INTERNATIONAL LABOUR OFFICE

ENCYCLOPAEDIA OF OCCUPATIONAL HEALTH AND SAFETY

VOLUME II

L – Z

GENEVA

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ENCYCLOPAEDIA OF OCCUPATIONAL HEALTH AND SAFETY

L

Laboratory workers *Hbod*

The variety, size, type and complexity of scientific laboratories preclude simple generalisations on the health and safety of laboratory workers. It must be recognised that laboratory workers are selected and employed primarily because of their specialised education, knowledge and skills, and not because of any qualifications related to health or safety interest. Unless the laboratory is intimately integrated with a manufacturing facility, the degree of regulation and control actually enforced is usually lower than that for production operations. In addition, there is a feeling which has been fostered by the academic community itself that little should be done to interfere with "academic freedom", no matter how serious the consequence of that freedom. This is true of freedom to formulate and express scientific ideas, but control must be exercised over the laboratory handling of materials that may be toxic, corrosive, flammable or explosive, and the scientific laboratory workers should be prepared to accept this control in return for the advantages that derive from a well-organised scientific establishment.

Problems of safety and health associated with laboratory work have been reviewed by many organisations; summaries of the facilities which promote safer operation have been published; and the need for a wider application and appreciation of industrial hygiene in the laboratory has been advocated. In spite of this, however, the basic problem remains that the laboratory worker has relatively limited appreciation of safety and health. Few academic institutions have made a serious attempt to integrate practical knowledge concerning hazardous materials and processes into their formal training, to ensure that the trained personnel will be able to recognise and to prevent excessive exposures. In addition, research laboratories in academic institutions and in government and industrial establishments are frequently at the frontiers of knowledge both of science and of hazards. For this reason, laboratory workers are often the first persons to be exposed to new chemical and physical dangers, and they may suffer unexpected injury unless effective control, monitoring and medical supervision are integrated into the planning of the laboratory operations.

Laboratory operations. No full detailed account could be given of the numerous and varied functions that are performed by laboratory workers in the great variety of laboratories in which research, analysis testing and process control are carried on. For the purpose of this article it may be sufficient to say that toxic, corrosive, flammable and explosive substances are handled often in fragile glass apparatus, ionising and other radiations are studied and used, electrical apparatus at lethal voltages may be assembled, tested and operated, and disease-infested tissue and animals may have to be examined, tested and assessed.

The hazards are not always obvious to the laboratory worker. Neglect of safety and health measures can have serious consequences.

SAFETY AND HEALTH MEASURES

A safety policy will be successful only if the arrangements are inaugurated and supported and enforced by the responsible director vested with adequate authority. His responsibilities will begin with the design of the laboratory and its fittings.

Laboratory facilities. If the laboratory is for chemical, biological or pathological work, certain basic safety provisions will almost certainly be necessary. One basic necessity is a properly designed and maintained

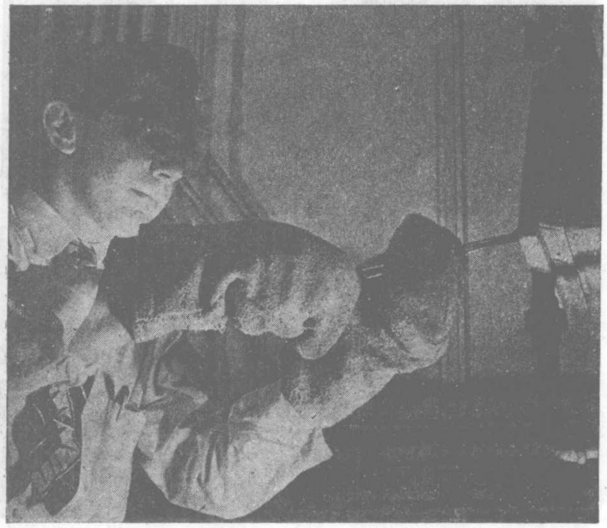

FIG. 341. A laboratory worker using tongs and wearing goggles and asbestos gloves whilst handling material in a laboratory furnace.

ventilation system including chemical fume cupboards or hoods with sash windows and adequate air velocity at the openings. The provision of fume cupboards or hoods should be generous and they should be conveniently situated in relation to the benches to ensure that dangerous operations will not be performed on open benches because of the inconvenience of transferring the apparatus to a remote situation where it cannot be kept under continuous observation. They should be provided with the usual services—gas, electricity, water and, in certain circumstances, compressed air.

The laboratory design should include appropriate fire protection for dangerous chemicals. If flammable liquids are extensively used in considerable quantity, provision should be made to reduce the fire hazard. Heating arrangements should avoid, as far as possible, the use of open gas burners: electric mantles or steam heating should be provided where there is a real danger that flammable vapours from volatile liquids would otherwise be ignited. Where necessary, sills and trays should be provided to retain accidentally spilled flammable liquid and to prevent it from flowing from a place of safety to a place where it could become ignited. Fire extinguishers should be compatible with the materials being used.

When work has to be done with explosively unstable substances, suitable shields should be designed which allow the necessary manipulation while providing protection for the scientist.

At least two means of escape in case of fire should be provided and these should be as widely separated as possible. Large laboratories and those in which the work is associated with a high fire risk should have a correspondingly larger number of fire exits.

Suitable, conveniently accessible storage accommodation is required to ensure that the quantity of dangerous materials in the operative part of the laboratory is kept at a minimum. The store should be designed to ensure that the risk associated with the presence of a considerable quantity of dangerous materials is reduced to a minimum; careful arrangements should be made, for instance, to segregate oxidising materials from flammable substances and to ensure that acids and cyanides or sulphides cannot mix. Many hazardous reactions from accidental admixing are known and documented. Compressed gas cylinders or bottles should be carefully controlled, and fuels should be segregated from oxygen and other oxidising or corrosive substances.

FIG. 342. The use of a "dry box" for protection against splash and fumes whilst transferring chemicals for a laboratory experiment.

The laboratory itself and related stores should be planned to avoid overcrowding of benches, shelves, fume cupboards or hoods, or floor space.

Bottles, drums, cans and other containers of chemicals, biological samples, etc., should be clearly labelled, and a system should be established to ensure that a label is replaced before it becomes unreadable. Safe methods should be devised for the disposal of hazardous waste chemicals and materials.

First-aid dressings for cuts, abrasions and burns should be available. If considerable quantities of corrosive or otherwise harmful materials are handled, safety showers or other suitable means of drenching are recommended. In certain circumstances associated with biological or pathological laboratories, antidotes, disinfectants, etc., may also have to be kept available. The nature of the work may justify the provision of resuscitation apparatus and the presence or immediate response of people trained in the administration of first aid. Respiratory protective equipment in the form of self-contained (oxygen or compressed air) breathing apparatus should be kept in convenient positions near the entrance for rescue work in emergencies. Filter-type canister masks should be discouraged or banned in emergencies.

Physical laboratories have different hazards. Many physicists are engaged in research on and routine manipulation of radioactive materials. Persons responsible for the direction and control of this work have very special responsibilities for the safety of their subordinates and must ensure that the highly sophisticated and effective precautionary measures developed for radiation protection, are fully implemented. Scientists should be provided with glove boxes, manipulators and should be subjected to screening and monitoring. Those who work with X-ray machines must be protected by interlocking arrangements to ensure that the machine cannot be switched on until all persons are out of the danger zone.

An equally strict attitude to safety precautions must be adopted for laser generators and arrangements should be made to ensure that workers and in particular the vulnerable parts of their bodies (e.g. eyes) cannot enter the path of the beam or its reflection.

The preventive measures that have been suggested are only the basic precautions that are common to each class of laboratory. In keeping with the specialised nature of the work being performed in the laboratory, special precautions may have to be provided in the design and fittings.

Because of the diversity and complexity of operations and equipment, and because perhaps scientists are preoccupied with their research rather than with the hazards associated with very advanced developments, certain more obvious dangers may be overlooked. For example, scientists engaged in research may ignore the electrical hazard of their experimental apparatus, and serious electrical accidents may occur, under conditions which could have been easily prevented or guarded against. The principles of electrical earthing (grounding) should be understood and religiously followed in laboratory set-ups unless other means have been taken to prevent electrical shock in case of fault. While some electrical apparatus does require a "hot" case, or a "floating earth", the hazard to personnel can be largely minimised by proper and complete circuit analysis followed by protective measures including isolation transformers and relays.

