accomplished by the judicious use of general and local exhaust ventilation. These ventilation systems should be tied in with the solvent recovery system, if economically feasible.

Owing to the nature of these operations, it is impossible to give specific recommendations for local exhaust ventilation. Slot-type hoods are suggested, attached to or located near the multiple funnel, which fits on the receptacles into which the mixers are dumped. The hoods should be exhaust-ventilated through a flexible metal hose which might be detachable from the hood if it is an integral part of or attached to the funnel device. The flexible metal tube might be connected to the solvent recovery system or to an auxiliary system, depending upon the various conditions. The ventilation rate should be such that the air movement toward the exhaust hood is at least 100 f.p.m. in the zone of vapor liberation.

In addition, good general ventilation will be necessary. Depending upon economic considerations, this should be accomplished by means of a mechanical ventilation system which may be part of the solvent recovery system; or it may be a separate system; or it may be partly separate and partly tied in to the solvent recovery system.

Each plant must be considered separately and the appropriate measures designed accordingly.

Before scraping the mixer blades, the mixers should be allowed to remain open sufficiently long to permit the vapors to escape. The workers should wear chemical-filter respirators (gas masks) or supplied-air (air-line) respirators approved by the U. S. Bureau of Mines for organic vapors.

The "air blowing" of mixers by compressed air which blows the ether alcohol vapors into the workroom atmosphere should be discontinued. The use of a suction-type exhaust hose attached to the mechanical exhaust ventilation system or to a suitable auxiliary system should be substituted.

Cotton Picking, Drying and Weighing

The potential health hazard in the picking, drying, and weighing of cotton is that of cotton dust. The maximum permissible safe concentration for cotton dust is the same as for other nuisance dusts, namely, 50 million particles per cubic foot of air. However in some instances, it is very annoying to the exposed workers in substantially lower concentrations.

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Local mechanical exhaust ventilation should be employed at the picking end and at the weighing end of the cotton drying machine. The minimum rate of air movement at the source of the dust should be 100 f.p.m. Adequate collectors should be provided for this dust to prevent a nuisance around the building on the plant grounds.

If local exhaust ventilation fails to prevent a concentration of cotton dust which is a nuisance to the workers, they should wear mechanical-filter respirators approved by the U. S. Bureau of Mines.

Crack Testing, Mercury (see Mercury Crack Testing)

Cup Loading, Booster (see Booster Cup Loading)

Decarbonizing

The health hazard in decarbonizing operations results from exposure to the solvent vapors escaping from the decarbonizing tanks. The solutions used for decarbonizing vary considerably but usually contain kerosene, creosote oil, and ethylene dichloride. Whereas the specific toxicity of some of these solvents is unknown, it is known that most of them are definitely toxic and require control measures. (The maximum allowable concentration for ethylene dichloride is believed to be about 100 p.p.m.)

The control measures are the same as given under *Degreasing*, which immediately follows.

Degreasing

Potential health hazards in solvent degreasing operations are vapors of trichlorethylene, ethylene dichloride, carbon tetrachloride, or other highly volatile solvents. The maximum allowable concentrations for an eight-hour daily exposure to vapors of trichlorethylene, ethylene dichloride, and carbon tetrachloride are 200 p.p.m., 100 p.p.m. and 100 p.p.m., respectively.

Degreasing operations should be carried out in properly designed tanks which may or may not be provided with local exhaust ventilation but should have adequate cooling or condensing capacity. The atmospheric contamination with the solvent vapors is usually low enough to present no health hazard when (1) the tanks are small (not over 10 square feet in cross-sectional area), (2) the heat input and cooling capacity of the cooling coils are carefully regulated, (3) the tanks are located

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in large rooms with high ceilings and not near open doors or windows, (4) the withdrawal rate of the cleaned objects is slow (not more than 12 f.p.m.), and (5) the general room ventilation is good. However, for large tanks, or for any tanks located near open doors or windows or in small rooms, local exhaust ventilation at the tanks is necessary. The usual type of ventilation consists of slot-type lateral exhaust hoods located along one or both long sides of the tanks at the upper edge. The recommended minimum exhaust ventilation rate may be computed as follows:

$$Q = 50\ LW$$

where Q = the exhaust ventilation rate in c.f.m.,
L = the length of the tank in feet, and,
W = the width of the tank in feet.

The exhausted air should be discharged at a point outside the building where it cannot reenter occupied buildings.

Tight-fitting covers should be employed on degreasing tanks whenever possible.

The cleaning out of degreasers, particularly those in which the workers must enter the tanks in the process, may involve exposures to excessive concentrations of solvent vapors for limited periods of time. Such exposures may be prevented by airing out the machine after withdrawal of the liquid, and by the use of supplied-air respirators (air-line respirators or hose masks) approved by the U. S. Bureau of Mines, when the exposures are severe and when their use does not impede the workers too greatly. Chemical cartridge respirators do not afford adequate protection when the exposures are severe.

If the odor of solvent persists in the vicinity of the machine, or if the workers complain of ill effects, the concentration of solvent vapors in the atmosphere should be determined to ascertain the efficiency of existing controls. The atmospheric concentration of solvent vapors should not exceed the maximum allowable concentration for the particular solvent used.

When carbon tetrachloride has been used for degreasing and it is removed from the degreased object by a centrifugal process, the carbon tetrachloride vapors should be kept from the room atmosphere by suitable means, such as enclosing the centrifuge and exhaust ventilating the enclosure at the minimum rate of 100 c.f.m. per square foot of opening in the enclosure. The opening in the enclosure obviously should not be in the line of throw of the centrifuge.

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The solvent containers which are used to hold carbon tetrachloride or other solvent used in small degreasing operations, such as wiping of metal parts, should be kept closed by tight-fitting covers whenever possible.

Dimethylaniline Sulfate (DMAS) Nitration (see Nitration)

Dimethylaniline (DMA) Sulfation

The principal potential hazard in the sulfation of DMA is DMA vapor. Although no maximum allowable concentration has been established for exposure to DMA vapor, the toxicity of DMA is believed to be of the same order as that of aniline, the maximum allowable concentration of which is 5 p.p.m. It is suggested, therefore, that the atmospheric concentration of DMA be maintained below a value of 5 p.p.m. wherever practicable.

Exposure of DMA vapor should be eliminated or reduced as much as possible by enclosure of the sulfation process, and use of adequate local exhaust ventilation with discharge of all DMA vapor to the outside atmosphere. The discharge vents should be located in such a manner that reentrance of the vapors to the workroom is prevented.

Dinitrotoluene (DNT) Crushing and Screening

The potential health hazard in DNT crushing and screening operations is DNT dust. Although no maximum allowable concentration has been established for DNT in the atmosphere, the toxicity of DNT is believed to be of the same order as that of TNT; therefore, it is recommended that the concentration of DNT in the atmosphere be kept below 1.5 mg./m.^{3}

Control of these operations should be secured by enclosing the operations, by the use of dust-tight sleeves, by the application of local exhaust ventilation, and by the use of personal respiratory protection where necessary. A program of strict personal hygiene should be observed at all times. Where possible, a gravity-type system should be used; the crushed DNT being discharged by gravity from the crusher onto the screen and, finally, the screened material falling into an enclosed receiving unit.

It is believed that complete enclosure of the operations will keep the atmospheric concentration of DNT below 1.5 mg./m.^{3} Local exhaust ventilation and respirators should be used only if the above method fails.

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An enclosed, mechanically-operated crusher should be used. Care should be taken in filling the crusher to avoid dissemination of dust into the room atmosphere. Discharge of crushed DNT from the crusher onto the screen and from the screen into the enclosed receiving unit should be done through dust-tight sleeve connections which will prevent escape of dust into the workroom air. The receiving hopper, or other unit, located beneath the screen, should be enclosed completely and should be kept closed during the actual screening.

If the use of local mechanical exhaust ventilation is indicated by continued high concentrations of DNT in the atmosphere, consideration should be given to its application at the crusher, at the screen, and at the final receiving unit beneath the screen. The rate of air movement at the source of dust should be at least 100 f.p.m. and should be 200 or more f.p.m. at the very dusty operations. The contaminated air should be discharged to the outside atmosphere in a manner such that it cannot reenter the building.

If workers are exposed intermittently to concentrations of DNT dust in excess of 1.5 mg./m.^{3}, they should wear mechanical-filter respirators approved by the U. S. Bureau of Mines.

Diphenylamine (DPA) Crystallization and Packing

The potential health hazards in the crystallization and packing of DPA are DPA vapors and dust. No maximum allowable concentration has been established for exposure to vapors and dust of DPA but the handling and processing of this material should be in accordance with good engineering practice.

Vapors of DPA should be removed from the crystallizers through canopy-type exhaust hoods which are located above the crystallizers and are exhausted mechanically to the outside atmosphere. The exhaust velocity in each case at the source of the vapor should be at least 100 f.p.m.

Dissemination of DPA dust into the room atmosphere should be controlled by installation of adequate side guards on the crystallizer discharge chutes, careful filling of the containers with crystalline DPA to prevent overflow, and maintenance of an effective clean-up schedule.

Electroplating

The potential health hazards associated with electroplating are chromic acid mists, metallic salts, cyanides, and other toxic

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gases. The maximum allowable concentrations for some of the materials which are encountered are as follows:

Chromic acid mist	0.1 mg./m.^{3}
Arsenic (as arsine)	1 p.p.m.
Hydrogen cyanide	20 p.p.m.
Cadmium	0.1 mg./m.^{3}

If toxic gases and mists are liberated in the electroplating process, as is the case with chromium and arsenic electroplating, and some anodizing operations using dilute solutions of chromic acid and strong electric currents, local exhaust ventilation is necessary at the plating tank. A lateral exhaust slot-type ventilation system removing at least 120 c.f.m. of air per square foot of tank area is recommended. Where high current densities are used in anodizing or electroplating, much higher ventilation rates are needed to remove the air contaminant effectively. For proper functioning of the exhaust ventilation system, the level of the plating solution should be at least 4 inches below the exhaust slots.

If toxic gases and mists are produced in the plating of cadmium, copper, and zinc, the above recommended exhaust ventilation system should be used.

The electroplating of zinc, copper, and nickel from acid or neutral solutions (non-cyanide baths) does not give rise to toxic gases and mists and therefore does not require mechanical exhaust ventilation of the plating tank. However, good natural ventilation is recommended.

In those operations using a cyanide bath, care should be taken to avoid introduction of acid into the bath since hydrogen cyanide is liberated under these conditions. All cyanide baths should be conspicuously marked *poisonous*.

It is also essential that skin contact with the plating baths be prevented. Care should be exercised to prevent splashing of the plating bath.

For more detailed information on all phases of safety in electroplating, see reference 7.

For a discussion of the health hazards connected with the cleaning process prior to electroplating, see *Pickling*.

Fabric Coating (see also Rubber Goods Fabrication)

In addition to the materials mentioned under "Rubber Goods Fabrication" chlorinated paraffins, chlorinated phenols, antimony oxide, chromic oxide, and other similar materials are used in

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weatherproofing, fireproofing, and mildewproofing of canvas fabrics such as tent cloth. These materials are largely dermatitis producers at room temperatures, but at elevated temperatures such as are employed in drying the fabric after it has been coated, vapors may be liberated from the chlorinated compounds.

The dermatitis may be prevented by means of suitable protective clothing and protective creams. The toxic vapors which may be liberated in the drying ovens should be removed by exhaust ventilating the ovens.

Forging

The potential health hazards associated with forging are carbon monoxide and high temperatures. The maximum allowable concentration of carbon monoxide for an eight-hour daily exposure is 100 p.p.m.

Good natural ventilation should be provided in order to avoid excessively high temperatures and this should be supplemented by mechanically-operated exhaust fans in roof ventilators.

Canopy-type hoods with large diameter stacks should be employed over the furnaces and if the atmospheric concentration of carbon monoxide exceeds 100 p.p.m., this ventilation should be improved by the use of propeller-type fans in the discharge stacks. The point of discharge should be so located that the exhausted air does not reenter any occupied buildings.

Propeller-type fans in these stacks will aid also in the maintenance of more suitable room temperatures.

Furnace (Coreless Induction) Lining Removal

The potential health hazard associated with the removal of the linings of coreless induction furnaces is silica dust. The maximum allowable concentration of free silica (SiO_2) for an eight-hour daily exposure is 5 m.p.p.c.f. of air as determined by the standard light field technique.

In removing the furnace lining, it is necessary for the worker to have his head and shoulders inside the furnace. Therefore, his exposure to dust is severe. Supplied-air (air-line) respirators approved by the U. S. Bureau of Mines should be worn for these operations, if possible.

If supplied-air respirators are impracticable, U. S. Bureau of Mines approved mechanical-filter respirators (for pneumoconiosis-producing dusts) should be worn. These respirators must be

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cleaned and repaired daily if they are to give satisfactory service and protection.

Fuze Cavity Reaming (see Tetryl Reaming)

Glycerine Nitration

The potential health hazards associated with the nitration of glycerine are nitrogen oxides and nitroglycerine. The maximum allowable concentration of nitrogen oxides in the atmosphere is 40 p.p.m. Although the maximum allowable concentration for nitroglycerine is not known, it is relatively toxic and the atmospheric concentration should be kept as low as possible.

All glycerine nitrators should be completely enclosed and located in rooms having good general ventilation.

In addition to absorption by inhalation, nitroglycerine is absorbed readily through the skin. Therefore, special attention should be paid to housekeeping (cleanliness of workroom) and to personal hygiene which should include changing work clothes daily, washing hands and face thoroughly before eating, taking showers at end of shift, and wearing protective clothing such as impervious gauntlets and gloves.

Grinding

The potential health hazards associated with grinding operations are abrasive, metallic, and lead dusts. The maximum permissible safe concentrations of the abrasive and metallic dusts will vary with the chemical composition of the dust generated but should never exceed 50 m.p.p.c.f. of air as determined by the standard light field technique. The maximum allowable concentration of lead in the atmosphere is 0.15 mg./m.^{3}

Control in grinding operations should be accomplished by the use of wet grinding, general exhaust ventilation, local exhaust ventilation, or personal respiratory protective devices.

Wet grinding operations do not require local exhaust ventilation. Good general room ventilation may be necessary if the operations are of such magnitude as to produce excessive mist and humidity.

Continuous *dry grinding operations* should be provided with local mechanical exhaust ventilation. The exhaust hoods should be so located that the dust thrown off from the grinding wheels will be in the direction of the air flow into the hood. The following exhaust duct sizes and rates of air removal are recommended:

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STANDARD GRINDER HOOD

Wheel Diameter (Inches)		Wheel Width (Inches)	Diameter of Exhaust Outlet (Inches)	Volume of Air Removed through Hood at 4500 f.p.m. Duct Velocity (c.f.m.)
Minimum	Maximum			
—	9	1.5	3	221
Over 9....	16	2	4	392
Over 16...	19	3	4.5	497
Over 19...	24	4	5	614
Over 24...	30	5	6	884

For more detailed information see references 15 and 16.

Where portable grinders are used, particularly if lead coated materials or materials containing considerable lead, such as solder, are being ground, U. S. Bureau of Mines approved respirators for toxic dusts should be worn if control by means of ventilation is either inadequate or impracticable.

Heat Treating

The principal potential health hazard in heat treating operations is carbon monoxide. The maximum allowable concentration for carbon monoxide in the atmosphere is 100 p.p.m. Other potential health hazards are cyanide and acrolein in certain types of heat treating. The currently accepted maximum allowable concentration for hydrocyanic acid gas is 20 p.p.m. and for acrolein, 1 p.p.m.

Heat treating furnaces should be examined periodically for defective equipment which would permit the escape of carbon monoxide into the workroom atmosphere. Partial control of carbon monoxide may be obtained by the use of suitable hoods enclosing the furnaces as much as possible and allowing the carbon monoxide and excessive heat to be removed by convection currents. If the above control is inadequate, as shown by the presence of excessive concentrations of carbon monoxide, the exhaust ducts from the hoods should be equipped with fans to provide mechanical exhaust ventilation and thereby increase the rate of air removal sufficiently to maintain the atmospheric concentration of carbon monoxide within the maximum allowable limit.

