CONCEPT OF INDUSTRIAL HYGIENE

2.1. INTRODUCTION

At present, Industrial Hygiene is being taught in very few universities and academic institutions in the country, even though the magnitude of the health hazard problems associated with the processes/operations involved in there industries are very complex in nature. The skill in the area of industrial hygiene is developed by experience and specialised training in the subject. In India, there are few departments/agencies engaged in carrying out industrial hygiene surveys/studies in the workplace environment of industries with two objectives:

- of identifying and then evaluating the levels of airborne chemicals to which workers are exposed, and
- of suggesting remedial measures, wherever necessary, for the control of airborne contaminants.

Considering the importance of Industrial Hygiene, the important points to be considered for Industrial Hygiene surveys have been highlighted.

2.2. INDUSTRIAL HYGIENE

Industrial Hygiene may be defined as a science (or art) for the recognition, evaluation and control of those environmental factors or stresses, arising in or from the workplace, which may cause sickness, impaired health and well-being, or significant discomfort and inefficiency among workers or among the citizens of the community.

2.3. INDUSTRIAL HYGIENIST

An industrial hygienist is a person with a college or university degrees in engineering, chemistry, physics or who, by virtue of special studies and training, has acquired competence in recognition, evaluation and control of health hazards in the workplace environment.

2.4. RECOGNITION

The identification of environmental factors and stresses associated with work and work operations, and understanding of their effects on man and his well being in
2.8.1. Dust

Dust includes solid particles generated by handling, crushing, grinding, rapid impact, detonation and decrepitation of organic or inorganic materials, such as rock, ore, metal, coal, wood and grain. Dust does not tend to flocculate except under electrostatic forces; it does not diffuse in air but settles under the influence of gravity.

Dust in the air may or may not have the same composition as its parent material. (Dust is a term used to describe airborne solid particles that range in size from 0.1 to 25 µ.) Dust above 25 µ in size, does not usually remain airborne long enough to pose an inhalation problem to exposed employees. e.g. metals, silica, asbestos etc.

2.8.2. Fumes

Fumes constitute solid particles generated by condensation from the gaseous state, generally after the volatilisation of molten metals, often accompanied by chemical reaction (oxidation); fumes coalesce and flocculate.

The solid particles that make up fumes are extremely fine, usually less than 0.1 µ, e.g. lead, zinc, cadmium, etc.

2.8.3. Smoke

Smoke carbon or soot particles, less than 0.1 µ in size are caused by the incomplete combustion of carbonaceous materials, such as coal or oil. Smoke generally contains droplets as well as dry particles. The size of the particles contained in tobacco smoke is about 0.25 µ.

2.8.4. Mist

Suspended liquid droplets generated by condensation from the gaseous to the liquid state or by breaking up a liquid into dispersed state, such as are known as mist splashing, foaming or atomising. Mist is formed when a finely divided liquid is suspended in the atmosphere.

Examples of mist are the oil mist produced during cutting and grinding operations, acid mists from electroplating, acid or alkali mists from spraying operations and the condensation of water vapour to form fog or rain.

2.8.5. Vapours

Vapours are gaseous forms of substances, which normally exist in solid or liquid state and can return to these states either by increase in pressure or decrease in temperature. Evaporation is the process by which a liquid gets converted into a vapour and mixes with the surrounding atmosphere. Solvents with low boiling points volatilise readily. Examples: Vapours of Trichloroethylene, benzene, xylene, toluene, etc.
2.8.6. Gases

Gases are normally formless fluids that occupy space or an enclosure, and can be changed into liquid or solid state by the combined effect of increased pressure and decreased temperature. Gases diffuse. For example, welding gases, internal combustion engine exhaust gases, sulphur dioxide, carbon monoxide, hydrogen cyanide etc.

2.9. MODES OF ENTRY

A chemical may exert a harmful effect if it comes into contact with a susceptible site in, or on the body. The basic modes of entry are inhalation, skin absorption and ingestion. The ratio of these three entry modes is about 90:9:1.

2.9.1. Inhalation

Inhalation is the most important route of intake of airborne contaminants. The respiratory system serves as the portal of entry into the body for a large variety of airborne contaminants, such as gaseous, vapours and particulate matter. Exchange of gases between inhaled air and blood occurs in the alveoli. The airways from the nasal cavity to the bronchioles are continuously wetted by a layer of mucous. The fate of inhaled chemical substances mainly depends upon their physical and chemical properties.

Gases and Vapours: These are directly absorbed into the blood or dissolved in the mucous in airways, depending on whether they are water or fat soluble.

- Highly soluble material dissolves into the fluid lining of the nasal cavity, the mouth and the larger airways.
- Less soluble material dissolves deeper into the lungs, where they may cause more damage.
- Highly insoluble material is exhaled.

Particulate Matter: Depending on their size, particles are trapped into the mucous layer or the alveoli. For particulate aerosols, the position is more complex. Particles of 1.0 micron diameter or more tend to be deposited, but only those less than about 7.0 microns, deposit deep inside the lungs. Those more than 7.0 microns deposit in the conductive airways. Particles in size less than 0.1 microns deposit in the alveolus. Most of the particles between 0.1 and 0 micron size are exhaled. The pattern and depth of breathing and irritant effects of inhaled material may alter the deposition of particles. Silica and Asbestos fibre may remain permanently within the lung tissue.