Personal protection. Laboratory workers have traditionally been acquainted with the need for some sort of protection against the harmful materials with which they work, but the scope of the protection has been rather limited and has generally been no greater than the provision of a laboratory apron or coat to prevent normal clothing from being damaged by corrosive materials. However, to ensure full safety in the handling of dangerous materials, laboratories should be fully equipped with a complete range of personal protective equipment, including protective working clothes, eye and face protection, hand and arm protection and respiratory protective equipment. The importance of personal hygiene should be stressed and it should be pointed out that long hair, beards, moustaches, and long sideboards or sideburns increase the hazard of contamination in biological laboratories or where protective equipment is worn.

Safety instruction. Knowledge of the potential danger and of the means of avoiding it are of great importance in a field where precautions may well have to be improvised or at least adapted from the safety equipment available. The laboratory directorate is responsible for instructing workers in safe laboratory practice. A very large number of academic institutions, research organisations and firms have issued booklets of advice and instruction to their laboratory staff. Sometimes these instructions are in the form of a code of rules, the breaking of any one of which is regarded as a definite infringement of the institution's or the firm's regulations with the possibility that disciplinary action may be taken. In this way, the tendency of many scientific workers to disregard their own safety and that of others is checked by instruction, persuasion and discipline.

Individual safety responsibility. Hitherto, emphasis has been placed upon the responsibility of management, but in laboratory work more reliance has to be placed upon the sense of responsibility of the individual than in any other field of communal work. The work in a research laboratory may be of such an advanced and original nature that only a senior scientist is aware of the hazards involved; the director or a safety officer may not be sufficiently familiar with the reactions or with the apparatus to be able to assess the risks. In his own interests and in the interests of those working with him, such a person should accept the responsibility of indicating the risks and of devising precautionary measures to minimise them. It is equally the duty of the junior scientists and assistants to observe these precautions and to collaborate by drawing attention to other unexpected dangers that become apparent to them in the course of the work.

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Labour legislation *Vut*

The term "labour legislation" refers in general to laws and regulations in the field of labour issued by the public authorities. It includes Acts of parliament, and regulations issued by the government to apply these Acts. These regulations may sometimes be called decrees or orders.

Labour legislation covers such matters as labour-management relations (e.g. employment contract, trade union rights, collective bargaining, labour disputes), labour administration, conditions of work and occupational health and safety. The legislative provisions are sometimes consolidated in a single text covering all of these matters or at least the main ones, which is known as a "labour code" or "basic labour Act".

Even in countries with a labour code, the question of occupational safety and health, in common with matters of social security, is frequently covered by separate provisions in view of its complex and technical character.

This national basic legislation contains a number of general standards and guidelines for the protection of workers' health at workplaces (medical examination, declaration of occupational diseases, first aid; hygiene of workplaces, area of premises, lighting, maintenance; removal of waste, sanitary installations, cloakrooms, ventilation; maximum weight of loads which may be carried by a single worker; guarding of machinery; storage of dangerous substances; fire fighting; protection against ionising radiations). These provisions are sometimes accompanied by specific standards for the protection of women workers (maternity, night work, underground work in mines), or of children and young workers (minimum age, medical examination).

In view of the technical character of the action required and the rapid evolution of techniques resulting in new hazards for the workers, frequent amendments or additions to legislation are necessary. In most countries, legislation states the basic principles but refers their practical application to a wide range of decrees, orders or regulations. These regulations may allow for the specific requirements in particular industries such as mining, ports or building, or they may apply to certain substances such as white lead or white phosphorus.

National legislation frequently also contains provisions concerning benefits in the event of employment accident or occupational disease or assistance for survivors.

Numerous countries have established a system of labour inspection or special bodies applying legislative provisions concerning conditions of work and the protection of workers in their occupation, including safety and health requirements; they provide information and technical advice to employers and workers concerning the most effective ways of observing the law and they draw the attention of the competent authorities to any anomalies or abuses not specifically covered in legislation (see INSPECTION, SAFETY AND HEALTH).

There are many countries in which employers' and workers' organisations are associated not only in preparing health and safety standards by giving their views on draft legislation but also to a considerable extent in their application by participating in the establishment of joint committees or simply in the appointment of safety officers or of health and safety representatives. Elsewhere the law provides for the establishment of works committees, joint committees or committees for hygiene, safety and the layout of workplaces, whose function is to supervise the safety and health situation at the workplace, to draw attention to abuses and to suggest improvements.

International legislation

International labour legislation is one of the principal means available to the ILO in performing its task. It consists of a comprehensive collection of minimum standards in the various areas of competence of the Organisation. These standards are laid down in the texts adopted by the International Labour Conference and they fall into two groups: Conventions and Recommendations. For the list of Conventions and Recommendations relating to occupational safety and health, see APPENDIX VIII.

The Conventions have had a considerable influence on national legislation in many countries for which they have frequently served as a basis and a model. For the ratifying countries they entail the undertaking to keep national law and practice in harmony with these provisions and to submit to the mutual control exercised by all member States in regard to each one's manner of discharging this obligation. For this purpose the ILO has bodies composed of representatives of the parties concerned, namely governments, employers and workers.

Recommendations must also be submitted to the competent national authorities but do not give rise to any direct obligation, being designed essentially to guide action in the national sphere. The whole collection of ILO Conventions and Recommendations makes up the International Labour Code.

The influence of ILO standards may also be brought to bear through technical co-operation. Governments frequently ask for the ILO's assistance in drafting or amending their labour legislation, in establishing or extending their social security system, in improving the operation of their labour inspection services or their employment services, etc. When they provide assistance in such cases the technical assistance experts can base their recommendations on ILO instruments dealing with the questions of concern. This is especially appropriate when governments ask the ILO to provide them with expert advice in the preparation of comprehensive labour legislation.

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Lactones

Lactones may be considered as inner esters of hydroxycarboxylic acids. For instance, β-propiolactone,

$$\underbrace{CH_2-CH_2-C=O}_{\text{—O—}}$$

may be regarded as the inner ester of β-hydroxypropionic acid

$$\begin{array}{lll} CH_2-CH_2-C=O \\ | \qquad\qquad\;\; | \\ OH \qquad\quad\; OH \end{array}$$

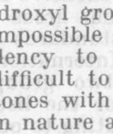
The preface β-, γ-, α-, etc., refers to the position of attachment of the lactone oxygen in relation to the carboxyl group; e.g. γ-butyrolactone has the structure

$$\underbrace{\overset{\gamma}{C}H_2-\overset{\beta}{C}H_2-\overset{\alpha}{C}H_2-C=O}_{\text{—O—}}$$

while β-butyrolactone is written as

$$\overset{\gamma}{C}H_3-\underbrace{\overset{\beta}{C}H_2-\overset{\alpha}{C}H_2-C=O}_{\text{—O—}}$$

The γ-lactones are formed extremely readily from acids containing a hydroxyl group in the γ-position; it is in fact nearly impossible to isolate such acids because of the tendency to form lactones. The β-lactones are more difficult to prepare and require special methods. Lactones with relatively large ring structures are found in nature as essences; coumarin, a constituent of lavender oil



is widespread in nature and, like other essential oils, can be extracted from the plants that contain it (see COUMARIN).

The majority of lactones are liquids with moderately high boiling points. The stability of the lactone ring varies; in general, the γ-lactones are more stable. Lactones have become more readily available in recent years and have their principal use as solvents and intermediates. Nevertheless the dangerous properties of relatively few commercially useful lactones have been studied in detail, but information is available concerning the following members of the group.

β-Propiolactone ($\underbrace{CH_2CH_2C=O}_{\text{—O—}}$)

sp.gr.	1.15
m.p.	–33.4 °C
b.p.	56 °C (15 mmHg)
f.p.	74 °C

a colourless liquid with a pungent odour.

β-Propiolactone is produced by the addition reaction of ketene and formaldehyde, catalysed by zinc chloride. It is used quite considerably in organic synthesis. It is a vapour sterilant, a disinfectant and is used specifically as a viricidal agent in plasma and tissue grafts.