The excessive room temperatures which are commonly met in heat treating workrooms should be reduced by the use of natural ventilation where possible and by the use of roof ventilators equipped with mechanically operated exhaust fans.

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Cyanide heat treating units should be controlled by the use of measures similar to those listed above.

The use of oil quenching baths in connection with heat treating operations presents possible hazards from acrolein, if vegetable oil is present in the quenching oil, and from carbon monoxide. The possibility of exposure to carbon monoxide is reduced by avoiding operation of oil quenching baths at excessively high temperatures, that is, by controlling the temperature of the substance to be quenched. The use of mineral oil as a quenching material eliminates the possibility of exposure to acrolein.

Igniter Mixture Preparation

The potential health hazard in the preparation of igniter mix is dust composed of igniter mix components. Even though the specific toxicity of these dusts is not known, it is believed that the total amount of dust in the atmosphere should not exceed 5.0 mg./m.^{3} and for barium peroxide the value should not exceed 0.5 mg./m.^{3}

The exposure time at these operations is short and intermittent and adequate protection may be obtained through the use of mechanical-filter respirators approved by the U. S. Bureau of Mines.

Incendiary Mixture Preparation

The potential health hazard in the preparation of incendiary mixture is carbon tetrachloride. The maximum allowable concentration of carbon tetrachloride is 100 p.p.m. for an eight-hour daily exposure.

All contaminated air from the blender discharge and the granulation of the blended material should be removed by adequate local exhaust systems and discharged to the outside atmosphere. No recirculation of air contaminated with carbon tetrachloride should be permitted.

Lead Bullet Casting

The potential health hazard associated with the operation of casting lead bullets is atmospheric lead. The maximum allowable concentration of lead in the air is 0.15 mg./m.^{3} based on an eight-hour daily exposure.

Partial enclosure of the operations and exhaust ventilation of the enclosure or local exhaust hoods near the source of contamination serve to control this exposure adequately. The ventila-

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tion rate should be such that the air velocity into the openings of the enclosure is not less than 100 f.p.m. and for local exhaust hoods it should be adequate to produce an air velocity in the proper direction at the source of contamination of at least 100 f.p.m.

Lead Burning

The principal potential health hazard in lead burning operations is lead fumes. The maximum allowable concentration for an eight-hour daily exposure to lead in the atmosphere is 0.15 mg./m.^{3} of air.

When lead burning is performed as a continuous operation at a fixed location, as on a workbench, a system of downdraft ventilation should be installed, consisting of a grille top workbench through which air is removed at a minimum rate of 200 c.f.m. per square foot of grille area.

When lead burning is performed as a continuous operation, but where some variation of the site is necessary, local exhaust ventilation should be provided by means of an adjustable, flexible tube with a mechanical source of exhaust ventilation. This tube should be three or four inches in diameter; the inlet should be located as close to the operation as practicable, and the source of exhaust should be sufficient to remove a minimum of 250 c.f.m. of air from each operating site.

When lead burning is a temporary or occasional operation, the workers should be required to use respirators approved by the U. S. Bureau of Mines for protection against lead fumes (type C supplied-air, if possible, otherwise mechanical-filter).

Lead Melting

The potential health hazards in lead melting operations are lead fumes and lead dust. The maximum allowable concentration for an eight-hour daily exposure to lead in the atmosphere is 0.15 mg./m.^{3} of air.

The melting pot or furnace should be enclosed with a hood and this hood should be connected to a source of mechanical exhaust ventilation capable of producing an air removal velocity of 100 f.p.m. at the hood openings. The fumes should be discharged to the outside atmosphere. The hood door should be closed except when it is necessary to remove melted lead from the furnace prior to pouring operations.

The *principal source of lead* is in the removal of lead dross

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from the melting pot or furnace, and the deposition of this dross in a haphazard fashion upon the floor in the vicinity of the melting furnace or the molds. The lead dross should be removed carefully and deposited in a suitable receptacle which should be closed whenever possible by means of a tight-fitting cover.

Lead Pouring

The potential health hazards in lead pouring operations are lead fumes and lead dust. The maximum allowable concentration for an eight-hour daily exposure to lead in the atmosphere is 0.15 mg./m.^{3} of air.

The temperature of the molten lead should be kept as low as possible while still permitting the pouring operation. Good housekeeping should be maintained in the vicinity of the pouring operation, and periodic checks should be made for the presence of lead fumes and lead dust in the atmosphere.

The disposal of lead dross should be controlled as outlined under *Lead Melting* to minimize the exposure of the workers to lead dust. Care should be taken to deposit the dross within the receptacle provided, so that lead dust will be controlled effectively.

Leather Cleaning

The potential health hazards in leather cleaning operations are solvent vapors. Some of the more commonly used solvents are Varsol, carbon tetrachloride, ethylene dichloride, sulfur dioxide as an acid sulfite, and mineral cleaning oils; the established maximum allowable concentrations for some of these materials are listed in the table at the end of this chapter. Solvents of low toxicity should be used in all cases in leather cleaning.

If the concentration of a particular solvent vapor in the atmosphere exceeds the maximum allowable concentration, adequate general ventilation or a local exhaust ventilation system should be provided. If local exhaust ventilation is used, the air velocity at the source of the solvent vapor should be about 100 f.p.m.

Lens Cleaning

The potential health hazards in lens cleaning operations are solvent vapors. Some of the more commonly used solvents are xylene, coal-oil, higher alcohols, and the soapless cleaning compounds; the established maximum allowable concentrations for some of these materials are listed in the table at the end of this

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chapter. Solvents of low toxicity should be used in all cases in lens cleaning.

If the concentration of a particular solvent vapor in the atmosphere exceeds the maximum allowable concentration, adequate general ventilation or a local exhaust ventilation system should be provided. If local exhaust ventilation is used, the air velocity at the source of the solvent vapor should be about 100 f.p.m.

Luminous Dial Painting

The potential health hazards in luminous dial painting and in the storage and handling of radioactive luminous compound incidental to dial painting are radioactive dust, gamma-rays, and radon, a gaseous decomposition product which is potentially dangerous when inhaled in excessive quantities. In addition to the commonly recognized luminous compounds, zinc sulfide, which has been given fluorescent properties by exposure to radium, should be handled with caution.

The exposure to gamma-rays should never exceed the rate of 0.1 roentgen per eight-hour working day per person. The maximum allowable concentration of radon gas in the atmosphere at any time is 10^{-11} curie per liter. See reference 17.

If the exposure to gamma-rays exceeds 0.1 roentgen per eight-hour working day per person, lead screening should be utilized to limit the exposure. The screening should conform to Failla's radium protection chart. See reference 18.

Control of radioactive dust and radon should be accomplished by (1) limiting the amounts of radioactive luminous compound issued to the workers, (2) partial or complete enclosure of processes, (3) the use of mechanical local exhaust ventilation, (4) general ventilation, (5) application of strict personal hygiene measures, and (6) personal respiratory protection.

Not more than the following amounts of radioactive luminous compound should be issued to each dial painter:

Luminosity (Microlamberts)	*Permissible Amount (Grams)*
0–12	20
12–38	10
38 or over	5

Where wet processing is impracticable in removing radioactive luminous compound preliminary to the repair or refinish-

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ing, the article should be placed on a moist paper during the removal operation and the worker should wear a supplied-air (air-line) respirator approved by the U. S. Bureau of Mines for protection against toxic dusts. Such respirators should be worn by all persons exposed to dust from radioactive luminous compound, including weighing and compounding activities.

The *main sources of radon* in radium dial painting, handling and storage operations are: (1) the painting process itself and specifically from the paint stored in the container and being applied to the work, (2) the finished dials not yet removed to the drying cabinet, (3) the dials as they rest in the drying cabinet, (4) the storage cabinet preparatory to shipment, and (5) the storage cabinet at the point of use. Controls must be applied at these points.

Each dial painting bench should be equipped with a transparent hood which encloses the bench with the exception of an open working face, and which is exhausted mechanically at a minimum average rate of 50 f.p.m. (100 f.p.m. preferred) at the hood face. See U. S. Bureau of Standards Handbook H27 for hood specifications.

Cabinets in which painted dials are stored or dried should be ventilated at either of the following rates: (1) not less than 360 c.f.m. per 1,000 dials stored, (2 to 10 pointers equivalent to one dial), and (2) not less than that sufficient to produce an average face velocity of 75 f.p.m. across the cabinet doorway when the door is open.

In addition, general ventilation should be provided in all rooms in which radioactive luminous compound is used or handled so that the radon content of the air in the room should not exceed 10^{-11} curie per liter.

Every employee should be instructed in the handling of radioactive luminous compound and in the observance of all rules that immediately affect or concern his conduct. Proper supervision of all workers should be maintained to insure the observance of these rules.

All dial painters and others handling radioactive luminous compound should change clothing before and after each day, observe strict personal hygiene, and be inspected by supervising personnel under ultraviolet light for traces of radioactive luminous compound whenever they leave the workroom. If any of the compound is detected on the skin or clothing, it should be removed promptly.

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For detailed information concerning the workrooms and equipment, inspection for hazards, transportation, and plant and personal hygiene, reference should be made to the U. S. Bureau of Standards Handbook H27, cited above.

Machining

Machining operations frequently involve the use of white lead and cutting oils. The potential health hazard is lead which may be ingested or absorbed through the skin directly or through the medium of the cutting oil.

A nontoxic lubricant should be used if possible in place of the white lead and all workers exposed to this hazard should observe strict personal hygiene, with particular attention to cleansing of hands before meals.

Magnesium Casting

This is a relatively new industry and presents some new potential hazards to health. The substances which are of concern as regards the health hazard are hydrogen fluoride, fluoride salts, and sulfur dioxide. The maximum allowable concentration for hydrogen fluoride is 3 p.p.m., and for sulfur dioxide is 10 p.p.m. based on an eight-hour daily exposure.

Whereas fluorides apparently are used in some magnesium casting, it has been found that their use is not essential, at least in some of the casting operations. Sulfur is used in the casting operation and sulfur dioxide is liberated during pouring; also, subsequent curing operations result in sulfur dioxide exposure. As a rule, the exposures are not serious and only under unusual conditions is a hazardous concentration encountered and then only for short periods. U. S. Bureau of Mines approved chemical-filter respirators (gas masks) for acid gases should be available for use when high concentrations are encountered.

Magnesium Screening (see Tracer Mix Preparation)

Mercury Crack Testing

The potential health hazard in mercury crack testing is mercury vapor. The maximum allowable concentration of mercury vapor for an eight-hour daily exposure is 0.1 mg./m.^{3}

The work table upon which the cartridges are coated with mercury, the sink into which the mercurous nitrate is poured, and the stove used for heating the coated cartridges and cases should be provided with adequate ventilation by means of a

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laboratory bench-type hood under which the operations are performed. This hood should be exhaust-ventilated at a minimum rate of 150 c.f.m. per square foot of face opening in the hood.

The use of pitchers rather than shallow glass dishes for the mercury coating process will tend to keep the mercury concentration lower since less surface is exposed in this manner. All mercury coated cases and cartridges should be discarded into a covered container and these containers should be removed frequently from the laboratory (at least twice per shift is necessary).

Rubber gloves and rubber aprons should be worn by the examiners during the visual inspection of the mercury coated cases and cartridges.

Where adequate control measures are not available or have broken down, U. S. Bureau of Mines approved chemical-filter respirators (gas masks) or supplied-air (air-line) respirators for mercury vapor should be worn as an emergency measure until the proper control measures are in operation.

Metal Cleaning (see Pickling)

Metal Finishing (Caustic Treatment to Produce a Gun-Metal Finish)

The health hazard in this operation results from exposure to the caustic mists and vapors liberated from the hot caustic solution into which the metal is dipped for treatment. The composition of the caustic solutions varies considerably and little is known concerning the maximum allowable concentrations; however, control measures are needed.

The caustic mists and vapors may be prevented from entering the general workroom air by the use of local exhaust ventilation at the hot caustic tanks. The recommended procedure consists of exhausting air at a minimum rate of 120 c.f.m. per square foot of tank area through slot-type lateral exhaust hoods located on one or both of the long sides of the tank.

Metal Spraying (Metalizing)

Metal spraying operations subject the operators to potential health hazards from metal fumes of all kinds including lead. The maximum allowable concentration of these metal fumes varies from as little as 0.15 mg./m.^{3} for lead to as much as 15 mg./m.^{3} for zinc and even more for iron.

Such operations should be performed in properly designed

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booths which are exhaust-ventilated at the minimum rate of 200 c.f.m. per square foot of opening at the face of the booths, and the workers should always be on the clean air side of the object being sprayed.

Motor Testing

The potential health hazards in the testing of motors (tank, automobile, aviation engines, and so forth) are carbon monoxide and excessive noise. The maximum allowable concentration of carbon monoxide for an eight-hour daily exposure is 100 p.p.m. Testing motors in a fixed position requires the discharge of the exhaust gases to the outside air if workers are in the same room as the motor. If back pressure on the motor is of no consequence, the motor exhaust pipes may be extended to the outside. Where back pressure is not permissible, the motor exhaust pipes should enter a mechanically exhaust-ventilated duct from which air is removed in excess of the maximum rate of exhaust from the motor. In either case, the discharge should be located at a point where the contaminated air will not enter any occupied buildings.

When motors are tested on a moving assembly line, downdraft exhaust ventilation should be provided through grilles in the floor beneath the assembly line. Sufficient air should be removed to keep the *carbon monoxide concentration* in the general room air less than 100 p.p.m.

For automobile engine repair and test work, flexible metal ducts of suitable diameter to fit over the motor exhaust pipe should be used to convey the exhaust gas from the exhaust pipe to (1) a mechanically exhaust-ventilated gutter in the floor, (2) a mechanically exhausted duct, or (3) directly to the outside. If method (3) is used, the motor under test should be located as close as possible to the door or wall so that the length of flexible pipe is kept at a minimum. Good general room ventilation in addition is advisable.

Excessive *noise* should be controlled, if possible, by means of suitable sound baffles, sound absorbing materials, and enclosure of the source of noise. Where adequate control cannot be obtained by these methods, the exposed workers should wear suitable ear protective devices.

Nitration, Dimethylaniline Sulfate

The potential health hazards associated with DMAS nitration are nitrogen oxides. The maximum allowable concentration of

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oxides of nitrogen for an eight-hour daily exposure is 40 p.p.m.

Since DMAS nitrators are enclosed and held under a slight negative pressure to remove the oxides of nitrogen liberated during the nitration reaction, there is little chance for oxides of nitrogen to be discharged to the general room air during normal operation. As an additional safety measure, the nitrators should have an auxiliary exhaust ventilation system to remove the nitrogen oxides in case of a breakdown or overloading of the exhaust system used to carry the nitrogen oxides to the acid recovery plant.

Nitrobenzene Distillation

The potential health hazard associated with nitrobenzene distillation is nitrobenzene vapor. The currently accepted maximum allowable safe concentration of nitrobenzene is 5 p.p.m.

The process should be completely enclosed and mechanical general room ventilation should be provided. Adequate ventilation may be provided by using roof ventilators equipped with mechanically operated fans. All doors and windows should be kept open as much as possible.

The overflow vents of the nitrobenzene storage tanks should extend outside the building to a point where the vapors will not reenter the building.

Nitrobenzene Neutralization, Separation and Storage

The potential health hazard associated with the neutralization, separation and storage of nitrobenzene is nitrobenzene vapor. The currently accepted maximum allowable concentration is 5 p.p.m.

The neutralization, separation and storage tanks should be completely enclosed. The overflow vents of the storage tanks should extend outside the building, at a point where the vapors will not reenter. Roof ventilators with mechanically operated fans should be provided for good general room ventilation.

Workers should observe strict precautions regarding general and personal cleanliness. Skin contact with nitrobenzene should be avoided.

Nitrocellulose Cutting and Graining

The potential health hazard found in cutting and graining of smokeless powder is from the ether and alcohol vapors.