In an industry, the worker has to undergo physical exertion depending upon the nature of work. Physical exertion creates an immediate demand for oxygen, resulting in stimulation of breathing. The volume of air breathed per minute varies with the
activity. Thus, the rate of inhalation of any toxic impurity in the air increases with an increase in exertion as shown below:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Air Inhaled (l/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resting in Bed</td>
<td>6</td>
</tr>
<tr>
<td>Sitting</td>
<td>7</td>
</tr>
<tr>
<td>Standing</td>
<td>8</td>
</tr>
<tr>
<td>Walking (3 km/hr)</td>
<td>14</td>
</tr>
<tr>
<td>Walking (6 km/hr)</td>
<td>28</td>
</tr>
<tr>
<td>Slow run</td>
<td>43</td>
</tr>
<tr>
<td>Maximum exertion</td>
<td>65-100</td>
</tr>
</tbody>
</table>

2.9.2. Skin Absorption

The skin acts as a barrier to most naturally occurring substances. However, penetration through the skin (transcutaneous) can occur in case of some liquids and dissolved materials. Lipid solubility and molecular size are the most important factors, so that high lipid solubility and small molecular size enhance penetration through the skin. Abrasion and irritation also encourage penetration. This route is particularly important for organic solvents and can occur in a number of ways.

- Direct absorption through wounds or abrasions
- Degreasing of the skin, followed by absorption of the degreasing agent
- Degreasing of the skin, allowing absorption of other chemicals, and
- Sensitisation, local and general

2.9.3. Ingestion

This is not a common mode of entry but can be a hazard where work hygiene is of low standard. Ingestion of toxic material may result from contaminated food, beverages or putting fingers or other contaminated objects into the mouth. Ingestion of toxic substances along with food in the workroom occurs where housekeeping is not good, or where workers are careless to de-dust their clothes, or wash their hands with soap. If the toxic dust swallowed with food or saliva is not soluble in body fluids, it is eliminated directly through the intestinal tract. Toxic materials that are readily soluble in body fluids are absorbed in the digestive system and circulated by the blood. Compared with inhalation and skin absorption, ingestion plays a minor role in the absorption of toxic materials in industries.
2.10. TOXICITY OF HAZARDOUS CHEMICALS IN THE WORKPLACE

The toxicity or hazardous properties of a chemical refer to its capacity to affect or injure the human body. The toxic effects of a chemical depend on the following:

- Nature of the chemical
- Type/form of the chemical
- Concentration of the chemical
- Length of exposure
- Personal susceptibility
- Mode of entry
- Environment
- Nutritional status
- Diet
- Sex
- Age
- Threshold limit value

2.11. PHYSIOLOGICAL CLASSIFICATION OF CHEMICALS

2.11.1. Chemicals Affecting Lungs and Respiratory System

The acute effects of chemicals are irritation and burns. Chemical irritation of the Tracheobronchial tree is called bronchitis and when the irritation extends to the lungs, it is called pneumonitis.

2.11.2. Pulmonary Irritants

- Ammonia
- Antimony
- Beryllium
- Boron trifluoride
- Bromine
- Cadmium dust/fumes
- Chlorine
- Chlorine trifluoride
- Chromic acid
- Diaxomethane
- Dichloroethyl ether
- Dimethyl sulphate
- Hydrogen fluoride
- Maleic anhydride
- Methyl bromide
- Methyl iodide
Chemical burns inside the lungs may lead to Pulmonary Oedema. The more fluid there is in the lungs, the less space is available for air, resulting in laboured breathing or dyspnea.

Chronic (long-term) conditions such as scarring or thickening of lung tissue can also result from exposure to chemical dusts (fibrosis or pneumoconiosis, a development of small modules called rantomatosis, example: Beryllium).

### 2.11.3. Lung Cancer Agents

- Arsenic and arsenide
- Asbestos
- Bis-chloro-methyl ether
- Chloro methyl ethyl ether
- Chromates
- Coke oven emission
- Asbestos can lead to mesothelioma

Another long-term reaction is sensitisation of the lungs, resulting in occupational asthma. Sensitisation is an allergic reaction and may result in tissue damage, examples, toluene di-isocyanate and isocyanates.

### 2.11.4. Chemicals Affecting Liver (Hepato-billiary system)

The liver is particularly vulnerable to chemical attack because it is not only the organ in the body where a great deal of metabolic activity takes place, but also because it is well supplied with blood, particularly from the gut. Chemicals which damage the liver are called Hepatotoxins.
To name some Hepatotoxins:

- Acetylene tetrabromide
- Carbon disulphide
- Carbon tetrachloride
- Chloro diphenyl
- Chloroform
- Dichlorobenzene
- Dimethyl acetamide
- Dimethyl formamide
- Diamino-diphenyl-methane
- Dioxane
- DDT
- Dinitrophenol
- Ethylene chlorohydrin
- Ethylene dibromide
- Ethylene dichloride
- Nitroethane
- Chlorinated naphthalene
- Chlorinated hydrocarbon
- Tetrachloroethane
- Trichloroethane
- Trichloroethylene
- Toluene
- Trinitrotoluene

Fibrosis of the liver can result in complete liver breakdown and even death.