γ-Butyrolactone ($\underbrace{CH_2CH_2CH_2C=O}_{\text{—O—}}$)

sp.gr.	1.13
m.p.	–44 °C
b.p.	204 °C
f.p.	98 °C

a colourless liquid with a pleasant odour.

γ-Butyrolactone is obtained from acetylene and formaldehyde by high pressure synthesis. It can also be obtained from γ-hydroxybutyric acid. This lactone is an intermediate for the manufacture of butyric and succinic acids. It is used as a solvent for resins, as a constituent of paint strippers and in petroleum processing.

γ-Valerolactone ($CH_3\underbrace{CHCH_2CH_2C=O}_{\text{—O—}}$)

γ-METHYL-γ-BUTYROLACTONE

sp.gr.	1.05
m.p.	–37 °C
b.p.	206 °C
f.p.	96 °C

This lactone is produced by the isomerisation of allylacetic acid, in the course of which oxygen and hydrogen atoms of the carboxyl group migrate to saturate the unsaturated allyl grouping. It may also be prepared by the reduction, with sodium amalgam, of the sodium salt of laevulic acid. Acidification of the resulting solution of the sodium salt of the hydroxyacid, followed by boiling, liberates the lactone.

γ-Valerolactone is used as a coupling agent in dye baths, as a constituent of brake fluids and cutting oils and as a solvent for adhesives, pesticides and lacquers.

Other lactones

α-Lactones and other lactones have been used in flavours and perfumes. The unsaturated α-lactone portion of digitalis glycosides is essential to their activity.

HAZARDS AND THEIR PREVENTION

Fire and explosion. These liquids are flammable but their vapour pressures are low, and flammable or explosive mixtures of vapour with air do not develop until the temperature of the liquid is much higher than that of the hottest workroom. Precautions must be taken when lactones are heated; spillage in the vicinity of an open flame could result in a serious fire. In particular, if heat has to be applied for the purpose of cutting or welding a vessel that has contained one of these liquids, care must be taken to ensure that the vessel is emptied and thoroughly purged to remove residual flammable material. Vapour explosions can be caused by a welding or cutting torch even when the flash point of the liquid is high.

Health hazards. Although a number of the lactones appear to be of low acute toxicity, β-propiolactone has a high degree of acute systemic toxicity by mouth or intraperitoneally in rats and is capable of penetrating intact guinea-pig skin. It is a strong irritant in the undiluted form and it is highly toxic by inhalation. Repeated short-term inhalation studies in rats did not show any trend toward a cumulative action.

By contrast, β-butyrolactone has a relatively low acute toxicity and could be tolerated in amounts as high as 100 mg/per rat subcutaneously at weekly intervals for a lifetime with minimal mortality. However, a moderately irritating effect was noted during skin painting studies in mice.

γ-Butyrolactone and γ-valerolactone also appear to have relatively low acute toxicity although the former appears to be readily absorbed through guinea-pig skin. Skin irritation was not marked with either compound. Mild anaesthetic effects have been noted in animals, especially with γ-valerolactone. Large doses of the γ-butyrolactone (2.5 g) given orally to human subjects caused mild sedation.

There seems little doubt that certain lactones can act as carcinogens in experimental animals although their potency is relatively weak compared with polycyclic hydrocarbons. Tumours have been produced by skin painting, subcutaneous injection and by peroral dosing with β-propiolactone and β-butyrolactone. It is felt that these substances are capable of acting as monofunctional alkylating agents and of combining *in vivo* with cysteine and methionine and probably other substances.

There appear to have been few studies on the metabolism of lactones, although some are apparently hydrolysed readily. It has been shown that γ-butyrolactone is rapidly hydrolysed by rat plasma *in vitro* forming γ-hydroxybutyric acid. γ-Valerolactone is also hydrolysed but at a slower rate. There is some speculation as to the role that the lactone structure may play in the carcinogenic action of some complex natural substances, e.g. aflatoxin.

SAFETY AND HEALTH MEASURES

Although the primary irritant and vesicant effects of β-propiolactone are well known, there appear to have been no reports of human local or systemic toxic effects from the use of other lactones in industry or with their use as essential oils. It would, however, seem desirable that persons working with lactones undergo regular medical examinations with special attention to the development of any skin lesions. Measures should be taken to prevent contact with skin or eye, especially with the β-lactones. Personal protective equipment including eye and face protection should be provided and worn. At room temperature the low vapour pressure of the lactones reduces the possibility of significant toxic effects by inhalation. Nevertheless they should be used with good ventilation. If they are heated, local exhaust ventilation should be provided to extract the vapour before it enters the air of the workroom.

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Ladders *Jmiz*

Ladders are used in every type of industry, particularly in the construction and decoration of buildings, in shops, offices, business premises, in window cleaning, in agriculture, especially in barns, lofts and other storage places and in the home. This widespread use accounts for many accidents, most of which could be prevented by proper care in the construction, maintenance and use of the various types of ladders concerned. This article deals with ladders commonly used in industry and not with ladders constructed to specifications for such special purposes as steeple-jack work or fire fighting.

Ladders may be either fixed or portable: portable ladders may be either single section or extension. Fixed ladders are usually made of steel: formerly wood was used almost exclusively in the construction of portable ladders but aluminium is now used for a significant proportion. Structural plastics are also coming to be used more widely.

The first principle of safety in the use of ladders is in a sense negative: ladders should not be used where other, safer means of access are possible. Where permanent access is necessary, e.g. to an overhead crane, a fixed stairway can often be installed; in painting and building work ladders should be used only for work of short duration where the use of a properly erected scaffolding or removable scaffold is not practicable. Where frequent but intermittent access is necessary to certain points, a fixed ladder is preferable to a portable ladder. Incidentally it is very desirable that planning of a plant should take account of the need for access: pipes, valves, measuring instruments, etc., are too often difficult of access. At new buildings, much can be done to allow safe window cleaning without the use of ladders.

A step-ladder, preferably fitted with a platform or handrail is most suitable where workers have to remain on a ladder for long periods (e.g. in storerooms) or where there is no reliable surface against which a ladder can be leant. A ladder or step-ladder is much to be preferred to improvised means of access such as piles of boxes or furniture.

Finally, wherever ladders are employed by workers the employer should give clear instructions on their safe use and ensure adequate supervision.

Ladder accidents

Serious accidents occur because a ladder has not been properly footed or properly secured and

FIG. 343. A proprietary captive device for l.shing the head of a linesman's ladder to a telegraph pole. (*By courtesy of the Postmaster-General, United Kingdom.*)

therefore slips: men may slip on rungs or fall because a rung is missing or breaks; or they may overbalance, especially when carrying goods or when leaning too far sideways to carry out work. In general,

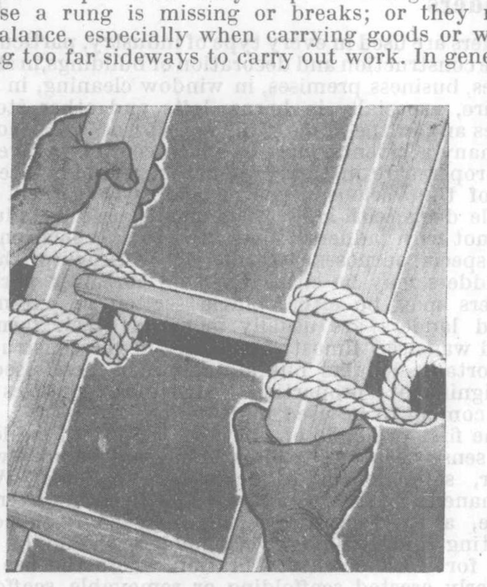

FIG. 344. A ladder properly lashed at the top.

accidents are more frequently caused by failure to exercise care and commonsense in their use than are caused by defective ladders.