Although the permissible safe concentrations are controver-

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sial at present, an attempt should be made to keep the concentrations as low as is feasible and it is believed that they should never exceed a total of 1000 p.p.m.

In rifle powder graining the containers under the distributors should have a bottom made of wire screening or perforated metal and should be located on a grille over a well in the floor which is exhaust-ventilated. The ventilation rate should be as low as is consistent with adequate control; a minimum of 100 c.f.m. per square foot of grille area is suggested.

In powder cutting the containers of grained powder should be placed over a well in the floor similar to that advocated for powder graining. The local exhaust ventilation should be connected to the solvent recovery system. The buckets used to collect the cut powder should be constructed similar to those used for graining. By placing these over wells which are exhaust-ventilated, the vapors are prevented from escaping into the atmosphere.

In cold weather the supplied air should be introduced into the room at a low velocity to prevent a dangerous draft over the workers.

Nitroglycerine Neutralization and Washing

The potential health hazard associated with the washing and neutralization of nitroglycerine is inhalation of nitroglycerine vapor and skin contact with nitroglycerine. While the maximum allowable safe concentration for nitroglycerine has not been established, its toxicity is relatively high and therefore the atmospheric concentration should be kept as low as possible; all nitroglycerine neutralizing and washing operations should be enclosed as completely as possible, and good general room ventilation should be provided.

In addition to being absorbed by inhalation, nitroglycerine is absorbed readily through the skin. Therefore, special attention should be paid to housekeeping (cleanliness of workroom), and to personal hygiene, which should include changing work clothes daily, washing hands and face thoroughly before eating, taking shower at end of shift, and wearing protective clothing such as impervious gauntlets and gloves.

Nitrometer Operation

The principal health hazards associated with the nitrometer operation are mercury vapors and oxides of nitrogen. The maxi-

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mum allowable atmospheric concentration of mercury vapor for an eight-hour daily exposure is 0.1 mg./m.^{3} while that of the oxides of nitrogen is 40 p.p.m.

Good housekeeping is essential in the prevention of mercurial poisoning. A collecting pan of sufficient size to receive any mercury spilled at the nitrometer should be installed just under the base supporting the nitrometer. The pan should slope to a central point and connect to a well to catch the spilled mercury. This well should be emptied frequently. The mercury should not be allowed to come in contact with any heated surface.

The nitrogen oxides from the nitrometer should not be permitted to enter the room air. These gases should be removed either by providing lateral mechanical exhaust ventilation at the point of discharge of the nitrogen oxides or by locating the nitrometer near a laboratory exhaust hood and attaching one end of a glass or rubber tube to the gas discharge end of the nitrometer and extending the other end of the tube well up into the laboratory exhaust hood or duct.

Paint Drying

The potential health hazard associated with drying painted articles is the vapor of the paint solvent. The toxicity of these solvents varies from the very toxic benzene to the relatively non-toxic acetone. The maximum allowable safe concentrations in the atmosphere for some of these solvents are listed in the table at the end of this chapter.

Drying of painted articles should be carried out in enclosed drying ovens provided with mechanical exhaust ventilation. The air removal rate should be sufficient to provide a minimum air velocity of 100 f.p.m. across the face of all openings in the drying oven. The point of discharge of the exhausted air should be so located that the vapors cannot reenter any occupied building.

Painting, Brush

The potential health hazards associated with brush painting are the paint pigments and the vapor of the paint solvent. Some of the more toxic pigment ingredients are lead and antimony, whereas the relatively harmless ingredients include zinc and iron. The toxicity of the solvents varies from the highly toxic benzene to the relatively non-toxic acetone. The maximum permissible safe concentrations for some of the solvents and pigment ingredients are listed in the table at the end of this chapter.

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The important methods for controlling the health hazards of brush painting are: (1) the use of paints having relatively harmless solvents and pigments, (2) the use of adequate ventilation, (3) the use of suitable personal protective devices, and (4) good personal hygiene.

For the purpose of this discussion, only brush painting pertaining to the repair or construction of buildings and equipment will be considered. Where brush painting is part of a production job, the control measures listed under spray painting (*Painting, Spray*) should be applied.

Even though good ventilation is needed for brush painting of all kinds, special attention should be paid to the ventilation when paints containing the more toxic ingredients are used. Good natural ventilation provided by open doors and windows will suffice in large airy rooms, whereas some mechanical means such as a fan or blower will be needed to provide ventilation in smaller rooms where painting is being done.

For painting in small enclosed spaces, a supplied-air respirator approved by the U. S. Bureau of Mines should be used if definite mechanical ventilation is impracticable.

Good personal hygiene is very important in all manual painting. The hands and face should be kept clean by frequent and thorough washing, clothes should be changed frequently, dirty hands and soiled objects should be kept out of the mouth, and other items of personal cleanliness should be practiced.

Painting, Spray

The potential health hazards associated with spray painting are the paint pigments and the mist and vapor of the paint solvent. Some of the more toxic pigment ingredients are compounds of antimony, lead, and other toxic metals whereas the relatively harmless ingredients include zinc and iron. The toxicity of the solvents varies from the very toxic benzene to the relatively nontoxic acetone. The maximum permissible safe concentrations for some of the solvents and pigment ingredients are listed in the table at the end of this chapter.

The important methods for controlling the health hazards of spray painting are: (1) the use of paints having relatively harmless solvents and pigments, (2) the use of mechanically exhaust-ventilated spray paint booths and rooms, (3) the use of suitable personal protective devices, and (4) good personal hygiene.

All spray paint booths and rooms should be mechanically

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ventilated at rates given below and the discharge should in all cases be located at a point where the contaminated air will not reenter any building.

Spray painting should be done in mechanically exhaust-ventilated spray paint booths, preferably of the water curtain type. The painting operation should be an automatic one on all production work, if practicable. The object being painted should be supported by a jig or other suitable mechanical device and should be located well within the confines of the booth.

Small spray painting booths (those having face areas of less than 50 square feet) should have a minimum exhaust ventilation rate of 200 c.f.m. per square foot of face area of the booth, whereas a minimum of 150 c.f.m. per square foot of face area will suffice for larger booths. The air velocity should be essentially uniform across the entire face of the booth.

Downdraft exhaust ventilation through a grid type floor is advisable in booths or rooms where cars, trucks and other large objects are spray-painted. A minimum air velocity of 150 f.p.m. toward the grids should be maintained at the painting location. However for intermittent painting operations of this nature any well ventilated room is satisfactory if the worker wears at all times while in the room a supplied-air (air-line) respirator approved by the U. S. Bureau of Mines.

Wherever it is necessary for the painter to work downstream (as regards air movement) of the object being painted or if the object being painted is large so that the painter is exposed to the paint mist, he should wear a supplied-air (air-line) respirator approved by the U. S. Bureau of Mines. Also all painters who use spray guns for painting in the repair and construction of buildings and equipment should wear approved supplied-air respirators at all times while painting.

In rare instances for intermittent operations, it will be found to be more feasible to provide the sprayer with a supplied-air hood covering the entire head than to provide the large amount of ventilation necessary to control adequately the exposure. In such cases, the use of supplied-air hoods is permissible.

Good personal hygiene as given under brush painting (*Painting, Brush*) should be practiced.

Paint Manufacture, Camouflage (see Camouflage Paint Manufacture)

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Pellet Density Testing

The principal health hazard associated with the tetryl pellet density testing operation is that of mercury vapor. The maximum allowable atmospheric concentration of mercury vapor for an eight-hour daily exposure is 0.1 mg./m.[3]

Although this operation is usually intermittent, any spilled mercury gives rise to a constant exposure. Good housekeeping is essential in the handling of mercury. Pellet density testing should not be done in areas adjacent to heated surfaces such as radiators or hot water pipes, and should preferably be done in areas having good general ventilation. The operations in density testing should be done on a large tray having a flanged edge and sloping to one corner containing a well. The mercury should be removed from the well frequently, and all mercury not in use should be kept in closed containers.

Pickling

The potential health hazards found in pickling are acid mists, acid gases, and gases liberated due to impurities either in the pickling acid or the metal being cleaned. The maximum allowable concentration in the atmosphere for some of these are:

Hydrogen chloride	10 p.p.m.
Hydrogen sulfide	20 p.p.m.
Sulfur dioxide	10 p.p.m.
Arsine	1 p.p.m.
Phosphine	1 p.p.m.
Nitrogen oxides	40 p.p.m.

The acid mists and gases liberated during pickling operations should be prevented from entering the room atmosphere by enclosing or partially enclosing the tank if possible and by providing mechanical exhaust ventilation at the enclosure. The rate of ventilation should be sufficient to produce an air movement into the enclosure of at least 100 f.p.m. at all openings. Where enclosure is not practicable, local exhaust ventilation should be provided at the tank by means of slot-type hoods at the upper perimeter of the tank. The minimum required ventilation rate will vary with the nature of the operations but should never be less than 120 c.f.m. per square foot of tank area. The exhaust system should be constructed of acid resisting material and the exhausted air should be discharged at a point where it will not reenter occupied buildings.

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Pickling operators should wear acid-proof protective clothing and should practice good personal hygiene.

Pontoon (Rubber) Manufacture (see Rubber Goods Fabrication)

Primer Mixture Screening

The potential health hazards of primer mixture screening are the dusts from the various ingredients of the primer mixture. The maximum allowable concentration of lead thiocyanate in terms of lead is 0.15 mg./m.^{3} of air while the currently accepted maximum allowable concentration of TNT in the atmosphere is 1.5 mg./m.^{3} Although the maximum allowable concentrations of many of the primer mixture ingredients are not known, they should be kept as low as is possible with good engineering practice.

Screening of the various ingredients of the primer mixture should be done in an enclosed system. This may be accomplished by providing a tight-fitting cover for the screen, and either attaching the receptacle directly to the screen or using a flexible dust-proof sleeve to connect the receptacle to the screen. Since the exposure is intermittent and for only brief periods of time and since the workers on this job are usually rotated, the most practicable control method is personal respiratory protection. The respirators (mechanical-filter type) should be approved by the U. S. Bureau of Mines and should be cleaned and repaired daily by one individual who should be assigned to this task.

Printing (Cleaning Type and Presses)

The potential health hazards in printing operations are solvent vapors. Some of the solvents commonly used to clean type and presses are benzene, carbon tetrachloride, methyl alcohol, and trichlorethylene.

The maximum allowable atmospheric concentrations for an eight-hour daily exposure to these solvents are:

Benzene	100 p.p.m.
Carbon tetrachloride	100 p.p.m.
Methyl alcohol	200 p.p.m.
Trichlorethylene	200 p.p.m.

No cleaning compounds containing any considerable amounts of benzene, carbon tetrachloride, or methyl alcohol should be used; petroleum naphthas are preferred.

The printing room should be large and have good natural ventilation. Mechanical exhaust ventilation fans should be lo-

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cated in roof ventilators if the room is small and the amount of work sufficient to raise the concentration of the solvents above the maximum allowable concentration.

Protectoscope Manufacture

In the manufacture of protectoscopes for tanks, a mirrored surface is coated with plexigum in ethylene dichloride. The maximum allowable concentration for ethylene dichloride is believed to be about 100 p.p.m. The exposures commonly encountered in these operations produce nausea and vomiting.

Owing to the nature of the operation, it is usually carried out in a room devoid of mechanical ventilation, and local exhaust ventilation likewise is impracticable because of the formation of bubbles on the mirrored surface. The exposures are usually of short duration and may be controlled effectively by the use of U. S. Bureau of Mines approved chemical-filter respirators (gas masks) for protection against organic vapors.

Rosin Melting (Melting Rosin for Filling Shrapnel Projectiles)

The health hazard in this operation is the exposure to decomposition products of the melted rosin at the temperature usually employed (400 to 450° F.). These products are acid in reaction and are very irritating to the mucous membranes of the operators.

The hazard should be controlled by partly enclosing the rosin melting pot and providing exhaust ventilation at the enclosure of not less than 100 c.f.m. per square foot of opening in the enclosure.

Rubber Boat Manufacture (see Rubber Goods Fabrication)

Rubber Goods Fabrication

The potential health hazard associated with the fabrication of rubber goods is the rubber or rubber cement solvent. Various solvents are used including carbon disulfide, benzene, toluol, xylol, carbon tetrachloride, methyl ethyl ketone, petroleum naphthas, and ethylene dichloride. The maximum allowable concentrations of these solvents vary from as little as 20 p.p.m. for carbon disulfide and 100 p.p.m. for benzene to as much as 1000 p.p.m. for the petroleum naphthas. Sometimes the petroleum naphthas contain such aromatics as trimethyl benzenes, ethyl benzenes, and other benzene homologues which serve to increase their toxicity.

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Inasmuch as the solvents in the rubber cements may be unknown or may vary from lot to lot, the control measures must be based on the assumption that the solvent is benzene, unless it is known to be otherwise, in which case the control measures may be relaxed accordingly. The operations vary considerably and include cementing operations on benches, on the floor, or on large objects at work-bench height; coating materials in mechanically operated spreaders; and the like. The exposure at some of these operations may be controlled by providing good general ventilation of the workroom. For some operations in small rooms as much as 40 to 80 air changes per hour are needed. (The minimum required ventilation may be computed by the equation $Q = \frac{X}{m}$ described earlier in this chapter.) However, in many instances, general ventilation does not suffice. In such cases, local exhaust ventilation should be used if practicable; otherwise, suitable respirators (supplied-air respirators approved by the U. S. Bureau of Mines) should be used. The type of local exhaust ventilation which should be employed will depend upon many circumstances. Ventilation through grilles in the tops of the work benches serves admirably if the material being fabricated does not cover the entire bench. If it does, lateral exhaust hoods along one or both sides of the bench may be employed. If neither bench top nor lateral exhaust ventilation is practicable, updraft ventilation through hoods located above but as close to the work as feasible may be satisfactory. In general, these operations vary sufficiently to make each a distinct problem which can be solved only by careful study of the operation. In any event, the quantity of air removed should be sufficient to provide a minimum velocity toward the exhaust hood of 100 f.p.m. at the source of contamination.

If the solvent odor persists, the actual exposures should be determined to decide whether additional ventilation is necessary or whether respirators must be used.

Sand Mixing and Screening

The potential health hazard associated with sand mixing and screening operations is silica dust. The maximum allowable concentration of free silica is 5 million particles per cubic foot of air as determined by the standard light field technique.

Inasmuch as dry sand mixing and screening operations produce an enormous amount of silica dust, these operations should

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be enclosed as much as possible and provided with local exhaust ventilation. Owing to the large number of ways these operations are carried out, no specific type of exhaust ventilation system can be suggested. However, the dust is usually controlled successfully if the ventilation rate is such that the air velocity toward the exhaust inlet is about 250 f.p.m. at the source of dust production. Periodic dust counts should be made in the area adjacent to these operations to check the performance of the exhaust ventilation system.

The exhausted air should be passed through a suitable collector to remove the dust before the air is discharged to the outside. The discharge outlet should be so located that the air will not reenter the buildings and in no case should the air be recirculated into the workroom even if the dust collector appears to be efficient. The collector should be cleaned frequently and routinely and should be maintained in good working condition.

A local exhaust ventilation system may not be necessary if the sand mixing and screening operations are intermittent so that the average exposure of the worker to silica dust is low. In such instances, the operations should be isolated to avoid exposing other workers to the dust and the exposed workers should wear respirators approved by the U. S. Bureau of Mines for protection against silica dust.

Self-sealing Fuel Tank Manufacture (see Rubber Goods Fabrication)

Shell Case Manufacture

A potential health hazard from metal fumes is encountered in the melting of brass in the initial billet casting operation. These fumes may be relatively toxic if the brass contains considerable lead (cartridge brass seldom contains lead) or they may be largely zinc oxide fumes. The maximum allowable concentration for lead in the atmosphere is 0.15 mg./m.^{3} and for zinc oxide, 15 mg./m.^{3}, based on an eight-hour daily exposure.

The exposure may sometimes be controlled adequately by good general ventilation whereas in many instances local exhaust ventilation through hoods located above the melting pots is necessary. The required ventilation rate varies tremendously, depending upon circumstances, but should be sufficient to remove all the contaminated air from the vicinity of the melting pot.