Some of the worst risks are taken in small undertakings and on small jobs, where there is no great choice of ladders and where use is intermittent or infrequent. There is a tendency to improvise, to keep defective

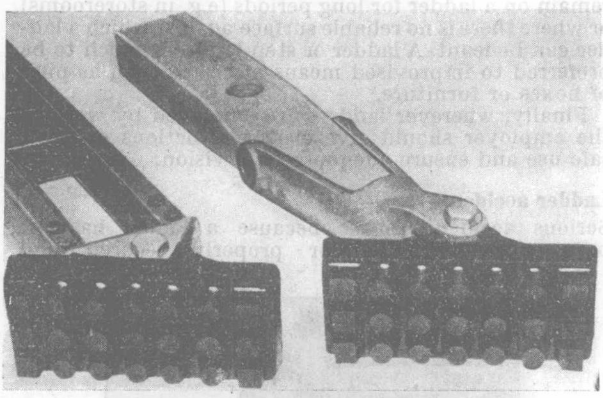

FIG. 345. Non-slip ladder shoes (versions for light metal *(left)* and wooden *(right)* ladders).

ladders still in service or to repair in an elementary or amateur way such as by nailing on slats of wood.

Electric shocks may be sustained if a metal ladder is used for electrical work or in proximity to live electrical conductors.

Ladder construction

Ladders should be of good construction and made of suitable material; there exist national and international standards specifications regarding the materials to be used, design and methods of manufacture. These should be closely followed.

Ladder-making in most countries has been a localised craft industry, relying heavily on hand methods but, in the last 30 years, manufacture has been industrialised in some countries and wider ranges of ladders are now produced. In others, for example the United Kingdom, trade associations collaborate voluntarily with standards institutions and government experts to ensure sound, safe and reliable products.

Use of portable ladders

The ladder should be suitable for the job and of adequate length: extension ladders should provide a safe margin of overlap. The ladder should be examined before use and rejected if defective in any way.

The ladder should be firmly secured at top (Fig. 344) and bottom. The feet should be on a level base: one foot should never be packed up. Safety shoes (Fig. 345) fitted to the stiles, pointed ferrules and fixed steps may be used in appropriate circumstances.

The correct angle of about 75° can be achieved by allowing a 1:4 relationship between the outward position of the base and the vertical rise (Fig. 346).

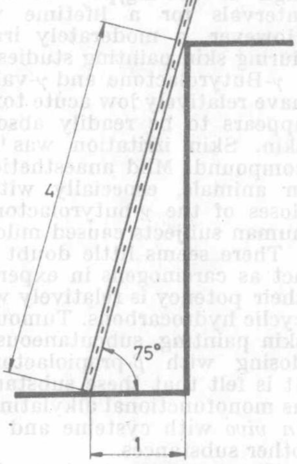

FIG. 346. The horizontal distance from top support to foot of ladder should be one-quarter of length of ladder between feet and upper resting point.

In fixing ladders, such as are used in construction work, a man should hold the base until it has been lashed firmly in place at the top (Fig. 347) with at least 1 m extending above the platform or working point. It is important to ensure that the structure to which it is lashed is itself firm. This also applies to other types of ladder secured by hooks where a retaining device may also be necessary.

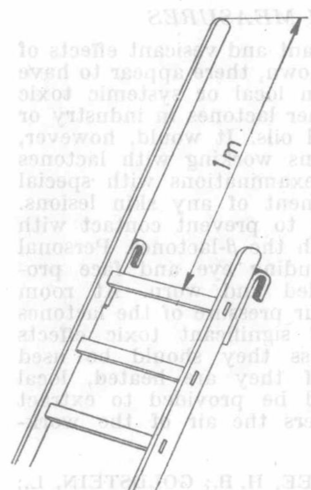

FIG. 347. Builder's ladder fitted with retaining hooks.

The ladder should be faced during ascent or descent with the hands gripping the stiles; both hands should be free and a hoist line may be used to carry materials, etc. It is not safe to lean sideways from a ladder: if the work requires it the ladder should be moved. Only one man should be on a ladder at any one time. If two men are required on the job a second ladder should be used. The rungs of a ladder should not be used to support planks.

Extra care should be taken when ladders are in use near entrances and gangways, particularly in premises where forklift trucks are operating. Doors should be locked and gangways blocked wherever possible: otherwise a look-out should be posted. Metal ladders should not be used for electrical work or near live conductors. When a ladder is carried, the front end should be kept high enough to clear a person's head and care with clearances at both ends is necessary.

Use of fixed ladders

Fixed ladders, usually made of steel, should be fitted with safety hoops at intervals to prevent persons falling outwards: on a long ladder, rest platforms are also necessary.

Fixed ladders are not intended to accommodate, in any one section, loads exceeding that of one person and care should be taken to ensure that neither ladders, safety hoops nor straps are used to support additional loads such as lifting appliances, scaffolding, etc., for which they are not designed. The provision of safety hoops may be a temptation to experienced operatives to mount the ladder by means of the hoops instead of the rungs. This should be prohibited. Where it is necessary for a person to open or close a trapdoor in a platform while ascending or descending a ladder, provision should be made for the adequate support of the person while performing the operation. It may be necessary to take steps to protect steel ladders against lightning.

Ladder storage

In order to prevent deterioration, ladders should be stored in conditions similar to those in which they will be used. They should be protected from direct exposure to the elements, with free air circulation. They should be adequately supported so as to prevent the development of permanent deformations or weakening of the joints.

Ladders should be stored well away from radiators, steam-pipes or other sources of heat to avoid deformation.

Maintenance and inspection

Where a number of ladders are kept, each should be marked with a number, and details of type, purchase, inspection, defects and repairs entered on a card index or in a register. All ladders should be inspected on receipt and again on issue. The user should inspect all items before use. All timber ladders should be inspected at least once in every 3 months and aluminium ladders every month.

Defects and preserving. The following should be noted during inspection: wear on rungs, also on head and feet of extension ladders, the ropes, pulleys and other metal parts should be examined and all moving parts lubricated. Steps should have tie-ropes examined for soundness and correct length. Metal ladders should be examined for soundness and also corrosion or rust.

Painting of ladders is not recommended as this has the tendency to mask defects in the timber. Preservation is better obtained by applying clear varnish or using a transparent rot-proofing liquid.

Aluminium ladders. Aluminium ladders should be inspected monthly. Attention should be given to the following details:

(*a*) distortion: this is usually visible by sighting along the stiles. A twisted or distorted ladder can be hazardous in use;
(*b*) no slackness of rungs in the stiles;
(*c*) ropes, pulleys, rivets, fastenings and other fittings to be secure and serviceable;
(*d*) no corrosion;
(*e*) no sharp edges on stiles and rungs;
(*f*) anti-slip end-pieces to be in satisfactory condition and not loose.

Fixed steel ladders. Fixed ladders should be regularly inspected by a competent person at intervals not exceeding 2 years. Where there is a high risk of corrosion, more frequent inspection may be necessary. Where ladders extend from ground level, additional precautions should be taken at the base point to prevent corrosion.

Testing. Aluminium ladders may be subjected to certain tests for sag, deflection and load. Load testing of timber ladders is not recommended. The practice of "proof testing" ladders has inherent dangers as, although the ladder may apparently come through the test undamaged, serious compression or tension stresses may have been induced, which may cause the ladder to fail subsequently in service.

The following tests are not harmful to a ladder which is in good condition, and if a ladder is not in good order may well reveal defects:

(*a*) At each end of the ladder in turn, try to pull the stiles apart and push them closer together. Movement will indicate defective tie-rods (or reinforcing wires) and insecurely fixed rungs.
(*b*) With one end of the ladder resting on the ground, raise the other end (each hand grasping a stile end) and try to displace the stiles by pushing on one and pulling on the other. Relative parallel movement will indicate insecurely fixed rungs.
(*c*) In the case of a ladder with round rungs, grasp and attempt to rotate each in turn. None should rotate.

Repair. Modern ladder products are made on production lines giving quality control and uniformity. Repairs of any extent involve the expensive costs of hand labour and carriage. A new stile can never be properly matched with an old one. A repaired product is never equal to new, although it can cost as much and sometimes even more. If one section of an extension ladder is damaged, it may be prudent for safety reasons and better value for money to buy a new section. Where repairs are appropriate, they should be carried out by experts and should not be attempted by those unacquainted with the structure of ladders.

Defective ladders should be broken up or burned at once: many accidents have occurred through the chance use of a ladder rejected on inspection but not immediately destroyed.

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Lasers

Bqh

A laser is essentially a device that produces a light of brightness, coherency and energy and power densities never before achieved either by nature or man. The word laser is an acronym of *l*ight *a*mplification by *s*timulated *e*mission of *r*adiation and signifies a system by which excited atoms are stimulated to emit radiation in the infrared, visible or ultraviolet regions.

In a conventional source of light (e.g. incandescent or fluorescent), the individual atoms or molecules emit, independently of each other, energy in the form of light quanta. The emitted light is an electromagnetic wave which is composed of a very large number of individual waves of different frequencies and of different phase in respect of each other. In a laser, the various atoms may be compared to oscillators which all oscillate at the same frequency and in phase, producing a single wave which is the sum of all the individual waves; for this reason, the radiation is called coherent (Fig. 348).

To produce radiation by stimulated emission, a laser requires a supply of atoms in a properly excited state. These are charged to a higher energy level by a rapid pumping mechanism. The source may be a solid, liquid or gas that can be made to fluoresce, and sources now being used include ruby, neodymium, helium and neon gas, argon, krypton, carbon dioxide and an yttrium-aluminium-garnet combination known as YAG.

Optically pumped lasers, i.e. sources excited by a broad-band or white light such as from a xenon flash lamp, an electrical discharge lamp or even an incandescent bulb, emit their energy in pulses that have a duration in the millisecond range. However, much higher powers can be obtained by the "Q-switching" technique in which a shutter is used in the optical path to excite the source much beyond the degree ordinarily needed; when the shutter is opened the stored energy is released in a great pulse lasting only nanoseconds or even picoseconds.

Gas-discharge lasers make use of non-equilibrium processes in a gas discharge. From some gases, a continuous discharge, using either direct or radio-frequency current, gives continuous laser action.

Since lasers are stable sources of virtually monochromatic, optical-frequency waves, i.e. highly coherent—their output can be collimated to form a beam or focused on to a small spot to give incredibly high power densities. For example, the power densities for a soldering iron are 0.4 W/cm² and for a hydrogen bomb explosion 5 000 W/cm²; however, the power density of a focused laser beam may exceed 100 MW/cm².

Uses. Lasers are used in physics and electro-optics. In the biomedical field, the laser has been used for microsurgery of orangelles such as the mitochondria of individual cells. Impacts on chromosomes are done. The laser is used as an operative instrument in experimental embryology. In the laboratory also, lasers are in use in micro-emission spectroscopy to volatilise small masses for emission spectroscopy without destruction of the entire sample. The diameter of the test site is approximately 50 μm and much less with some techniques. The laser has great value in the analysis of cations even of the individual cell. Laser micro-emission spectroscopy may be combined with mass spectroscopy to permit even micro-analysis of organic radicals. Lasers may be used in holography to obtain three-dimensional pictures of living material and interference patterns of laser impacts.

In surgical laser research on animals, the laser is used as a type of optical knife especially in work on highly vascularised viscera. One of the first fields of investigation was the use of the laser in ophthalmology. The initial work on laser photocoagulation in eye research was in comparative studies with the xenon photocoagulator, and in cryosurgery for retinal detachments. To date, thousands of patients have been treated by laser photocoagulation. Recently, argon lasers have been used in particular in progressive diabetic retinopathy to obliterate blood vessels of the neovascularisation. In dermatology, lasers have been used for the erasure of tattoos, the treatment of port-wine naevi, skin malignancies and seborrhoeic warty growths.

In industry, lasers are used for drilling, welding, wheel-balancing, communications, and computer systems and, in the military field, for ranging, communications, and weaponry.

HAZARDS

The beam from a laser may cause injury to both the eye and the skin.

The eye is extremely vulnerable to injury if exposed to the beams of most types of lasers now in use. The beam from a laser emitting light with a wavelength in the visible or near-infrared regions of the spectrum will be readily transmitted by the ocular media. It is also focused by the lens to produce an intense concentration of light energy on the retina, which, when absorbed by the pigment epithelium, is converted to heat and causes a retinal burn; the resultant scar causes visual loss which is all the more pronounced if the injury is located on the macula at the centre of the retina. The radiation from lasers such as the carbon dioxide laser operating in the infrared region of the spectrum is readily absorbed by the tissues at the surface of the body and may, consequently, cause corneal damage resulting in corneal scarring and loss of vision.

Laser beams of sufficiently high energy levels may cause burns of the skin; reports have also been made of other damage such as the rupture of cell walls and injury to internal organs of animals.

The use of laser equipment may also involve such ancilliary hazards as the risk of electrocution from high-voltage equipment; contact with cryogenic fluids; explosion of glass components; and inhalation of toxic atmospheric contaminants intentionally or unintentionally produced as a result of laser applications.

Suggested preliminary guidelines for permissible corneal and skin exposures are shown in Table 62.

SAFETY AND HEALTH MEASURES

The prime essential is to ensure that accidental exposure of the human body to the direct or reflected

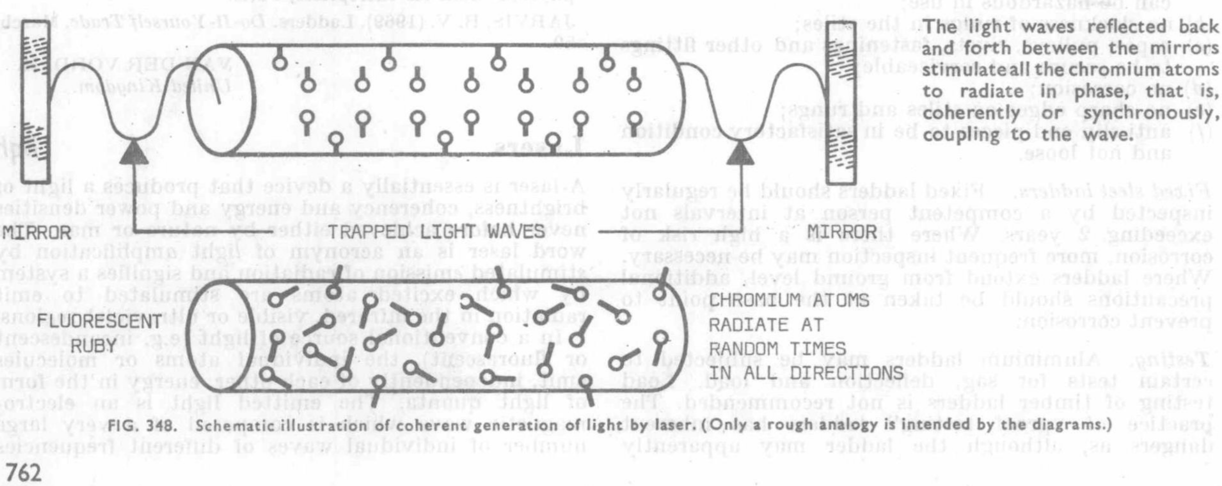

FIG. 348. Schematic illustration of coherent generation of light by laser. (Only a rough analogy is intended by the diagrams.)

TABLE 62. PRELIMINARY GUIDELINES FOR PERMISSIBLE POWER AND/OR ENERGY DENSITIES AT THE CORNEA FOR LASER IRRADIATION AT A WAVELENGTH OF 694.3 nm, AND AT THE SKIN FOR VISIBLE, NEAR-INFRARED AND INFRARED RANGES

Target organ	Permissible power or energy density		
	Q-switched, pulsed (J/cm^2)	Non-Q-switched, pulsed (J/cm^2)	Continuous wave (W/cm^2)
Cornea (3 mm pupil diameter)	5.0×10^{-8}	5.0×10^{-7}	5.0×10^{-6}
Cornea (7 mm pupil diameter)	1.0×10^{-8}	1.0×10^{-7}	1.0×10^{-6}
Skin	0.1	0.1	1.0

beam from a laser is impossible and, where a laser is to be used for medical, industrial or research purposes, a safety programme should be established to cover both area control and personnel control.

To ensure area control, laser units should be established as separate installations. In laboratory applications where the laser is usually an open unit, the controlled area may be a separate room or a partitioned-off zone, clearly indicated by warning signs and to which entry is prohibited to unauthorised persons. The installation should be designed to avoid specular reflections, with laser safety panels in the power area, plume traps to prevent air pollution when high-output pulsed laser systems are being used, e.g. for metal volatilisation (colour plate 26), and a system of interlocks to prevent accidental operation of the beam source. All persons who are to enter the controlled area should be instructed in safe working procedures.