Shrapnel Projectile Loading (see Rosin Melting)

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Smokeless Powder Cutting and Graining (see Nitrocellulose Cutting and Graining)

Soldering

The potential health hazards associated with soldering operations are lead fumes and hydrogen chloride gas from the acid flux. The maximum allowable concentration for an eight-hour daily exposure to lead fumes in the atmosphere is 0.15 mg./m.^{3} and to hydrogen chloride gas, 10 p.p.m.

Control measures should consist of local exhaust ventilation, general ventilation, and the use of personal respiratory protective devices, according to the nature of the operation. All soldering sites should have good natural ventilation, if possible.

Continuous or production soldering operations require local mechanical exhaust ventilation for the removal of lead fumes and acid gas. The workbench should be equipped with a grille-top through which the air is exhausted at the minimum rate of 100 c.f.m. per square foot of grille area. In addition, the stove or heater for the iron should be enclosed on three sides in a hood which is exhaust ventilated at the rate of about 100 c.f.m. per square foot of opening in the hood. The exhausted air should be discharged to the outside atmosphere in such a manner that it will not reenter the building.

For intermittent soldering operation of a repair nature, good general ventilation will control the exposure adequately.

For all operations which are done in confined spaces, adequate ventilation should be provided by any suitable means such as a portable blower, fan, or air-operated ejector, or if this is impracticable, suitable respiratory protective devices should be worn. If an acid free flux is used, a mechanical-filter respirator approved by the U. S. Bureau of Mines for toxic dusts will suffice; otherwise, an approved supplied-air (air-line) respirator will be needed.

Spray Coating (see Painting, Spray)

Stenciling (see Painting, Spray)

Sulfation, Dimethylaniline (see Dimethylaniline Sulfation)

Sweetie Barrel Operation

The principal potential health hazard associated with the sweetie barrel operation is dinitrotoluene in the form of dust,

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fume, and vapor. While no maximum allowable atmospheric concentration has been established for DNT, it is believed to be of the same order of toxicity as TNT. The currently accepted maximum allowable atmospheric concentration for an eight-hour daily exposure to TNT is 1.5 mg./m.^{3}

All weighing and sweetie barrel operations should be isolated insofar as it is practicable. Mechanical-filter respirators or supplied-air (air-line) respirators approved by the U. S. Bureau of Mines for protection against toxic dusts should be worn by the workers while scraping the insides of the sweetie barrels, and while holding the bags receiving the discharge from the sweetie barrels.

Tank (Aircraft Fuel) Manufacture (see Rubber Goods Fabrication)

Testing, Ballistics (see Ballistics Testing)

Tetryl Blending

The potential health hazard in tetryl blending is tetryl dust. Although no maximum allowable concentration has been established for tetryl dust in the atmosphere, the concentration of the dust should be maintained as low as possible within the limits of good engineering practice. It is suggested that the atmospheric concentration of tetryl be maintained below a value of 1.5 mg./m.^{3} wherever practicable.

During periods of filling and discharging of the blender, a dust-tight connection should be maintained between the tetryl screen and the blender, and a dust-tight sleeve should be attached to the discharge end of the blender and should extend to the bottom of, or be removably attached to, the receiving unit. If the sleeve extends to the bottom of the receptacle, it should be manipulated by hand to release the tetryl with a minimum of dusting.

If the above suggestions do not reduce the atmospheric concentration of tetryl dust below 1.5 mg./m.^{3}, mechanical-filter respirators approved by the U. S. Bureau of Mines should be worn by the workers while in the blending room.

Tetryl Crystallization

The potential health hazards in the tetryl crystallization operations are benzene vapors and acetone vapors. The maximum allowable concentration for an eight-hour daily exposure to ben-

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zene in the atmosphere is 100 p.p.m. and while no maximum permissible safe limit has been established for acetone, it is known to be relatively non-toxic.

A substitute for benzene should be used if possible and the necessary precautions should be observed in handling the substituted solvent.

If benzene is used, the process should be enclosed as much as possible and adequate mechanical local exhaust ventilation should be provided at the vacuum pan. The rate of air removal at the source of benzene vapors should be not less than 100 f.p.m.

Tetryl Drying

The potential health hazard in tetryl drying operations is tetryl dust which is generated during the loading and unloading of drying screens in the tetryl dry house. The concentration of tetryl dust in the atmosphere should be maintained as low as possible within the limits of good engineering practice. A maximum concentration of 1.5 mg./m.^{3} is suggested. See *Tetryl Blending*.

A system of mechanical local exhaust ventilation should be installed to remove tetryl dust generated during the drying screen loading and unloading operations. The system should be such that the air movement is at least 100 f.p.m. at all points of dust production. If the use of local exhaust ventilation is impracticable or inadequate, the workers should wear respirators approved by the U. S. Bureau of Mines for protection against toxic dusts.

Due precautions should be observed with regard to the collection of tetryl dust in the duct work of the ventilating system, and with regard to the disposition of the dust removed by the ventilating system. A wet type collector located as close as possible to the source of dust removal is suggested for filtering the dust from the air before it is discharged to the outside.

Tetryl Mixing with TNT

The potential health hazards in the mixing of tetryl with TNT are tetryl dust and TNT vapors and fumes. The currently accepted maximum allowable concentration of TNT in the atmosphere is 1.5 mg./m.^{3} and a maximum atmospheric concentration of 1.5 mg./m.^{3} is suggested also for tetryl. See *Tetryl Blending*.

The mixing process should be partially enclosed and controlled by a mechanical exhaust system which produces an air movement of at least 100 f.p.m. at the face of the hood opening.

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Tetryl Packing

The potential health hazard in tetryl packing operations is tetryl dust. The tetryl concentration in the atmosphere should be maintained below 1.5 mg./m.^{3} wherever feasible. See *Tetryl Blending*.

Local exhaust ventilation should be applied near the chute discharge from the tetryl hopper to the tetryl boxes at the source of tetryl dust. The rate should be sufficient to prevent the escape of dust into the atmosphere; a minimum velocity of 200 f.p.m. at the source of dust production is suggested.

Tetryl Pellet Density Testing (see Pellet Density Testing)

Tetryl Pelleting

The potential health hazard in tetryl pelleting operations is tetryl dust. The tetryl concentration in the atmosphere should be maintained below 1.5 mg./m.^{3} wherever feasible. See *Tetryl Blending*.

In most instances the only atmospheric exposure to tetryl dust in tetryl pelleting occurs during the filling of the pelleting hopper and cleaning of the pelleting machine. Since these operations are intermittent and brief, the workers may be adequately protected by the use of respirators approved by the U. S. Bureau of Mines.

Tetryl Reaming

The potential health hazard in tetryl reaming operations for fuzes is tetryl dust. The tetryl concentration in the atmosphere should be maintained below 1.5 mg./m.^{3} wherever feasible. See *Tetryl Blending*.

A mechanical local exhaust system should be installed to control the tetryl dust at its source. The rate of air movement should be at least 100 f.p.m. at the source of the dust.

Tetryl Screening

The potential health hazard in tetryl screening operations is tetryl dust. The tetryl concentration in the atmosphere should be maintained below 1.5 mg./m.^{3} wherever feasible. See *Tetryl Blending*.

To accomplish the best results and to insure safe working conditions, the entire screening process, including the charging and discharging, should be enclosed as much as possible and

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provided with exhaust ventilation at a rate which will produce an air velocity into all openings of not less than 100 f.p.m. and should be about 300 f.p.m. at the openings or leaks at the screen where the dust is liberated with considerable velocity. The charging hopper and the receptacles should be attached to the screen by means of flexible dust-tight sleeves. The exhausted air should be conveyed to a wet collector located as close to the source of dust as possible and consideration should be given to keeping the duct work upstream of the collector free from tetryl deposits. Partial enclosure of the charging hopper with one side open for charging will aid in the prevention of atmospheric contamination at this point. At the discharges (both the coarse and fine outlets) the flexible dust-tight sleeve attached to the screen outlets should be permanently attached to a receptacle cover which may be transparent, if necessary. If this is not practicable, a ventilated canopy-type hood should be attached to the sleeve and located above but as close as possible to the receptacle. The minimum ventilation rate through the canopy hood should be 300 c.f.m. per square foot of opening between the receptacle and hood perimeter.

If the operation is intermittent or if exhaust ventilation is impracticable, the charging hopper should be entirely enclosed and provided with a door large enough to receive a box of tetryl and with a frame and crank such that a box of tetryl may be held in the frame and inverted by means of the crank outside the enclosure while the door is closed; also the hopper and receptacle should be connected to the screen by means of flexible dust-tight sleeves, and the workers should wear at all times while in the screening room mechanical-filter respirators approved by the U. S. Bureau of Mines for toxic dusts.

Tinning Process, Cold (see Cold Tinning Process)

TNT Break-Up (see Amatol Break-Up)

TNT Cooling

The operation in which tubs of liquid TNT are cooled to the desired temperature before pouring, presents an exposure to TNT vapor and fume. The maximum allowable safe concentration for atmospheric TNT is 1.5 mg./m.^{3}

If the cooling tubs are stirred manually or if a number of tubs are cooling at the same time in a bay or room, the atmos-

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pheric contamination in the room will be excessive. This condition may be prevented by (1) providing exhaust ventilation at each tub, or (2) ventilating the bay or room adequately. It is preferable that the tubs be stirred mechanically, but if each tub is ventilated properly, this is not essential.

Each tub may be ventilated adequately by installing a partially enclosing or a semicircular hood at the locations where the tubs are stirred so that when the tubs are in cooling position the enclosure or hood will be close to and almost adjoining the kettle. The recommended minimum exhaust ventilation rate for a hood is 120 c.f.m. per square foot of tub area and for a partial enclosure is 100 c.f.m. per square foot of opening in the enclosure. A suitable collector (preferably wet) should be located as close to the hoods or enclosures as possible so that the contaminated air is conveyed only a short distance in the duct work.

If local exhaust ventilation is impracticable, the contamination may be prevented from escaping into adjoining rooms by exhaust-ventilating the cooling bay or room at a minimum rate of 50 c.f.m. per square foot of opening into the bay. If general ventilation is used, the workers should wear U. S. Bureau of Mines approved mechanical-filter respirators at all times while in the cooling bay.

TNT Drying

The potential health hazard in TNT drying operations is TNT in the form of vapor and fume. The currently accepted maximum allowable concentration for TNT in the atmosphere is 1.5 mg./m.^{3}

This operation should be completely enclosed to prevent the contamination of the atmosphere with TNT vapor. Provision should be made to exhaust the vapor from the drier to the outside atmosphere.

TNT Flaking

The potential health hazard in TNT flaking operations is TNT in the form of vapor, dust and fume. The currently accepted maximum allowable concentration of TNT in the atmosphere is 1.5 mg./m.^{3}

The flaking machine should be partially enclosed and mechanically exhaust-ventilated at a rate sufficient to produce a velocity into the enclosure of at least 150 f.p.m. at all openings.

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TNT Graining

The potential health hazard in TNT graining operations is TNT vapor and dust. The currently accepted maximum allowable concentration for an eight-hour daily exposure to TNT in the atmosphere is 1.5 mg./m.^{3}

Each graining kettle should be enclosed completely by a hood which has an observation lid that may be opened; the hood should be exhausted mechanically at a rate sufficient to produce an air velocity of at least 100 f.p.m. at the hood face when the observation lid is open. All contaminated air should be discharged to the outside atmosphere in such a manner that it will not reenter the building.

TNT Melting

The potential health hazard in TNT melting operations is TNT vapor, fume and dust. The currently accepted maximum allowable concentration for an eight-hour daily exposure to TNT is 1.5 mg./m.^{3}

The melting kettles should be enclosed and should be mechanically exhaust ventilated. The enclosure should be provided with the necessary number of lids or access doors which may be opened. The exhaust ventilation rate should be such that the air movement at the hood face when one lid is open is not less than 100 f.p.m.

In filling the TNT hoppers above the melting units, precautions should be observed to create as little dust as possible. If these hoppers are of good design and the charging is done properly, no atmospheric dust hazard should exist. However, if the concentration of TNT in the atmosphere during the filling operation exceeds 1.5 mg./m.^{3}, the workers should wear respirators approved by the U. S. Bureau of Mines.

TNT Metal Tub Cleaning (see also Amatol Bucket Cleaning)

The potential health hazard in TNT metal tub cleaning operations is TNT dust. The currently accepted maximum allowable concentration of TNT in the atmosphere is 1.5 mg./m.^{3}

For intermittent operations, mechanical-filter respirators approved by the U. S. Bureau of Mines should be worn by workers engaged in metal tub cleaning.

For continuous operations, the work should be done in mechanically ventilated exhaust booths which have a face velocity of not less than 200 f.p.m. and the operator to avoid excessive

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exposure should remain upstream of the tub at all times while cleaning. The exhausted air should be discharged at a point on the outside where it will not reenter the buildings. Consideration should be given to the safety hazard associated with the collection of TNT dust in the ductwork; a wet collector close to the booth is suggested.

TNT Pouring and Puddling (see Amatol Pouring and Puddling)

TNT Purification

The potential health hazard in TNT purification operations is TNT vapor and fume. The currently accepted maximum allowable concentration of TNT in the atmosphere is 1.5 mg./m.^{3}

The TNT purification process should be entirely enclosed to prevent the contamination of the workroom atmosphere.

TNT Screening

The potential health hazard in TNT screening operations is TNT dust. The currently accepted maximum allowable concentration of TNT in the atmosphere is 1.5 mg./m.^{3}

As a rule, TNT screening operations require local exhaust ventilation to maintain safe working conditions. The hopper from which TNT is fed onto the screen should be partially enclosed with an open face hood to permit filling of the hopper. The hood should be mechanically exhausted so that the hood face velocity will be at least 100 f.p.m. Care should be taken in filling the hopper to disseminate as little TNT dust as possible into the room atmosphere.

The connection between the hopper and the screen should be dust-tight at all times. Dust-tight sleeves or boots should be used between the screen outlet and the receiving unit; this applies to the coarse material discharge as well as to the screened TNT. These sleeves may either be attachable to the top of the receptacles by means of dust-tight connections or extend to the bottom of the receptacles to prevent the escape of dust into the atmosphere.

The screen should be enclosed, mechanically operated and mechanically ventilated, if necessary. The ventilation rate should be such that the air velocity at all openings is not less than 300 f.p.m. All contaminated air should be discharged to the outside atmosphere in such a manner that it cannot reenter the room.

Wherever the TNT dust concentration exceeds 1.5 mg./m.^{3}

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in the workroom atmosphere, workers exposed should wear mechanical-filter respirators approved by the U. S. Bureau of Mines.

Toluene Nitration

The potential health hazards associated with the nitration of toluene are toluene, nitrogen oxides, mononitrotoluene, dinitrotoluene, and TNT. The currently accepted maximum allowable concentrations of these substances for an eight-hour daily exposure are as follows:

Toluene	200 p.p.m.
Nitrogen oxides	40 p.p.m.
Mononitrotoluene	Similar to nitrobenzene, which is generally 5 p.p.m.
Dinitrotoluene	Similar to TNT
TNT	1.5 mg./m.^{3}

All toluene nitrators should be enclosed and connected to an acid recovery plant by means of a local exhaust ventilation system. The nitrators should be held under a sufficient negative pressure to prevent the escape of nitrogen oxides into the room atmosphere during the nitration operation. As an additional protective measure, an auxiliary exhaust system should be installed on all nitrators for use in case of a breakdown or overloading of the regular exhaust system.

The observation section of the drain pipe leading from the nitrator should also be provided with local exhaust ventilation to prevent escape of nitrogen oxides and other toxic materials into the room atmosphere during the separating operation.

Tracer Bullet Charging

The potential health hazards in the charging of copper jackets with tracer mixture and igniter mixture are the tracer and igniter mixture dusts and the solvent vapors (carbon tetrachloride and methyl alcohol) resulting from the removal of the dusts from the charging machines and from the washing of the dies. The maximum allowable concentration of tracer mixture and primer mixture are not known but it is believed that no harm will result to the workers if the total dust concentration is kept below 5.0 mg./m.^{3} and the barium peroxide concentration below 0.5 mg./m.^{3} The allowable concentration of carbon tetrachloride in the atmosphere is 100 p.p.m. while that for methyl alcohol is 200 p.p.m.