Lasers for use in industry should, wherever possible, be of the fully enclosed variety, e.g. the radiation output from a laser drilling or welding machine should be fully retained by an enclosure of opaque material of sufficient strength to resist penetration in the event of an accident. An interlock system should be installed to prevent operation of the laser when workpieces are being changed. Where the laser system cannot be enclosed, a closed-circuit television viewing system may be used to permit remote observation and control of operations.

When lasers are used in the field, extreme care should be taken in ensuring the safety of persons not engaged in the operations. Where the laser is beamed parallel to the ground the danger area should be cordoned off.

The essential element of personnel control is the use of effective laser eye protection. Different filter characteristics will be required for the various laser systems and the glasses should be mounted in goggle-type frames to ensure all-round protection; goggles should be marked clearly, showing the type of laser for which they should be used. The condition of eye protection equipment should be checked regularly to detect cracks in the filter glasses or deterioration in the mountings, in particular that resulting in loose fitting around the eyes, especially at the temples. Little is known of chronic skin exposure hazards, and hand protection should, therefore, be worn for work in or near the target area. The value of reflectant protective creams, liquid crystal systems and laser-detection badges is being studied.

In facilities where extensive use is made of the laser, a special laser safety officer (usually an industrial hygienist with special laser-hazard training) should be appointed and the laser safety programme reviewed periodically to ensure that it is kept abreast of new developments. Persons who possess retinal defects should not be employed on work involving exposure to radiation from lasers. Persons who are to be employed on such work should receive a retinal examination and a photographic record should be made of the retinal appearance; this examination should be repeated periodically.

In the USA, a National Repository of Laser Accidents has been established by the US Public Health Service and is now at the Bureau of Radiological Health.

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Laundries Xyl

A small laundry employing only a few workers and having little or no machinery is usually a domestic workshop housed in or adjacent to the dwelling house of the owner, and engaged in washing articles of clothing and household linen for customers living in the neighbourhood. The larger laundries equipped with considerable machinery may employ from about a dozen up to about 500 workers and some of them also do dry-cleaning work. There are special laundries catering for large passenger ships: a transatlantic liner may require as many as 250 000 pieces of linen to be laundered at the end of a round trip. Hospitals, prisons, mental institutions, military and naval establishments, large hotels, factories and airports often have their own laundries and employ their own personnel instead of outside labour. The proportion of women workers in the industry is very high, usually 80–90%.

Self-service laundries. The basic idea of a self-service laundry is that a number of small washing machines are installed in a shop and supervised by the owner while the customers bring garments or other small items of laundry which they place in the washing machines and process themselves. A large number of such self-service laundries have come into existence during the last few years, and it has been estimated that there are over 30 000 in the USA. Some of them have installed additional machines to do ironing and garment pressing and the washing of small rugs.

Processes. After sorting and marking, the articles are washed in a machine which consists of a rotating horizontal metal drum into which the articles are placed through a side-loading door. The drum is housed in a metal casing into which soap, water and steam are fed. Very large machines may be fed mechanically and some used in hospitals are designed to work at high temperatures and pressures.

After washing, water is removed from the articles in a type of centrifuge called a hydro-extractor. A recent development for laundry dewatering is the use of a hydraulic press. In small laundries, not equipped with a hydro-extractor, the wet articles are passed through a manual- or power-driven wringer or mangling machine. Hand smoothing irons are usually electrically heated but in some cases they are heated by placing against a hot stove. The larger laundries use calendering machines consisting of one or more steam-heated steel cylinders covered with a layer of woollen cloth and an outer covering of cotton cloth. The articles are fed to the first roller on a tape conveyor.

Tumbler dryers are rotating drums with a warm-air circulation, generally electrically driven. Those running at low speeds, often known as "shakers", are used to open up a compact mass of washed articles prior to passing them through the calender machine.

Garment presses are available in a number of versions. The garment to be pressed is placed on a table and a steam-heated pressure head is lowered either manually or by power.

HAZARDS

In mechanised laundries, the number of accidents is high. New machines with larger capacities and higher operating speeds are constantly being introduced and these often present increased hazards. The commonest types of machinery accidents are as follows:

(*a*) crushing of fingers by power-operated identification marking machines;
(*b*) entanglement of clothing or hair on shafting, belts and pulleys, particularly on the back shafting and pulleys of washing machines;
(*c*) trapping of fingers between the rotating cage and the casing of washing machines;
(*d*) arm amputation or other serious and often fatal injury due to contact with the high-speed rotating cage of a hydro-extractor not provided with an interlocking cover;
(*e*) injuries from a hydro-extractor cage which bursts due to over-speeding, overloading or to being out of balance;
(*f*) trapping of fingers or hands in the feed intake of calender machine rolls resulting in crushing and burns;
(*g*) trapping of fingers or hands in the inrunning nip of wringers or mangle rollers;
(*h*) injuries caused by contact with the rotating cage or the fan blades of a tumbling machine;
(*i*) trapping of hands between the head and the table of garment pressing machines;
(*j*) trapping of hands or arms between the vertical platens of a cabinet garment press.

Other common accidents include:

(*a*) scalding by steam or hot liquids or burns from hot surfaces;
(*b*) falls on floors made slippery by water and soap;
(*c*) electric shock resulting from contact with electrical installations not designed for hot humid conditions;
(*d*) fires caused by the hot pressing irons;
(*e*) explosion of pressure vessels or steam receivers;
(*f*) failure of parts of laundry machinery under air or steam pressure.

Diseases. Sorters may be subject to the risk of handling infected clothing or bed linen, especially in hospital laundries. There have been many cases of skin diseases of the hands due to immersion into hot water and detergents over a long period of time. Foot disorders including mycoses may arise from working on wet, inadequately drained floors. Most of the work is carried on in hot workrooms with the formation of large amounts of steam. In the absence of adequate ventilation, the environmental conditions can be very unhealthy and tiring especially in hot and humid climate countries.

SAFETY AND HEALTH MEASURES

Of prime importance is the training of the workers, who should be taught the safe way of using all machinery or plant, and receive instruction on all possible dangers. Some countries require special precautions if young persons work on machines such as hydro-extractors, washing machines, calenders and garment presses. These young persons must:

(*a*) be given sufficient training to work at the machine; or
(*b*) be under the supervision of a person who has a thorough knowledge and experience of it.

Accidents sometimes occur when two persons work at a machine which is normally operated by one worker, e.g. at garment presses during operator training. The usual two-handed controls or press buttons do not provide protection for a second person at the machine. Some makes of garment presses do have four press button controls so that the instructor and the worker being trained must have both hands engaged and in a safe position before the pressure head can descend.

In addition to the general fencing of belt drives, pulleys, shafting and gear wheels, certain laundry equipment requires special machinery guarding. On washing machines, the lid of the outer casing should be kept closed whenever the cage is in motion and it should be interlocked so that it cannot be opened unless the cage is at rest. Steam pressure should be regulated since excessive pressure may cause steam or scalding liquid to be ejected through such openings as the soap box. When the lid is open the cage should be locked in position to prevent rotation during loading and unloading. The guarding of hydro-extractors is dealt with in the article CENTRIFUGES.

Wringing machines with power-driven rollers should be provided with guards to prevent fingers being trapped in inrunning roller nips. On calender machines, a trip finger guard should be provided at the nip of the front ironing roller. The space for the feed opening, that is the distance from the feed table to the underside of the finger guard, should not exceed 9 mm. The trip guard should not be removed from the machine when the rollers are periodically reclothed.

Garment presses should be provided with the most efficient type of safety device; double-handed operating controls are not always completely safe since it may be possible to scotch or jam one control or operate it with the knee, or the two controls may be so close together that they can be operated with a single hand. A daily check by a competent person should be made of all hand controls. Twin-table garment presses are safer since the operator is remote from the pressing head; however, the back of the press remote from the operator still requires guarding as other workers or maintenance men may from time to time pass round the back of the press and be exposed to danger. Cabinet garment presses should have double hand controls and the heated platens should be guarded to prevent access to them as they close on the form. Tumbler dryers should have interlocked doors to prevent contact with the moving tumbler, the circulating fan or blower and the drive mechanism.