General room ventilation should be provided to keep the tracer and igniter mixture dust in the air near the charging machines

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and in the breathing zone of the workers below the allowable limit. Mechanical air conditioning with sufficient air changes per hour should be satisfactory if the air is not recirculated. If recirculation of part of the air is necessary, an efficient collector for both the dusts and vapors is necessary in the conditioning system to remove the contaminating materials from the air before recirculation. All charging machines should be cleaned at least once an hour, and oftener, if necessary. Air blowing of the dust on the machines should not be permitted; a commercial vacuum cleaning apparatus with an efficient filter should be used. Trichlorethylene, ethyl alcohol and coal oil should be used for wiping the machines and cleaning the dies; the use of carbon tetrachloride and methyl alcohol should be avoided.

Tracer Mixture Blending

The potential health hazard during tracer mixture blending operations is tracer mixture dust. Although the specific maximum allowable concentration of tracer mixture dust has not been determined, it is believed that the total amount of this dust in the workroom atmosphere should not exceed 5.0 mg./m.^{3}

A flexible dust-tight sleeve or boot should be attached to the outlet of the blender and should either be attachable to the top of the receptacle by means of a dust-tight connection or extend to the bottom of the receptacle so that the dust created in the fall is not permitted to escape into the workroom atmosphere. With the latter arrangement, the sleeve should be manipulated by hand and care should be taken to avoid any unnecessary disturbance which would disseminate dust into the air. If the total tracer mixture dust content in the air exceeds 5.0 mg./m.^{3}, the workers should wear mechanical-filter respirators approved by the U. S. Bureau of Mines. This may be necessary, particularly when charging the blender. The operators should practice good personal hygiene and good housekeeping.

Tracer Mixture Screening and Mixing

The potential health hazards of the tracer mixture screening and mixing operations, when conducted in the same room, are tracer mixture constituent dusts and carbon tetrachloride vapor. The maximum allowable concentration for carbon tetrachloride in the atmosphere is 100 p.p.m. Although the specific maximum allowable concentration for tracer mixture dust in the atmosphere has not been determined, it is believed that the total amount

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of this dust in the workroom atmosphere should not exceed 5.0 mg./m.^{3}

If possible, precipitated calcium resinate should be used in the preparation of tracer mixture, thereby eliminating the necessity of using carbon tetrachloride. If carbon tetrachloride is used, all of the air contaminated with the carbon tetrachloride vapors should be exhausted directly to the outside atmosphere.

Dust producing operations should be done in mechanically exhaust-ventilated hoods which have a minimum face area consistent with proper performance of the operations. The average hood face velocity for the control of operations which produce only a slight amount of dust may be as low as 100 f.p.m. but the average hood face velocity at very dusty operations should be not less than 150 f.p.m. In all instances, the hood design should be such that the necessary minimum control velocities exist in the zone of dust production.

Welding (Oxyacetylene and Electric)

The potential health hazards found in oxyacetylene and electric welding are fumes, gases, and infra-red and ultraviolet radiation. On some welding or cutting operations, such as the repair of ships or other painted structures, severe exposures to lead may result from the paint, or to mercury if mercury containing anti-fouling paint had been used. Also where welding rods having fluoride fluxes are used, there is an exposure to hydrogen fluoride and volatile fluoride salts. The maximum allowable concentrations on the basis of eight hours' daily exposure for some of the substances which may be encountered are:

Mercury	0.10	mg./m.^{3}
Lead	0.15	mg./m.^{3}
Hydrogen fluoride	3	p.p.m.
Nitrogen oxides	40	p.p.m.
Zinc oxides	15	mg./m.^{3}

Welding sites should be isolated from nearby workers by the use of screens or shields which protect the surrounding workers from the injurious light rays. At the same time these shields should not be more enclosing than necessary lest the ventilation at the welding site be reduced more than is desirable. Goggles, shields or helmets and other necessary protective clothing should be worn by the welders to protect their eyes and skin from the infra-red and ultraviolet radiation given off while welding.

The fume and gas hazard may be controlled by (1) ventila-

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tion, and (2) personal protection. Wherever practicable, local exhaust ventilation should be employed and in other cases either general ventilation alone or general ventilation supplemented by respiratory protective devices is necessary. On routine operations, at more or less permanent locations or in places where continuous welding is done and conditions permit, local exhaust ventilation should be provided. For those operations where the welder moves about, a 3- or 4-inch flexible metal hose may serve as the hood and exhaust duct. Some systems are available also in which the flexible hose is counterweighted and the terminal end or hood is readily adjustable to any location. The minimum amount of air which must be exhausted from each welding operation is 250 c.f.m. and may be as high as 1,200 c.f.m. where large amounts of fumes and gases are produced. The exhaust hood should be kept as close to the operation as possible and should never be more than 12 or 15 inches away.

If welding is done in the open, natural ventilation is usually sufficient to prevent a health hazard. When welding in small enclosed spaces, the welder should wear an approved respirator of the supplied-air type (air-line) if adequate local exhaust ventilation is impracticable.

In many types of resistance welding, for example, seam and spot welding, ultraviolet and infra-red rays are not produced. However, welding fumes and gases are produced. If the amounts of toxic material in the atmosphere near such operations exceed the maximum permissible safe concentrations, and if workers are located in these areas, sufficient local exhaust ventilation should be provided to control the hazard.

Wood Veneer Processing

In the manufacture of airplane wings, propellers and other similar products from laminated wood, the component parts are dipped in phenolic resins which are heated and subjected to pressure. In such operations, there is a potential exposure to high atmospheric concentrations of phenolic resins unless appropriate control measures are observed. The maximum allowable concentration of this material has not been determined, but it is known to be quite toxic.

The dipping operation should be carried out in an exhaust-ventilated spray booth similar to a spray-painting booth. The ventilation rate through the booth should be not less than 100 c.f.m. per square foot of booth opening.

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TABLE 3.—TOXIC LIMITS OF VARIOUS SUBSTANCES

Substance	*Maximum Allowable Concentration**
Acrolein	1 p.p.m.
Acrylonitrile	20 p.p.m.†
Ammonia	100 p.p.m.
Amyl acetate	400 p.p.m.†
Aniline	5 p.p.m.
Arsine	1 p.p.m.
Benzene (Benzol)	100 p.p.m.
Butyl acetate	400 p.p.m.†
Butyl alcohol	200 p.p.m.†
Carbon dioxide	5000 p.p.m.
Carbon disulfide	20 p.p.m.
Carbon monoxide	100 p.p.m.
Carbon tetrachloride	100 p.p.m.
Dichlorobenzene	75 p.p.m.
Dimethylaniline	similar to aniline
Ethylene dichloride	100 p.p.m.
Gasoline (Petroleum)	1000 p.p.m.
Hydrogen chloride	10 p.p.m.
Hydrogen cyanide	20 p.p.m.
Hydrogen fluoride	3 p.p.m.
Hydrogen sulfide	20 p.p.m.
Methyl alcohol	200 p.p.m.
Monochlorobenzene	75 p.p.m.
Mononitrotoluene	similar to nitrobenzene
Nitrobenzene	5 p.p.m.
Nitrogen oxides	40 p.p.m.
Petroleum naphthas	1000 p.p.m.
Phosgene	1 p.p.m.
Phosphine	1 p.p.m.
Sulfur dioxide	10 p.p.m.
Tetrachloroethane	10 p.p.m.
Tetrachloroethylene	200 p.p.m.
Toluene (Toluol)	200 p.p.m.
Trichlorethylene	200 p.p.m.
Turpentine	200 p.p.m.
Xylene (Xylol)	200 p.p.m.
Barium peroxide	0.5 mg./m.³‡
Cadmium	0.1 mg./m.³
Chromic acid	0.1 mg./m.³
Lead	0.15 mg./m.³
Mercury	0.1 mg./m.³
Dinitrotoluene	similar to TNT
Tetryl	1.5 mg./m.³‡
TNT	1.5 mg./m.³
Zinc oxides	15.0 mg./m.³
Silica (SiO_2) (free or uncombined)	5 m.p.p.c.f.

* The maximum allowable concentration for the various substances listed are the values most widely accepted today and are based on an eight-hour daily exposure.

† These values have not been definitely established but are included to serve as a guide.

‡ No specific information available, but believed to present no health hazard at this concentration.

Note: p.p.m. = Parts of substance per million parts of air by volume.
mg./m.³ = Milligrams of substance per cubic meter of air.
m.p.p.c.f. = Millions of particles of substance per cubic foot of air.

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TABLE OF TOXIC LIMITS

From time to time, it is necessary for industry to change from one material or substance to another for one of several reasons, such as scarcity of materials, improvement of product, change in process, or reduction in the health hazard. When this becomes necessary, it is important that a substance be selected which is less toxic than the former substance. Whereas the relative toxicity of many materials is unknown at present, there is presented in Table 3 a list of substances and their relative toxicities. This table will be found useful as a guide in the selection of less toxic substitutes.

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CHAPTER 12

MEDICAL CONTROL OF RESPIRATORY DISEASES

W. C. Dreessen, M.D.

THE PROBLEM

TODAY, as never before, the comparative lack of specific control measures and the terrific toll of the respiratory diseases—colds, influenza, pneumonia, and tuberculosis—are making rigid demands upon the acumen of every industrial physician, and at the same time cast out a challenge to preventive medicine which cannot be ignored. Fully one-half of the sick absenteeism and over one-third of the work days lost by industrial workers through disability are attributable to respiratory disease. The strategic position of the plant physician for the control of these diseases is not as favorable as it is in the case of such diseases as malaria and syphilis for which specific chemotherapeutic agents are available or in the case of smallpox against which active immunity can be attained.

Workplaces not infrequently provide many of the predisposing factors regarded as significant in respiratory infections. Many workers for the first time in their lives are coming face to face with such conditions as a relatively crowded environment and exposure to gases, fumes, and dust. They must contend with occupational fatigue in becoming hardened to a new form of work. Many are exposed to inclement weather and extreme changes in weather conditions. Malnutrition, allergy, alcoholism, personal handicaps, and other factors contribute to the decreased ability of the individual to resist infection.

It is the purpose of this chapter, first, to review certain measures as they pertain to the control of acute respiratory diseases, and second. to outline similar measures as they apply to tuberculosis and other chronic pulmonary diseases in industry.

ACUTE RESPIRATORY INFECTIONS

The acute respiratory infections are a heterogeneous group of ailments caused by various agents. It is highly probable that many of the so-called colds are caused by filterable viruses. More

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than thirty types of pneumococci are involved in pneumococcal pneumonia; more than two types of viruses are known to cause epidemic influenza. The filterable viruses are particularly likely to initiate the disease process. Moreover, it is now recognized that the common pathogens of the respiratory tract participate in the pathogenesis of acute respiratory syndromes. Only too frequently is the common cold followed by such formidable sequelae as pneumonia and tuberculosis.

Prevalence of Colds

The extensive studies by the U. S. Public Health Service and other organizations have contributed many important facts regarding the common cold. Since it is obviously impossible to present a complete review, only certain etiologic and epidemiologic features will be stressed. The attack rate per person usually averages 2 to 3 per year. Almost all persons are susceptible and very few persons avoid an attack of acute respiratory infection during the course of any one year. Townsend,[1] for instance, stated that in a group followed for 5½ months 90 per cent reported one or more attacks. There is typically, but not always, a period of high prevalance in early spring, a decline in midsummer, another period of high prevalence in autumn, and some decline in December. The peak in the fall of the year is reached with almost explosive suddenness and a high incidence will usually be reported simultaneously in all sections of the country.

Gover, Reed, and Collins,[2] studying data from students in various universities in the United States over a period of 18 months, concluded that there is "no definite association of respiratory attack rate with marked variations in climate as represented by six American cities with wide geographic and climatic differences."

Other investigators[3] have also failed to observe a consistent relation between the incidence of colds and latitude, longitude, and climate.

The above conditions apply to continental United States, but, lest we overlook the infectious nature of colds, the Spitzbergen observations[4] may be recalled. Spitzbergen is comparatively free of colds in winter, but with the opening of the shipping season about three-fourths of the community's population suffer an attack of the common cold within a week following the arrival of the first ship. Similar observations, as well as clinical and experimental investigations, indicate that the incubation period

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for the common cold is probably between 12 and 48 hours or possibly as long as 72 hours.

Cold Vaccine

Prophylactic immunization against the common cold has been tried by means of filterable virus vaccine and by vaccines prepared from mixtures of various pathogens of the respiratory tract. The virus vaccine has had only limited trial and has not proved to be efficacious. According to Dochez,[5] the future value of common cold virus vaccine is problematical because an attack of cold gives little or no immunity. Bacterial vaccines containing a variety of respiratory pathogens have been used on a wide scale. Many industrial physicians have had first-hand experience with them.[6] The stock vaccines contain killed pneumococci, *H. influenzae, M. catarrhalis,* staphylococci, and streptococci. These organisms tend to be present in the normal nasopharyngeal flora and in case of an attack are assumed to act as secondary invaders. As a result of using such vaccines one would expect a lessening in the harmful effect of these organisms. According to some authorities, these secondary invaders play an important role in a small group of adults who suffer each year from prolonged infections of the upper respiratory tract with such complications as sinusitis and bronchitis. For theoretical reasons, some believe that such vaccines are of considerable value if restricted to that group of individuals in which secondary bacterial infection presumably plays an important part. *The use of these vaccines, however, has not received the endorsement of public health workers, mainly because of lack of scientific proof.*

Influenza Prophylaxis

The etiologic agent of certain epidemics of influenza, as in the instance of the common cold, is a filterable virus. Influenza occurs mainly in a pandemic, an epidemic, or an endemic form.[8] The cause of pandemic influenza, such as occurred in 1918–1919, is not yet known. In the epidemic form, at least three filterable viruses have been isolated. The cause of endemic influenza, or sporadic grippe is also undetermined. In influenza such organisms as *H. influenzae,* streptococcus, pneumococcus, and *M. catarrhalis* are regarded as secondary invaders which aggravate the pathologic picture by frequently inducing severe and fatal bronchopneumonias. Immunization would be an ideal method of prevention, but no efficacious procedure has been available in past

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epidemics, probably as the cause had not been fully determined. "Individual immunity to the virus of influenza as measured by the development of neutralizing antibodies in the blood can be readily accomplished by inoculation of human beings with either living or killed cultures of influenza virus."[5] Extensive studies are now being carried out with different antigenic strains of the virus. A flu-distemper viral vaccine has been used recently.[7] Horsfall[8] in his recent review, however, concludes that the average extent of immunity induced by vaccines containing influenza A virus was too insufficient to allow it to be considered as a practicable prophylactic measure.

Pneumonia Prophylaxis

Artificial immunization against lobar pneumonia, whether active or passive, is of questionable value for prevention. It is known that immunity develops to pneumococci, but the duration of the immunity thus induced is limited.

Environmental Control

Besides control along immunologic lines, measures directed at environment have recently been receiving increased attention. The new "air-borne" or indirect hypothesis "postulates that the greatest spread of respiratory infection is produced by small dried droplets floating in air for relatively long times and distances or by the resuspension of dried droplets in air after they have settled to surfaces such as floors, clothing, and bed clothes."[9] Alpha hemolytic streptococci of nasopharyngeal origin are widely distributed. The virulence of the microorganism is never more than slightly impaired by sojourn in rooms. One of the outgrowths of these observations as related to surgery is that it has been possible to reduce wound infections by less frequent dressings.

The object in environmental control is to destroy the respiratory pathogens in air either by radiation, or by chemical sprays or aerosols. It has been observed that the concentration of organisms in the air is reduced by natural sunlight; even diffuse daylight has been found to have a lethal effect. These observations suggest planning for maximum window space in occupied buildings.

Ultraviolet radiation, while more potent than visible light, cannot, at present, be unreservedly endorsed for use in industrial plants for the purpose of controlling acute respiratory infections.