Hot water sumps and drains for scalding liquids should be covered and fitted with steams traps. Electric installations should be placed above the level at which there is exposure to water. Frequent inspection of all electrical equipment is necessary. Suitable insulated rests should be provided to accommodate hot irons to reduce the risk of fire. Steam pipes should be lagged to reduce heat losses and the danger of burns due to direct contact. Good ventilation is required to remove steam and reduce the heat of the working environment, which causes operator fatigue especially in hot weather. Stoves for heating the non-electric type of smoothing irons should be in an area apart from any ironing room to protect the workers from the heat thereof. Gas-heated irons emitting noxious fumes should be prohibited.

Workers engaged in wet processes should be provided with waterproof foot and leg protection and aprons. Most laundries provide ordinary overalls for workers not exposed to wet processes. As practically all the work is done standing, there should be a rest interval during each working period. Pre-employment medical examinations for laundry workers are desirable. Special attention should be paid to skin disorders in new workers and a watch should be kept for the development of skin disorders among workers exposed to hot water, soap and detergents.

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Lead, alkyl compounds

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Lead combines with the alkyl radical to form lead alkyl compounds, a considerable number of which have been prepared or isolated, but the only compounds of industrial significance at the present time are tetraethyllead and tetramethyllead.

Tetraethyllead ($Pb(C_2H_5)_4$)

sp.gr. 1.66
m.p. –136.8 °C
b.p. (19 mmHg) 91 °C
soluble in benzene, ethyl alcohol and ethyl ether
TLV ACGIH 0.075 mg/m³*
MAC USSR 0.005 mg/m³
colourless oily liquid with a characteristic odour.

Tetramethyllead ($Pb(CH_3)_4$)

sp.gr. 1.99
m.p. –27.5 °C
b.p. 110 °C
slightly soluble in benzene, ethyl alcohol and ethyl ether
TLV ACGIH 0.075 mg/m³*
colourless liquid.

* This figure is not accepted by the author of the article.

Production. Tetraethyllead is produced by reacting a sodium-lead alloy with chloroethane under suitable conditions of temperature and pressure. A similar reaction produces tetramethyllead, under somewhat different conditions, when chloromethane is substituted for chloroethane. Halogenated hydrocarbons with which it is mixed in the commercial formulations may be produced in an integrated plant or purchased elsewhere. A simplified flow diagram of manufacturing operations is given in Fig. 349.

Transportation. The antiknock formulations are transported, mainly in bulk, in rail tank cars, road tank trucks (short hauls), tank ships and, in much smaller volume, in specially constructed steel drums by rail and on ships (in connecting trucks as required), with special provision for the avoidance of contact with other cargo. Every effort is made to prevent handling of the product, in normal transit or in emergencies, by unauthorised or uninstructed persons. Shipments of small quantities (1 litre or less), for research or testing, are made in special containers accompanied by precautionary instructions.

Uses. Tetraethyllead and tetramethyllead are liquid compounds of lead, which are miscible in all proportions with gasoline (and other organic solvents), and so are available as "antiknock" ingredients in gasoline as fuel for the internal combustion engine. These compounds, singly or together, averaging about 56% by weight in the various formulations, are mixed with chlorinated or brominated hydrocarbons (and with distinguishing dyes) in sufficient quantities to convert the lead into inorganic halogen salts in the course of its combustion.

The maximum concentration of the alkyl lead compounds in gasolines is subject to legal prescriptions

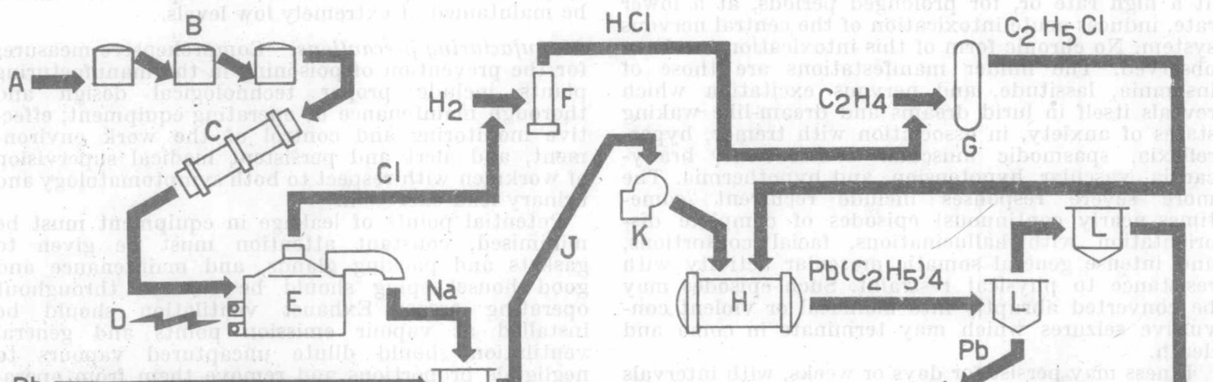

FIG. 349. Manufacture of antiknock compound. A. Salt brine. B. Evaporators. C. Dryer. D. d.c. supply. E. Electrolytic cell. F. Burner. G. Reactor. H. Autoclave. I. Mixer. J. Sodium lead alloy. K. Caster. L. Purifier. M. Filters. N. Smelter. O. Recovered lead. P. Blending plant. Q. Ethylene dichloride. R. Ethylene dibromide. S. Dye. Cl Chlorine. H_2 Hydrogen. HCl Hydrogen chloride. C_2H_4 Ethylene. C_2H_5Cl Chloroethane. Na Sodium. Pb Lead. $Pb(C_2H_5)_4$ Tetraethyllead.

in many countries, and to limitation by the manufacturers with governmental concurrence in others. In no case does it exceed 1.12 g/l.

HAZARDS

Tetraethyllead and tetramethyllead, as well as the halogenated hydrocarbon components of lead anti-knock compounds, have toxic properties which require stringent precautions against both their percutaneous and respiratory absorption. Their ingestion is not a significant occupational hazard if cutaneous contact and inhalation are controlled adequately. In view, however, of the comprehensive means required to avoid a significant degree of cumulative absorption of the alkyl lead compounds, no special problem arises out of their association with the halogenated hydrocarbons, and nothing further need be said here about the latter.

Both tetraethyl- and tetramethyllead are miscible in fats and oils, and so are absorbed through the skin, although tetramethyllead is absorbed considerably less readily than tetraethyllead. The percutaneous absorption of both compounds is greatly diminished by their dilution in gasoline and becomes negligible when they have been diluted to about 1 part per 1 000 parts by volume. Air saturated with tetraethyllead at 25 °C has a lead content of 5 mg/l; under the same conditions, tetramethyllead vaporises to a much greater extent.

Tetraethyllead decomposes slowly in air, rapidly in bright sunlight, to yield needle-like crystals of tri-, di- and mono-ethyl lead compounds. These have a garlic-like odour, and are less soluble in petroleum hydrocarbons and more soluble in water than tetraethyllead. In their dry state, they may be dispersed mechanically in air, to be inhaled or deposited on the skin. Their inhalation induces vigorous, even paroxysmal sneezing, irritation of the upper respiratory tract and, in sufficient dosage, mild to severe systemic responses similar to those induced by the absorption of toxic quantities of tetraethyllead. In contact with the warm, moist skin and unprotected ocular membranes, they induce itching, burning and transient redness.

Tetraethyllead intoxication. The absorption of a sufficient quantity of tetraethyllead, whether briefly at a high rate or, for prolonged periods, at a lower rate, induces acute intoxication of the central nervous system. No chronic form of this intoxication has been observed. The milder manifestations are those of insomnia, lassitude, and nervous excitation which reveals itself in lurid dreams and dream-like waking states of anxiety, in association with tremor, hyperreflexia, spasmodic muscular contractions, bradycardia, vascular hypotension, and hypothermia. The more severe responses include recurrent (sometimes nearly continuous) episodes of complete disorientation with hallucinations, facial contortions, and intense general somatic muscular activity with resistance to physical restraint. Such episodes may be converted abruptly into maniacal or violent convulsive seizures which may terminate in coma and death.