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If it is used, special attention must be given for protection of individuals, particularly as regards exposure of skin and eyes.

Aerosols.—Various germicides in an appropriate solvent and sometimes incorporating a wetting agent have been used as aerosols. Among the various agents that have been used in experimental work are resorcinol, resorcinol glycerine, hexyl resorcinol in propylene glycol, formaldehyde-water, and hypochlorite solutions. Twort and his coworkers[10] found that 10 per cent hexyl resorcinol dissolved in propylene glycol added to 0.05 per cent sulfonated lorol was the most effective all-around germicidal mixture of those they tested. Minimal effective mist concentration of resorcinol glycerine aerosol was about 1:400,000,000 by volume. This level was confirmed by Williamson and Gotaas.[11] The latter, in referring to the practical use of aerosols in places occupied by persons, state that the aerosol must be nontoxic to man, nonirritating to the eyes and lungs, rapidly lethal to the bacteria when present in small concentrations, inodorous, invisible, noninflammable, noncorrosive, persistent, and should not leave films and coatings on walls and furniture. Needless to say, considerable investigation is necessary before aerosols can be used in occupied rooms. It may be used in such rooms as laboratories and media rooms where the aerial germicide may be allowed to dissipate before the room is occupied.

General Measures in the Control of Colds, Influenza, and Pneumonia

Since no satisfactory immunity can be established against these acute respiratory infections and even the new chemotherapeutic agents are of little avail in viral pneumonias and most other viral diseases, it is apparent that many procedures are necessary to cope with an epidemic of one or all of these diseases. Specific measures of hygiene and sanitation are to be recommended during epidemic periods. Such measures have been tersely summarized for these respiratory diseases, as well as other communicable diseases, in a report of a committee of the American Public Health Association.[12] This pamphlet should be in the hands of every plant medical director.

Because the minor and acute respiratory ailments, such as common cold, not infrequently lead to disabling pneumonia, otitis media, and mastoiditis, a major effort should be directed toward controlling colds. Remembering that colds are spread by close contact in the acute stages of the disease, certain public

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health procedures should be seriously considered. These include, among others, (1) isolation at home during the early and highly contagious stage of a cold which will lessen the spread of the infection, and (2) avoidance of close contact with persons suffering from colds, and of closed spaces where large numbers of infected persons congregate, which may be recommended through a health education program.

The spread of these diseases most frequently takes place through the medium of infected particles sprayed into the air by talking, coughing, and sneezing. Where general public health measures for control have been applied, they have included improvement of general hygiene and living conditions, especially overcrowding. Persons suffering from minor respiratory infections should take unusual care in the avoidance of dangerous contacts, allow themselves periods of rest, and avoid such predisposing factors as chilling, exposure to severe climatic changes, fatigue, and excesses of all kinds.

Many procedures in the plant medical department if adopted as routine may aid materially. The preemployment examination should pick out those prone to acute exacerbation, sinusitis, asthma, and bronchitis. Employees should be required to check through the medical department when they become ill on the job and after acute illness. These checks afford an excellent opportunity for directing those ill to prompt treatment by the new therapeutic techniques now available. Contact between persons in the more contagious phases of minor respiratory diseases can therefore be avoided. By thus encouraging prompt treatment, disabling effects may be reduced in number and severity. That an all-around industrial hygiene program will yield substantial results is attested to by a number of recent reports by industrial physicians.

CHRONIC RESPIRATORY INFECTIONS

In addition to the acute respiratory diseases, those of a chronic nature exact a large toll of lost time. These diseases are exemplified by pulmonary tuberculosis, which claims the lives of sixty thousand Americans each year. It is more and more becoming recognized as an affliction of older occupied men.[13] As an example of American industrial tuberculosis experience, it is gratifying to note that the death rate[14] among industrial policyholders of the Metropolitan Life Insurance Company has been reduced to about one-fifth that of 1917. With the changeover to

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war production, however, attention must be directed to a possible increase of this disease, particularly as regards women. The single exception to a satisfactory public health situation in Britain was a rise of almost 10 per cent in the mortality from tuberculosis in 1939 and 1940.[15] The increment in this case was greatest in young women and was thought to be related to malnutrition.

Control Programs

By directing medical measures for the control of the chronic respiratory diseases at pulmonary tuberculosis, tangible results are obtainable with nontuberculous affections as well. The essence of the medical program is the radiographic examination of the chest. This procedure has been the basis of medical control of silicosis, in which disease the infective element, particularly tuberculosis, is the principal cause of disability. As in pneumoconiosis, X-ray examination of the chest, if supplemented by clinical study, will aid in obtaining proper medical management for such other pulmonic conditions as bronchiectasis, asthma, and cancer.

As an illustration of what can be accomplished in tuberculosis control by a plant, reference is made to the experience of Sawyer.[16, 17] An X-ray survey of 3,280 apparently healthy employees in 1921 showed 2.3 per cent positive for clinical tuberculosis. From 1928 on, the medical department has been doing serial or annual X-rays of the chest. In a group of 4,665 employees, averaging 33 years in age, and studied from 1928 to 1935, only 0.5 per cent showed active or clinical tuberculosis. By 1940 this percentage was down to 0.2 per cent, which is probably close to the irreducible minimum. What has been done by Sawyer can to a considerable extent be achieved in any employed group if a definite program is outlined and followed.

The Metropolitan Life Insurance Company,[18] following the adoption of a tuberculosis control program, reduced the number of cases of significant pulmonary tuberculosis from 40 per 10,000 employees in 1930 to 10 per 10,000 in 1939. Use was made of routine preemployment X-rays and the Metropolitan sanatorium. It was observed, however, that during the period, 1930 to 1939, the prevalence of tuberculosis among applicants for employment had not been reduced; the experience indicates 80 cases of significant tuberculosis per 10,000 applicants and, according to Sherman,[19] this probably represents a fair average.

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Other industries also have had anti-tuberculosis programs in effect. There should be no relaxation in the program of controlling pulmonary infection and indeed an extension of the program to the smaller industrial plants is indicated.

X-ray Methods.—Recent radiographic surveys of employed groups, who had not been X-rayed previously, have revealed 1 to 2 per cent of the employees with significant tuberculosis. Case finding is an important feature in a tuberculosis control program that can be effected by the industrial physician. A number of X-ray procedures are available, such as single or stereo 14 by 17 inch films, 14 by 17 inch paper, 35 mm., 4 by 5 inch, or 4 by 10 inch photofluorographic methods, and fluoroscopic examination.

Photofluorograms have been adapted for mass X-raying work in the armed forces, as well as in the medical departments of a number of large industrial plants. If a grid is used, very satisfactory photofluorograms can be obtained. For best results this will require at least 200 milliampere equipment. It has been the practice not to rely on the fluorograms, particularly the 35 mm. size, for diagnoses, but, instead, this technique is expected to pick out persons with definitely abnormal or suspicious chest findings. These individuals are then rechecked with standard 14 by 17 inch single or stereoroentgenograms taken for diagnostic interpretation.

In advocating small film X-ray pictures as a routine for all patients admitted to general hospitals, Hilleboe[20] refers to the experience of the University Hospital, Ann Arbor, Michigan, where it was found by this technique that 10 per cent of the patients admitted showed lesions of the organs in the chest. The U. S. Public Health Service now has eleven photofluorographic units in the field, each accompanied by a medical officer, technician, and clerk. Plants may appeal to the Public Health Service through the State health department for the services of one of these 35 mm. units if no other means for mass X-raying is available. Experience has shown that 300 to 500 photofluorograms a day can be made with one of the units.

Administrative Procedures.—Sawyer,[16, 17] who has had years of experience administering a tuberculosis control program, offers helpful suggestions in its conduct. His program is directed at three groups: (1) applicants for employment, (2) employees with negative X-rays, and (3) employees with suspected tuberculosis. He has noted that it has been too time-consuming to furnish each individual a report on the findings yielded by his radiogram. Hence, he recommends issuing a mimeographed statement

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to the patient at the time of X-ray, stating that if his X-ray is negative he will not receive a report, but if his lungs are affected he will be so notified. Employees having latent, clinically insignificant lesions are reported as having lungs that are negative or clear.

Employability.—Applicants with healed primary tuberculosis or inactive types of reinfection tuberculosis are ordinarily acceptable for employment. For a number of years the Public Health Service has advocated, even in the dusty trades, that the worker with evidence of healed primary tuberculosis should not be denied employment on this account alone. There are many types of employment where persons are acceptable with clinically negative, stabilized lesions, minimal or moderately advanced in extent. If adequate X-ray equipment is available, it may be possible in some instances to accept individuals with small soft lesions, but these workers will require close medical supervision. The individuals with active and questionably active tuberculosis are not acceptable for employment, but should be referred to their physician, the local public health authorities, or a clinic.

Frequency of Periodic X-Ray.—The means toward the end of obtaining satisfactory periodic X-rays is an adequate record system. This will make it possible to call back the employee for reexamination, according to the need for recheck. The Public Health Service has recommended annual medical examination of workers in the siliceous dusty trades to detect evidence of pulmonary tuberculosis and early silicotic changes. Sawyer[21] recommends annual X-ray for young workers (ages 18 to 25), whose preemployment X-ray was negative for clinical tuberculosis, gradually increasing the time interval between examinations to three years if the chest roentgenogram continues to be negative. Individuals 30 years of age and over with negative X-rays at the beginning of employment are scheduled for re-X-ray at 3-year intervals.

The frequency of X-raying workers with evidence of tuberculosis depends on the extent of pulmonary involvement and dynamic status of the disease. Sherman.[19] in the instance of ex-patients, has suggested X-ray and sputum study every three months for the first two years following their discharge from a sanatorium, and every six months thereafter. He feels that those with a history of contact should be X-rayed at once and every six months for a period of three years and annually thereafter.

Follow-Up, After-Care, Rehabilitation.—Next to finding the case of tuberculosis, adequate follow-up is of extreme importance,

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particularly from the patient's standpoint. The patient should be referred to his private physician or to a clinic and the case reported to the local health department. Public health officials and local voluntary tuberculosis agencies are especially helpful in this follow-up stage. They can assist in arranging for sanatorial care and be of material assistance in checking on possible contacts in the home. If sanatoria are not available, outpatient supervision is far superior to no care at all.

In the development and the successful prosecution of a tuberculosis control program in any community, it is essential for public health officers to have the cooperation of the State and local medical society, management, labor, and voluntary agencies. This procedure will insure appropriate follow-up and after-care, and also pave the way for rehabilitation of the affected individual to industry. In this connection, from 65 to 75 per cent of the workers with minimal and moderately advanced tuberculosis[19] can be expected to return to their former positions in industry after an adequate stay in a modern sanatorium. Many industrial organizations reemploy workers with arrested tuberculosis. Factors to be considered in the employment of a worker with arrested tuberculosis are as follows:[17] (1) extent of the lesion, (2) completeness of the cure, (3) character of the job, and (4) the necessity for adequate medical supervision after return to work.

CONCLUSION

In this period of profound socio-economic stress every facility for searching out active cases and getting them under treatment should be employed to prevent an unfavorable effect on the present downward trend of the American tuberculosis mortality rate. The X-ray is a potent tool to this end and the medical departments of many industrial organizations have demonstrated how much can be done in promoting the control of tuberculosis. The plant physician should formulate a program making use of the X-ray for preemployment and periodic examinations of his employees. To provide for satisfactory disposition of cases found, the plant physician should also establish liaison with local workers in the field of tuberculosis control.

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CHAPTER 20

ILLUMINATION, NOISE, AND RADIANT ENERGY

Allen D. Brandt, D.Sc., and Harry E. Seifert, C.E., M.S.P.H.

ILLUMINATION *

ON February 28, 1942, the Chairman of the War Production Board, announced that the President of the United States had officially launched a production drive with certain war production quotas which had to be met in that year. To meet the specified quotas each war production plant was asked to organize a Production Drive Committee to give close attention to such problems as: (1) taking care of tools, (2) preventing breakdowns, (3) cutting down accidents, (4) good lighting, (5) maintenance and repair, (6) adapting old machines to new uses, (7) cutting wastage, (8) breaking production bottlenecks, and (9) using every machine to the fullest extent.

From this list of nine items it will be recognized that the solution of the lighting problem will greatly contribute toward the solution of the others. In wartime good lighting might be classified as both an offensive and a defensive weapon. As an offensive weapon, it increases human efficiency and production by conserving priceless manhours. As a defensive weapon it minimizes eyestrain, reduces accidents and provides for human safety, and protects the manufactured products from the destructive effects of carelessness and sabotage.

Beneficial Effects of Good Illumination

Illumination is a factor of primary importance which affects the environment in every industrial establishment. The beneficial effects of good illumination, both natural and artificial, have been established in extensive tests over many years. The advantages to industry are many: (1) greater accuracy of workmanship, resulting in an improved quality of product with less spoilage and rework, (2) increased production and decreased costs, (3) better utilization of floor space, (4) greater ease of seeing es-

* Based on information contained in material cited,[13] with the permission of the Illuminating Engineering Society.

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pecially among older employees, thus making them more efficient, (5) less eyestrain among employees, (6) improved morale among employees resulting in decreased labor turnover, (7) more easily maintained cleanliness and neatness in the plant, and (8) greater safety.

Greater Accuracy of Workmanship[1]

Under good illumination it is possible to see an object of much smaller size than under poor illumination. Thus a closer check can be made throughout the manufacturing process which will result in earlier discovery of visible defects, permitting rejection prior to final inspection.

Increased Production

It takes time to see—the eye is somewhat like a camera in this respect. An increase in illumination from one footcandle to a moderate level of approximately 20 footcandles, a condition often occurring upon the installation of a modern lighting system, results in increasing the speed of seeing approximately three times.[2] This enormous improvement in perception and recognition of surroundings affects practically everything the worker does. It reduces the time required for seeing and some of this time, at least, becomes available for production. The experiences of many plants which have improved their lighting bear out this point.[3]

Better Utilization of Floor Space[4]

A uniform level of general lighting makes possible the most efficient arrangement of machinery and conveyors and better utilization of floor space. Manufacturers have discovered that more work can be achieved with less floor space when the work flows in straight lines through assembly or inspection sections. Good lighting facilitates such proper arrangement of the work and practically eliminates the likelihood for crowding.

Greater Ease of Seeing

Very frequently the older employee is well fitted physically and mentally for the responsible work for which his years of experience have prepared him. In many instances, however, failing vision will prevent such an employee from carrying on exacting work and thus he is relegated to simple routine tasks

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in which his experience is of little value. It is desirable to preserve the experience of the older worker and receive the advantage of his long accumulated skill and knowledge.

It has long been known that as the eyes grow older there is a progressive loss in visual acuity and the prevalence of defective vision increases markedly. Much can be done to give assistance to eyes that are defective. Eyeglasses may correct refractive errors and permit the eyes to focus upon near and far objects. Higher illuminations are likewise an effective aid toward better seeing.

Many of these valuable, skilled, older workers can continue to perform efficiently if the simple expedient of assisting their eyes with good illumination is adopted.

Less Eyestrain

It should not be construed that good lighting is of assistance only to the older employees. Good lighting also aids all the visually handicapped to a greater extent than those with perfect vision, but even those in the latter group find, under good lighting, a noticeable improvement in eye comfort which results in reduced fatigue.

Improved Morale of the Employees

There is an important psychological effect connected with cheerful, pleasant, modern working surroundings as compared to the dim, gloomy interiors which were formerly so prevalent. In addition to the more cheerful appearance of a well-lighted interior, many minor frustrations due to poor lighting which continually harass the workers are eliminated; it is sufficient to refer to the difficulty in reading scales and micrometers, and to the finding of proper drills and other tools.

Plant Cleanliness

All industry has found that cleanliness invariably pays. Poor illumination makes it difficult to see into corners or under machinery and these dark areas inevitably collect dirt and waste which would otherwise be cleaned out. Where dirt can be seen it is more likely to be removed. In the well-lighted plant such dingy areas do not exist and sanitary conditions prevail.

In industrial plants that have their own engineering departments it is desirable that the combined efforts of the electrical engineering department, the operating department and the safety

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department be enlisted to secure adequate maintenance of lighting equipment and to study lighting problems.

It is urged that those plants which do not have engineering departments consult a competent illuminating engineer.

Safety

Engineering for safe plant operation consists essentially of preparing a safe environment for the worker. The environment should be designed to match and to compensate for the limitations of human capability. On the other hand, the worker must understand his personal responsibilities regarding acts which might conceivably cause injury to himself or to others, and carefully follow plant safety regulations. The admirable activities of those organizations and individuals interested in the promotion of safety are successfully implanting this sense of responsibility in the individual worker.

However, as revealed by an analysis of accidents and their causes, this is but one phase of the safety problem. All personal injury accidents involve a combination of *personal* and *mechanical causes*. The chain of circumstances or series of causes which has brought a worker to the verge of an injury frequently can be broken only if the worker can see quickly and accurately the causes, and hence act to prevent the accident.

Any factor which aids seeing will increase the probability that the worker will detect the causes of an accident and act to avert it. It is realized that with rapidly-moving material, mechanical failures often result in accidents occurring too rapidly for any reaction on the part of the worker. However, mechanical failures of this nature are usually preceded by evidences of undue stresses or strains which may be detected if sufficient illumination is provided.

The close correlation between the personal injury rates and illumination is not generally understood. In most cases, where accidents are attributed to poor illumination, they occur because there is an improper quality of illumination or practically no illumination at all. Poor or indifferent lighting, even though it may provide measurable quantities of light, has been frequently overlooked as a contributing cause of accidents. Many factors associated with poor illumination, such as glare, light reflected from the work, and dark shadows, hamper seeing and cause afterimages and excessive visual fatigue which are important contributing causes of industrial accidents. Many accidents are also

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caused by delayed eye adaptation when coming from bright surroundings into dark interiors. Frequently accidents which are attributed to the worker's carelessness can actually be traced to difficulty of *seeing*.[5]

One important cause of industrial losses is the minor accident where the employee may or may not report for first aid but continues his work, with a decrease in the quantity and quality of his work.

The condition of the illumination at the point of accident and in the surrounding area should always be inspected and reported in accident investigations.

Factors of Good Illumination

There are many factors involved in good illumination. Lighting installations, therefore, should be designed by a competent illuminating engineer. However, those who live with the lighting and those who must justify its cost should be acquainted with some of the factors to be considered. These can be summed up under the headings of *quality*, which includes, among other things, the color of light, its direction, diffusion, and absence of glare, and *quantity*, or the amount of illumination.

Quality of Lighting

The quality of the lighting[6] whether natural or artificial is highly important in providing good seeing conditions. Glare, diffusion, direction, and distribution have significant effects on visibility and the ability to see easily, accurately and quickly.

Glare.—Glare may be defined as any brightness within the field of vision of such character as to cause discomfort, annoyance, interference with vision, or eye fatigue. It is one of the most common and serious faults of lighting installations.

Glare is objectionable because: (1) when continued it tends to injure the eye and disturb the nervous system; (2) it causes discomfort and fatigue and thus reduces the efficiency of the worker, and (3) it interferes with, and often prevents, clear vision and thus reduces efficiency, and in many instances increases the risk of accidents or injury to the workers. From both a humanitarian and a business viewpoint, the owner or operator of a factory should be interested in avoiding glare whether caused by daylight or by artificial light.

There are two common forms of glare, *direct* and *reflected*. *Direct glare* is caused by excessive brightness or brightness-con-

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trast within the visual field, that is, unshielded lamps or high-brightness surfaces of fixtures.

To reduce direct glare from the artificial lighting, direct general-lighting luminaries should be mounted at a sufficient height to keep them well above the normal line of vision. They should be properly designed to limit both the brightness and the quantity of light emitted in directions directly below the horizonal since such light is well within the normal field of view and interferes with vision.

High brightness-contrasts should be avoided. For example, an unshielded lamp viewed against the low brightness of a dark ceiling may be very glaring, similarly, a bright window seen against darker surrounding walls.

Supplementary lighting sources should be carefully designed so that the light is confined to the immediate working area. Failure to observe this precaution may cause extreme annoyance not only to the worker using the source but to others in the vicinity. Care should also be exercised to prevent excessive brightness-contrasts between the work and the surroundings.

Reflected glare, as its name implies, is caused by high brightnesses, images or brightness-contrasts reflected from ceilings, walls, desk tops, or other surfaces within the visual field such as materials and machines. These brightnesses are accentuated when the surfaces are glossy or specular in character, such as highly-polished machine parts, smooth-finished surfaces, varnished table tops or other highly-reflective surfaces. Reflected glare is frequently more annoying than direct glare because it is so close to the line of vision that the eye cannot avoid it. The effect of reflected glare for a given image brightness is reduced with higher levels of general illumination due to the reduction in contrast.

Diffusion and Distribution of Light.[6]—Some directional and shadow effects are desirable in general illumination for accentuating the depth and form of solid objects, but harsh shadows should be avoided. Shadows are softer and less pronounced when diffusing units and units having a wide distribution of light are used, since then the object is illuminated from many sources. Alternate light and dark areas in strong contrast are undesirable because the eye has difficulty in adjusting itself to the two illuminations and seeing becomes tiring. For this reason, purely local lighting restricted to a small work area is unsatisfactory unless there is sufficient general illumination in the room.

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Clearly defined shadows, without excessive contrast, are a distinct aid to sight in certain types of operations such as engraving on polished surfaces, scribed layout work, and textile inspection. When such shadow effect is indicated, it is best obtained by supplementary directional light combined with diffused illumination of ample intensity.

Much attention has been given to measurement of footcandles on the horizontal plane. Actually many of the seeing tasks in industry are on vertical or nearly vertical surfaces. Hence the amount and the distribution of light on vertical surfaces may be of great importance.

Color Quality of Light.—It appears that with equal footcandles of illumination, variations in color quality of light have little or no effect upon clearness and quickness of seeing.[7, 8] A recent study has indicated that the same is true for fluorescent light.[9] However, in certain industries color discrimination is highly important, and light sources which provide lighting that will enable the matching to be performed most accurately should be used. This again is a matter in which the illuminating engineer should be consulted.

Color of Surroundings.—Light-colored surfaces serve several purposes in the factory. They are of particular value in providing a high utilization of light because they reflect more light toward the working areas. Also, bright window areas and artificial light sources are less uncomfortable to the eye when viewed against light backgrounds.

Many progressive establishments are painting all of their machinery with light-tinted durable paints. This provides an increased amount of light which is reflected to the otherwise shadowed sections of the machine. Some manufacturers paint stationary and moving parts of machines different colors to aid seeing and thus prevent accidents.

Quantity of Light

The desirable quantity of light for any particular installation depends primarily upon the work which is being done. The degree of accuracy, the fineness of detail to be observed, the color and reflectivity of the work as well as of the immediate surroundings materially affect the distribution of brightness which will produce maximum seeing conditions. Investigations in the field and laboratory have proved that as the illumination on the task is increased, the ease, speed and accuracy with which the task can

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be accomplished are increased. These tests have not yet established an upper limit but the harmful effects of low-foot-candle values are well known.[2]

It is possible to measure quantity of light quickly and with reasonable accuracy by the use of any of the various meters employing light-sensitive cells. These instruments are direct-reading and simple, but they should be calibrated at frequent intervals. It is highly important that the measurement be made at the point and in the plane in which the seeing task is performed, whether it be horizontal, vertical, or at some intermediate angle. If lighting is a combination of natural and artificial illumination, that part due to natural light should be measured separately from that due to the artificial light since in many instances at one hour of the day there is a great amount of natural light while at a different time it may fail entirely.

Brightness measurements hitherto difficult of accomplishment are now easily made with a Brightness Meter.

Recommended Minimum Standards of Illumination.—The majority of the recommended values of illumination in Table 1[18] refers to the general lighting or lighting throughout the total area involved as measured on a horizontal plane 30 inches above the floor. In some instances where an illumination of more than 50 footcandles is necessary it may be obtained by a combination of general lighting plus supplementary lighting at the point of work. An asterisk after the footcandle figure denotes that the combination of general and supplementary illumination is desirable.

The Illuminating Engineering Society has been studying the illumination needs of specific industries in recent years. Wherever reports of these industries have been completed, the footcandles included in Table 1 are taken from the appropriate report. In other instances the values are based upon current good practice. These reports[10-17] should be consulted for detailed lighting specifications for manufacturing processes.

Attention is called to the fact that the values given are minimum operating values; that is, they apply to measurements of the lighting system in use, not simply when the lamps and reflectors are new and clean—and in almost every instance higher values may be used with greater benefit.

To insure that a given illumination will be maintained even where conditions are favorable it is necessary to design the system to give initially at least 25 per cent more light than the re-

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TABLE 1.—MINIMUM FOOTCANDLES IN SERVICE.[16] RECOMMENDED MINIMUM STANDARDS OF ILLUMINATION FOR INDUSTRIAL INTERIORS. (These Footcandle Values Represent Order of Magnitude Rather than Exact Levels of Illumination.)

	Minimum Footcandles in Service Measured 30 inches above the Floor
ASSEMBLY:	
Rough	10
Medium	20
Fine	B*
Extra fine	A*
AUTOMOBILE MANUFACTURING:	
Assembly line	B*
Frame assembly	20
Body manufacturing—	
Parts	20
Assembly	20
Finishing and inspecting	A*
BAKERIES	20
BOOK BINDING:	
Folding, assembling, pasting, etc.	10
Cutting, punching and stitching	20
Embossing	20
BREWERIES:	
Brew house	5
Boiling, keg washing and filling	10
Bottling	20
CANDY MAKING:	
Box department	20
Chocolate department—	
Husking, winnowing, fat extraction, crushing and refining, feeding	10
Bean cleaning and sorting, dipping, packing, wrapping	20
Milling	30
Cream making—	
Mixing, cooking and molding	20
Gum drops and jellied forms	20
Hand decorating	50
Hard candy—	
Mixing, cooking and molding	20
Die cutting and sorting	30
Kiss making and wrapping	30
CANNING AND PRESERVING	20
CHEMICAL WORKS:	
Hand furnaces, boiling tanks, stationary driers, stationary and gravity crystallizers	5
Mechanical furnaces, generators and stills, mechanical driers, evaporators, filtration, mechanical crystallizers, bleaching	10
Tanks for cooking, extractors, percolators, nitrators, electrolytic cells	15
CLAY PRODUCTS AND CEMENTS:	
Grinding, filter presses, kiln rooms	5
Molding, pressing, cleaning and trimming	10
Enameling	15
Color and glazing	20
CLEANING AND PRESSING INDUSTRY:	
Checking and sorting	20
Dry and wet cleaning and steaming	10
Inspection and spotting	A*
Pressing—	
Machine	20
Hand	50
Receiving and shipping	10
Repair and alteration	50
CLOTH PRODUCTS:	
Cutting, inspecting, sewing—	
Light goods	20
Dark goods	A*
Pressing, cloth treating (oilcloth, etc.)—	
Light goods	10
Dark goods	20
COAL TIPPLES AND CLEANING PLANTS:	
Breaking, screening and cleaning	10
Picking	A*
CONSTRUCTION—INDOOR:	
General	10
ELEVATORS—FREIGHT AND PASSENGER	10
ENGRAVING	A*
FORGE SHOPS AND WELDING	10
GARAGES—AUTOMOBILE:	
Storage—live	10

* See reference footnote at end of table.

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TABLE 1.—*Continued*

	Minimum Footcandles in Service Measured 30 inches above the Floor
GARAGES—AUTOMOBILE:—*Cont'd.*	
Storage—dead	2
Repair department and washing	30
GLASS WORKS:	
Mix and furnace rooms, pressing and lehr, glass blowing machines	10
Grinding, cutting glass to size, silvering	20
Fine grinding, polishing, beveling, etching and decorating	50 C*
Inspection	B* C*
GLOVE MANUFACTURING:	
Pressing, knitting, sorting—	
Light goods	10
Dark goods	20
Cutting, stitching, trimming, inspection—	
Light goods	20
Dark goods	A*
HANGARS—AIRPLANE:	
Storage—live	10
Repair department	50
HAT MANUFACTURING:	
Dyeing, stiffening, braiding, cleaning and refining—	
Light	20
Dark	30
Forming, sizing, pouncing, flanging, finishing and ironing—	
Light	20
Dark	30
Sewing—	
Light	20
Dark	A*
ICE MAKING—ENGINE AND COMPRESSOR ROOM	10
INSPECTION:	
Rough	20
Medium	30
Fine	B*
Extra fine	A*
IRON AND STEEL MANUFACTURING.†	
JEWELRY AND WATCH MANUFACTURING	A*
LAUNDRIES	20

	Minimum Footcandles in Service Measured 30 inches above the Floor
LEATHER MANUFACTURING:	
Vats	5
Cleaning, tanning and stretching	10
Cutting, fleshing and stuffing	20
Finishing and scarfing	30
LEATHER WORKING:	
Pressing, winding and glazing—	
Light	10
Dark	20
Grading, matching, cutting, scarfing, sewing—	
Light	20
Dark	A*
LOCKER ROOMS	10
MACHINE SHOPS:	
Rough bench and machine work	20
Medium bench and machine work, ordinary automatic machines, rough grinding, medium buffing and polishing	30
Fine bench and machine work, fine automatic machines, medium grinding, fine buffing and polishing	B*
Extra fine bench and machine work, grinding—	
Fine work	A*
MEAT PACKING:	
Slaughtering	10
Cleaning, cutting, cooking, grinding, canning, packing	20
MILLING—GRAIN FOODS:	
Cleaning, grinding and rolling	10
Baking or roasting	20
Flour grading	30
OFFICES:	
Bookkeeping, typing and accounting	50
Business machines—power driven (transcribing and tabulating)—	
Calculators, key punch, bookkeeping	B*

* See reference footnote at end of table.

† Consideration is now being given to the proposition of issuing a report on recommended lighting practice for the entire iron and steel industry.

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TABLE 1.—*Continued*

	Minimum Footcandles in Service Measured 30 inches above the Floor
Conference room—	
General meetings	25
Office activities—See deskwork	
Corridors and stairways	5
Deskwork—	
Intermittent reading and writing	25
Prolonged close work, computing, studying, designing, etc.	50
Reading blueprints and plans	30
Drafting—	
Prolonged close work, art drafting and designing in detail	50
Rough drawing and sketching	30
Filing and index references	25
Lobby	10
Mail sorting	25
Reception rooms	10
Stenographic work	50
Vault	10
PACKING AND BOXING	10
PAINT MIXING	10
PAINT SHOPS:	
Dipping, simple spraying, firing	10
Rubbing, ordinary hand painting and finishing art, stencil and special spraying	20
Fine hand painting and finishing	B*
Extra fine hand painting and finishing (automobile bodies, piano cases, etc.)	A*
PAPER BOX MANUFACTURING:	
Light	10
Dark	20
Storage	5
PAPER MANUFACTURING:	
Beaters, grinding, calendering	10
Finishing, cutting, trimming, paper making machines	20
PLATING	10
POLISHING AND BURNISHING	20
POWER PLANTS, ENGINE ROOM, BOILERS:	
Boilers, coal and ash handling, storage battery rooms	5
Auxiliary equipment, oil switches and transformers	10
Engines, generators, blowers, compressors	20
Switchboards	30
PRINTING INDUSTRIES:	
Type foundries—	
Matrix making, dressing type	A*
Font assembly—sorting	B*
Hand casting	30
Machine casting	20
PRINTING PLANTS:	
Presses	30
Imposing stones	A* C*
Proof reading	A*
ELECTROTYPING:	
Molding, finishing, leveling molds, routing, trimming	B*
Blocking, tinning	30
Electroplating, washing, backing	20
PHOTO ENGRAVING:	
Etching, staging	20
Blocking	30
Routing, finishing, proofing	B*
Tint laying	A*
RECEIVING AND SHIPPING	10
RUBBER TIRE AND TUBE MANUFACTURING:	
Stock preparation—	
Plasticating	20
Milling	20
Calendering	30
Branbury	20
Fabric Preparation—	
Stock Cutting	30
Bead Building	30
Tube Tubing Machines	20
Tread Tubing Machines	20
Tire building—	
Solid tire	20
Pneumatic tire	50
Curing department—	
Tube curing	B*
Casing curing	B*

* See reference footnote at end of table.