Illness may persist for days or weeks, with intervals of quietude readily triggered into over-activity by any type of disturbance. In these less acute cases, fall in blood pressure and loss of body weight are common. When the onset of such symptomatology follows promptly (within a few hours) after brief, severe exposure to tetraethyllead, and when the symptomatology develops rapidly, an early fatal outcome is to be feared. When, however, the interval between the termination of brief or prolonged exposure and the onset of symptoms is delayed (by up to 8 days), the prognosis is guardedly hopeful, although partial or recurrent disorientation and depressed circulatory function may persist for weeks. No peripheral neuropathy has been observed in more than 100 well-documented cases of this intoxication, nor has there been evidence of residual damage to the nervous system.

Tetramethyllead poisoning, as induced in experimental animals, resembles tetraethyllead poisoning, but no cases of human poisoning from the absorption of tetramethyllead alone have come to the author's attention. All the clinical discussions relate, therefore, to tetraethyllead.

Diagnosis. The initial diagnosis is suggested by a valid history of significant exposure to tetraethyllead, or by the clinical pattern of the presenting illness. It may be supported by the further development of the illness, and confirmed by evidence of a significant degree of absorption of tetraethyllead, provided by analyses of urine and blood which reveal typical findings, i.e. a striking elevation of the rate of excretion of lead in the urine, and a concurrently negligible or slight elevation of the concentration of lead in the blood. Rarely is the concentration of lead in the whole blood found to exceed 50 μg/100 g, while that in the urine, in severe tetraethyllead poisoning, is rarely less than 350 μg/100 g, often ranging upward to more than a 1 mg/l. There is also a total absence of morphological or chemical abnormalities in the haematological findings, when the occupational exposure to lead has been limited to tetraethyllead.

SAFETY AND HEALTH MEASURES

The foregoing properties require that contact of the skin of workmen with these compounds, alone or in concentrated mixtures in commercial formulations or in gasoline or other organic solvents, must be avoided through appropriate indoctrination and the use of personal protective equipment. Personnel should not be allowed to eat, smoke or keep unsealed food or beverages at the workplace. Good sanitary facilities, including showers, should be provided and workers should be encouraged to practice good personal hygiene, especially by showering or washing after the work shift. Separate lockers should be supplied for working and private clothes.

It is essential that atmospheric concentrations of alkyl lead compounds in the workplace air should be maintained at extremely low levels.

Manufacturing precautions. Comprehensive measures for the prevention of poisoning in the manufacturing plants include proper technological design and thorough maintenance of operating equipment, effective monitoring and control of the work environment, and alert and persistent medical supervision of workmen with respect to both symptomatology and urinary lead excretion.

Potential points of leakage in equipment must be minimised, constant attention must be given to gaskets and packing glands, and maintenance and good housekeeping should be ensured throughout operating areas. Exhaust ventilation should be installed at vapour emission points and general ventilation should dilute uncaptured vapours to negligible proportions and remove them from operating areas. In providing for operating routines and emergencies, a system for distributing fresh, clean air under positive pressure to appropriate sites for the immediate use of hose masks, must be installed. As a further precaution against the failure of supplied air for the hose masks, canister (charcoal) masks must be at hand for immediate use over specified periods of time. Continuous sampling and analysis of the air in all areas of the plant, in specific relationship to operating equipment under stress, should be carried out as a dependable indication of the quality of the maintenance of such equipment.

Medical prevention. Pre-employment medical examinations should be carried out to prevent alcoholics and persons suffering from mental disorders or hypotension from working in contact with these substances. Production workers should receive periodic medical examinations (adjusted in frequency, e.g. between 7 days and 3 months, according to the potential hazards of lead absorption involved in specific occupations), to detect physical or emotional responses to the occupational environment. In addition, illnesses of any type call for appropriate clinical investigation and handling.

Urine analysis will indicate levels of lead absorption; frequency of analysis, in the absence of complaints or unusual circumstances, is determined by the potential lead hazards of specific occupations. Any occurrence of suggestive symptomatology requires further analytical investigation, as does also the occurrence of an operating incident involving an opportunity for unusual exposure of workmen to lead.

The rate of urinary excretion makes it possible to differentiate between harmless and potentially dangerous lead absorption. Experience shows that a lead urine concentration of about 150 μg/l indicates a dangerous degree of absorption; when, following unusual circumstances, a worker's urine lead level approaches this figure, he should be put under critical medical and analytical observation. If the worker remains asymptomatic but, nevertheless, his urine lead level rises to 180 μg/l, he should be removed from further exposure to lead and maintained under medical supervision until his urinary excretion of lead has diminished to at least the upper normal range; however, he may still be employed on otherwise similar work. Circumstances which may lead to excessive exposure include: equipment failures, excessive overtime, unusual maintenance or repair operations, errors of personal judgement, and accidents. When such circumstances are uncovered, they should be analysed and correct action should be taken.

Mixing with gasoline. At petroleum refineries, antiknock compounds are stored and mixed with gasoline in standardised installations designed to prevent any exposure of the operating personnel to the liquid or its vapours. The operators should be selected for physical fitness and reliability and examined periodically. The installations, likewise, should be subjected to periodic technical and hygienic scrutiny. These provisions for the prevention of poisoning have proved to be adequate, and this aspect of this hygienic problem will not be mentioned further. Working clothes should preferably be white to make it easier to detect contamination by antiknock compounds which are dyed a distinctive colour (usually, red).

Treatment. Clinical study of cases of tetraethyllead poisoning has suggested that fatalities have resulted mainly from exhaustion, and vigorous efforts to combat exhaustion have been rewarding. Even in serious cases, complete recovery has followed upon sustained supportive therapy (nutrition, electrolyte and water balance) in association with persistent, vigorous sedation therapy. The longer-acting barbiturates have been used with good results. An essential feature of the care of these patients is that of having reliable persons in constant attendance upon them. The frequency, suddenness and severity of their lapses into irrationality, over periods of weeks or even months, and after periods of lucidity, is unusual in intoxications (as distinguished from purely mental disease), and the failure to maintain effective surveillance has resulted occasionally in serious injury to the patients, other persons and property.

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Lead, alloys and compounds *Cud*

Lead (Pb)

sp.gr. 11.3
m.p. 327 °C
b.p. 1 525 °C

slightly soluble in water in the presence of nitrates, ammonium salts and carbon dioxide; the calcium carbonates in hard water form a deposit on exposed lead thus preventing solution.

TLV ACGIH 0.2 mg/m³
MAC USSR 0.01 mg/m³

a blue-grey metal which tarnishes in moist air; it is very soft and malleable, and is easily cast, moulded and extruded.

Sources. Lead ores are found in many parts of the world. The richest ore is galena (lead sulphide) and this is the main commercial source of lead. Other lead ores include cerussite (carbonate), anglesite (sulphate), corcoite (chromate), wulfenite (molybdate), pyromorphite (phosphate), mutlockite (chloride), vanadinite (vanadate). In many cases, the lead ores may also contain other toxic metals.

Production. Lead minerals are separated from gangue and other materials in the ore by dry crushing, wet grinding (to produce a slurry), gravity classification and flotation. The liberated lead minerals are smelted by a three-stage process of charge preparation (blending, conditioning etc.), blast sintering and blast furnace reduction. The blast-furnace bullion is then refined by the removal of copper, tin, arsenic, antimony, zinc, silver and bismuth.

Uses. Metallic lead is used in the form of sheeting or pipes where pliability and resistance to corrosion are required such as in chemical plant and the building industry; it is used also for cable sheathing, as an ingredient in solder, and as a filler in the automobile industry. It is a valuable shielding material for ionising radiations. It is used for metallising to provide protective coatings, in the manufacture of storage batteries and as a heat treatment bath in wire drawing. Lead is present in a variety of alloys and its compounds are prepared and used in large quantities in many industries.

Lead alloys

Other metals such as antimony, arsenic, tin and bismuth may be added to lead to improve its mechanical or chemical properties, and lead itself may be added to alloys such as brass, bronze and steel, to obtain certain desirable characteristics.

Lead compounds

Space is not available to describe the very large number of organic and inorganic lead compounds