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TABLE 1.—*Continued*

	Minimum Footcandles in Service Measured 30 inches above the Floor
RUBBER TIRE AND TUBE MANUFACTURING:—*Cont'd.*	
Final inspection—	
Tube	B*
Casing	A*
Wrapping	20
Warehouse	5
MECHANICAL RUBBER GOODS:	
Stock preparation—	
Plasticating	20
Milling	20
Calendering	30
Branbury	20
Fabric preparation—	
Stock cutting	30
Hose looms	30
Molded products	B*
Extruded products	30
Curing	B*
Inspection	A*
Boxing	20
Warehouse	5
SHEET METAL WORKS:	
Miscellaneous machines, ordinary bench work	20
Punches, presses, shears, stamps, spinning, medium bench work	20 C*
Tin plate inspection	B* C*
SHOE MANUFACTURING (LEATHER):	
Cutting and stitching—	
Cutting tables	20
Marking, buttonholing, skiving, sorting, vamping and counting—	
Light materials	20
Dark materials	50
Stitching—	
Light materials	50
Dark materials	B*
Making and Finishing—	
Stitchers, nailers, sole layers, welt beaters and scarfers, trimmers, welters, lasters, edge setters, sluggers, randers, wheelers, treers, cleaning, spraying, buffing, polishing, embossing—	
Light materials	30
Dark materials	50
Storage, packing and shipping	10
SHOE MANUFACTURING (RUBBER):	
Washing, coating, mill run compounding	10
Varnishing, vulcanizing, calendering, upper and sole cutting	30
Sole rolling, lining, making and finishing processes	50
SOAP MANUFACTURING:	
Kettle houses, cutting, soap chip and powder	10
Stamping, wrapping and packing, filling and packing soap powder	20
STAIRWAYS, PASSAGEWAYS	5
STONE CRUSHING AND SCREENING:	
Belt conveyor tubes, main line shafting spaces, chute rooms, inside of bins	5
Primary breaker room, auxiliary breakers under bins	5
Screens	10
STORAGE BATTERY MANUFACTURING:	
Molding of grids	10
STORE AND STOCK ROOMS:	
Rough bulky material	5
Medium or fine material requiring care	10
STRUCTURAL STEEL FABRICATION	10
SUGAR GRADING	30
TESTING:	
Rough	20
Fine	30
Extra fine instruments, scales, etc	A*
TEXTILE MILLS (COTTON):	
Opening, mixing, picking, carding and drawing	10
Slubbing, roving, spinning	20
Spooling, warping on comb	20
Beaming and slashing on comb—	
Gray goods	20
Denims	B*

* See reference footnote at end of table.

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TABLE 1.—*Continued*

	Minimum Footcandles in Service Measured 30 inches above the Floor
Inspection—	
Gray goods (hand turning)	50
Denims (rapidly moving)	A*
Automatic tying-in, weaving	B*
Drawing-in by hand	A*
Weaving	25
SILK AND RAYON MANUFACTURING:	
Soaking, fugitive tinting, and conditioning or setting of twist	10
Winding, twisting, rewinding, and coning, quilling, slashing	30
Warping (silk or cotton system) on creel, on running ends, on reel, on beam, on warp at beaming	50
Drawing-in—	
On heddles	A*
On reed	A*
Weaving—	
On heddles and reeds	10
On warp back of harness	20
On woven cloth	30
WOOLEN:	
Carding, picking, washing, combing	15
Twisting, dyeing	15
Drawing-in, warping	A*
Weaving—	
Light goods	25
Dark goods	50
Knitting machines	20
TOBACCO PRODUCTS:	
Drying, stripping, general	10
Grading and sorting	A*
TOILETS AND WASH ROOMS	10
UPHOLSTERING—AUTOMOBILE, COACH FURNITURE	20
WAREHOUSE	5
WELDING	30
WOODWORKING:	
Rough sawing and bench work	15
Sizing, planing, rough sanding, medium machine and bench work, glueing, veneering, cooperage	20
Fine bench and machine work, fine sanding and finishing	50

* Lighting recommendations for the more difficult seeing tasks, as indicated by A, B, and C in the foregoing table, are given in the following:

GROUP A.—*These seeing tasks involve (a) the discrimination of extremely fine detail under conditions of (b) extremely poor contrast, (c) for long periods of time. To meet these requirements, illumination levels above 100 footcandles are recommended.*

To provide illumination of this order, a combination of at least 20 footcandles of general lighting plus specialized supplementary lighting is necessary. The design and installation of the combination systems must not only provide a sufficient amount of light but also must provide the proper direction of light, diffusion, eye protection, and insofar as possible must eliminate direct and reflected glare as well as objectionable shadows.

GROUP B.—*This group of visual tasks involves (a) the discrimination of fine detail under conditions of (b) a fair degree of contrast (c) for long periods of time. Illumination levels from 50 to 100 footcandles are required.*

To provide illumination of this order a combination of at least 20 footcandles of general lighting plus specialized supplementary lighting is necessary. The design and installation of the combination systems must not only provide a sufficient amount of light but also must provide the proper direction of light diffusion, eye protection, and insofar as possible must eliminate direct and reflected glare as well as objectionable shadows.

GROUP C.—*The seeing tasks of this group require the discrimination of fine detail by utiliring (a) the reflected image of a luminous area or (b) the transmitted light from a luminous area.*

The essential requirements are (1) that the luminous area shall be large enough to cover the surface which is being inspected and (2) that the brightness be within the limits necessary to obtain comfortable contrast conditions. This involves the use of sources of large area and relatively low brightness in which the source brightness is the principal factor rather than the footcandles produced at a given point.

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quired minimum. In locations where the dirt will collect rapidly and where adequate maintenance is not provided, the initial value should be at least 50 per cent above the minimum requirement.

Where safety goggles are worn, the light reaching the eye is likely to be materially reduced and the general level of lighting should, therefore, be increased accordingly in such locations.

In addition to the foregoing table of recommended minimum standards, Table 2 presents the recommended minimum illumination for many of the war production activities not specifically included in Table 1.

NOISE

There is both practical and experimental evidence to indicate that noise produces fatigue, impaired hearing, neuroses, decreased efficiency, and emotional disturbances.[19] Noise levels of 90 decibels (intensity of noise in an airplane) and higher have been found by experience to be harmful to the human ear.[20] Exposure to prolonged noise at lower levels, including the intensity of many occupational noises, is also harmful.[21]

As a guide in the evaluation of a noise problem, it is well to know that the intensity of noise near an airplane with motor running is about 95 decibels; in a New York subway it is about 80 decibels; in a large stenographic room it is about 70 decibels; and the intensity of sound in usual conversation varies from 35 to 70 decibels. Intensity alone is not the deciding factor, however. Of equal importance is the nature of the operation, and whether the noise is continuous or interrupted. For example, the average conversation of workers does not interfere with other workers in a machine shop but any conversation interferes with occupants of a library. Similarly a carpenter hammering and sawing does not affect the normal working of other nearby carpenters, but would reduce very much the efficiency in a room where stenographic work is being performed.

To reduce or eliminate the production loss resulting from noise, it is necessary in many industries to reduce the intensity of noise exposures as far as is feasible with good engineering practice. Noise may be prevented, or removed from the workers, by one or more of the following methods: (1) elimination of noise at its source, (2) isolation of noisy operations, (3) reduction of noise by sound insulation, and (4) the use of personal protective devices against noise.

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TABLE 2.—RECOMMENDED MINIMUM STANDARDS OF ILLUMINATION FOR WAR PRODUCTION AND ASSOCIATED ACTIVITIES. (The Footcandle Values are Average in Service and Represent Order of Magnitude Rather than Exact Levels.)

	Minimum Footcandles in Service
AIRPLANE MANUFACTURING:	
Stock parts—	
Production	50
Inspection	A*
Parts manufacturing—	
Welding, drilling, riveting and screw fastening	30
Spray booths	30
Sheet aluminum layout and template work; shaping and smoothing of small parts for fuselage, wing sections, cowling, etc.	50
Sub-assembly—	
Landing gear, fuselage, wind sections, cowling and other large units	30
Final assembly—	
Placing of motors, propellers, wing sections and landing gear; mounting of guns and other large equipment	30
Inspection of assembled ship and its equipment	B*
Machine tool repairs	A*
ARTILLERY MANUFACTURING:	
Forging and casting of gun barrels and mounts	10
Machining and grinding of gun barrels, breeches, mounts and carriages	30
Measuring and testing of parts; barrel boring; machining and assembly of range adjusters, and firing mechanisms	B*
General assembly	50
CONSTRUCTION—GENERAL:	
Excavation	2
Exterior	5
Indoor	10
EXPLOSIVES:	
Hand furnaces, boiling tanks, stationary driers, stationary and gravity crystallizers	5
Mechanical furnaces, generators and stills, mechanical driers, evaporators, filtration, mechanical crystallizers	10
Tanks for cooking, extractors, percolators, nitrators	15
PRECISION WAR EQUIPMENT:	
Assembly and adjustment of range finders, binoculars, periscopes, timing equipment, gun sights, electronic devices, torpedo mechanisms, etc.	A*
PROTECTIVE INDUSTRIAL LIGHTING:	
General	0.2
Vulnerable areas	1
SHELL LOADING PLANTS:	
Fuse and booster manufacturing	50
Inspecting, cleaning and spraying of shell forging	30
Loading of shells, bombs, mines and depth charges—	
Hand	B*
Automatic	30
Cleaning and inspection	30
Assembly of shells, bombs, mines and depth charges	50
Packing and boxing, storage	10
SHIPYARDS:	
General	5
Ways and fabrication areas	10
TANK MANUFACTURING:	
Assembly line	B*
Frame assembly	20
Body manufacturing—	
Parts	20
Assembly	20
Finishing and inspecting	A*

* Same as for Table 1.

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Elimination of Noise at Its Source

The causes of much of the noise in industry are faulty design of machinery, worn machine parts, improper machine mounting, improper location of machines, and carelessness in operating machinery. While it may be expensive in some cases to eliminate these sources of noise, it is frequently a profitable investment over a period of years. Silent operation may be accomplished by (1) replacing worn parts early, (2) using well balanced parts, (3) mounting machinery and guards so that they will not vibrate, (4) keeping moving parts well oiled, (5) having direct or belt drive in place of open gears, or using nonmetallic gears where gears are necessary, and (6) mounting machinery on appropriate bases. A good example of an operation wherein noise has been effectively reduced is that of pressure riveting or welding in place of pneumatic riveting.

Isolation of Noisy Operations

Noise-producing machinery frequently requires only one or two operators, but is so located that many workers are exposed to the noise. Operations of this type should be isolated in well-insulated enclosures so that only the operators are exposed to the noise. Likewise, noisy motors and gears can frequently be housed in sound insulating enclosures to reduce the workers' exposure. Those workers who must remain near the noise may be protected by means of suitable ear protectors or may even be isolated from the noise in well-insulated chambers or rooms which are adequately ventilated. An excellent example of noise prevention by this method is that of testing airplane motors in which the motor test rooms are so well insulated that little noise escapes from the enclosure.

Reduction of Noise by Sound Insulation

Where a large part of the noise in a room or building is caused by reflection of the noise back and forth between the walls, ceiling, objects, and floors, a great reduction can be accomplished conveniently by covering as much of the reflecting surface as possible with suitable sound absorbing materials. An example of this method is the application of sound absorbing materials to the ceiling, and sometimes the walls, of air-conditioned office spaces.

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Personal Protective Devices

Where one of the preceding methods is not applicable, or adequate, or does not protect all of the workers, cotton plugs or some of the commercial ear protectors[22] may be used to reduce the effect upon the exposed workers. Some of these protective devices reduce the intensity of severe noises appreciably; at the same time, however, they permit the hearing of conversation and thus do not create the safety hazard which would exist if conversation could not be heard.

RADIANT ENERGY

The most important exposure to radiant energy, and one which has been increased many-fold by the war effort, is that of ultraviolet, infra-red, and intense visible light radiation from electric welding arcs. In addition to this important health hazard, there are exposures to infra-red radiation in the heavy metal industries, to roentgen rays and radium emanation in the inspection and testing departments of many industries, to radium, thorium, and other radioactive materials in luminous dial painting and illuminating tube manufacture, to potential hazards from mercury vapor lamps, and to infra-red from drying lamps.

The important exposure, as indicated above, is to the harmful rays produced in welding operations. However, the methods and protective devices for controlling these exposures are so well known and so effective that only a brief summary is necessary. Table 3 gives the protection required for different welding operations.[23]

To protect the workers in nearby areas, the welding operations should be shielded as much as possible by means of suitable permanent or portable shields placed about the operation. On the other hand, the welding operation should not be enclosed to such an extent that a serious health hazard to the welder is produced by the reduced ventilation. See *Welding*, Chapter 11.

For continuous exposures to infra-red radiation in the heavy metal processing industries, permanent shields and barriers, as well as protective goggles and helmets, will serve adequately. Spot cooling, if practicable, is helpful to keep such workers comfortable. See *Air Conditioning*, Chapter 21.

X-ray testing equipment used in the inspection of materials presents a potential exposure to radiant energy which is readily controllable. All X-ray equipment should be so shielded or en-

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closed by lead that none of the roentgen rays will escape into the room. Where this control is not adequate, protective clothing may be used but it is better to shield the machine properly. Frequent inspections are necessary to guard against any leaks which may result in serious consequences.

The radiation emitted by radium employed in material inspection is more difficult to control than roentgen rays. While lead sheathing around the radium reduces the intensity of the rays somewhat, depending upon the thickness of the lead, it does not eliminate the hazard entirely unless the lead casing is too thick to be practicable. The method of preventing serious

TABLE 3.—PROTECTION REQUIRED FOR WELDING OPERATIONS

Operation	*Protection*
Production welding at a permanent location	Permanent shield with proper density light filter; helmet or hand shield with proper density light filter; or goggles with proper density lens.
Working in the vicinity of a welding operation	Goggles or spectacles with No. 3 or No. 4 shade lens.
Light gas cutting and welding, and light electric spot welding	Goggles or spectacles with No. 5 shade lens.
Gas cutting, medium gas welding, arc welding up to 30 amps	Helmet, shield or goggles with No. 6 shade filter glass.
Heavy gas welding, arc cutting, and welding between 30 and 75 amps	Helmet, shield or in some cases goggles with No. 8 shade filter glass.
Arc welding and cutting between 75 and 200 amps	Helmet or shield with No. 10 shade filter glass.
Arc welding and cutting between 200 and 400 amps	Helmet or shield with No. 12 shade filter glass.
Arc welding and cutting above 400 amps	Helmet or shield with No. 14 shade filter glass.

health effects in this instance is to use as little radium as possible, to enclose it in a lead container, and for the operator to remain as far away as possible from the source of energy. The desired combination of these three factors is given in a chart commonly known as the Failla Radium Protection Chart. This chart is presented in the reference cited,[24] where complete information on radium protection may be found.

The war effort and the manufacture of new types of lighting tubes have increased tremendously the number of workers exposed to radioactive materials. The control measures are similar to those given in the preceding paragraph for radium except that the amounts of radioactive materials handled are much less and the protective measures may be relaxed accordingly. Luminous

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dial painting is covered in detail under *Luminous Dial Painting* in Chapter 11 and the information cited[25] is applicable to all exposures of this nature.

Mercury vapor lamps present potential exposures to ultraviolet radiation. The potential health hazard may be eliminated by employing a different type of illumination. Where this is not feasible, frequent inspection should be made to determine whether a hazard exists and if it does, the offending lights should be screened to prevent the ultraviolet rays from reaching the workers.

Infra-red radiation from drying lamps is usually limited to the drying enclosure and presents no significant health hazard as a rule, since no workers are inside the drying enclosure for any length of time.

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