2.11.5. Chemicals Affecting the Blood (Hematological system)
Another area of the body that is sensitive to the effects of chemicals is the bone marrow, where blood cells are produced. Benzene is very hazardous for the bone marrow, causing a severe form of anaemia called Aplastic anaemia, and cancer of the blood or Leukaemia.

Other bone marrow depressants include:

- Aniline
- Dinitrophenol
- Nitrobenzene
- Tetryl
- Trinitrotoluene

The chemicals, which destroy red blood cells circulating in the blood, causing another form of anaemia, are called haemolytic agents. They include:
14 Industrial Hygiene and Chemical Safety

- Arsine
- Betyl cellusolve
- Naphthalene
- Phenyl hydrazine
- Stibine

Lead causes anaemia by directly interfering in the biosynthetic pathway of haem, the pigment in red blood cells.

2.11.6. Chemicals Affecting the Nervous System

Neurotoxins are those chemicals which affect the brain and nervous system. Some chemicals have immediate effect on the brain. Loss of brain function is called narcosis, and so these materials are known are narcotics.

The chemicals of these categories include:

- Acetaldehyde
- Acetone
- Amyl acetate
- Benzene
- Butyl acetate
- Carbon disulphide
- Chlorobenzene
- Cyclohexane
- Diglycidyl ether
- Ethyl acetate
- Ethyl bromide
- Ethylene oxide
- N-heptane
- n-hexane
- Iso-amyl alcohol
- Iso-butyl alcohol
- Iso-propyl alcohol
- Methyl acetate
- Methyl ethyl ketone
- Methyl iso-butyl ketone
- Octane
- Pentane
- Propyl alcohol
- Styrene
- Tetra chloro ethane
- Tetrachloro ethylene
- Toluene
- Trichloroethylene
Vinyl chloride manomer
Xylene

The materials which produce convulsive effects are called convulsants, or central nervous stimulants. These include:

- Aldrin
- Chlordane
- Dieldrin
- Heptachlor
- Methyl iodide
- Methyl mercaptan
- Oxalic acid
- Tetraethyl lead
- Toxaphene

Chemicals which attack the spinal cord and lower parts of the brain, causing muscle weakness, tremors and spasticity, include:

- Carbon disulphide
- DDT
- Manganese
- Mercury
- Organic lead
- Organic tin

Lead, mercury, heavy metals and their compounds can cause insomnia, disorientation, and eventually severe psychological disturbances.

### 2.11.7. Chemicals Affecting the Kidneys (renal urological system)

The kidneys being vulnerable organs because they filter the blood or materials that are to be excreted, their cells are particularly exposed to pollutants.

Chemicals which damage the kidneys are called nephrotoxins.

Examples:

- 4-Aminodiphenyl
- Carbon disulphide
- Carbon tetrachloride
- Chloroform
- Dioxane
- Ethylene chlorohydrin
- Ethylene dibromide
- Ethylene glycol
- Mercury
- Oxalic acid
- Picric acid
- Tetrachloroethane
- Trinitrotoluene
- Turpentine
- Uranium and its compounds

The short-term effects of these chemicals result in difficulty in passing urine and blood stained urine.

Example: Carbon tetrachloride

The long-term effects of these classes of chemicals result in chronic kidney diseases, which also includes complete kidney breakdown. The presence of proteins in the urine, called proteinurea or albuminurea, is an index that kidney damage is being inflicted by nephrotoxins.

Chronic kidney diseases can also lead to high blood pressure, which in turn results in cardiovascular and cerebrovascular diseases.

Oxalic acid and ethylene glycol which are metabolised can oxalate in the body and lead to kidney stones (by the depression of calcium oxalate crystals in the renal tubules).

2.11.8. Chemicals Affecting the Reproductive System

The reproductive system encompasses the ovaries in a women and the testis in man. The ovaries and testis are called gonads, and chemicals that have adverse effects on them are called gonadotoxins.

Effects on Male Organs

Chemicals known to exert a toxic effect on the production of sperms in men, resulting in total failure to produce sperms (sterility) or diminished sperm counts (asthenospermia and hypospermia) and deformed sperms (Teralospermia), are:

- Cadmium (animal test only)
- Chloropyrene
- Dibromochloropane
- Epichlorohydrin (animal test only)
- Ethylene dibromide (animal test only)
- Glycidyl ethers (animal test only)
- Lead
- Mercury (animal test only)
- Oxtendazole (animal test only)
Effects on Female Organs

Gonadotoxins affect the female organs, resulting in sterility, “spontaneous” abortions and miscarriages, as well as suspected birth deformities.

Chemicals for which there is human or experimental evidence of toxic effects on the foetus include:

- Aminopterin
- Anaesthetic gases
- Halogens
- Nitrous oxide
- Arsenic
- Bysulphan
- Benzene
- Benzinidazoles
- Cadmium
- Carbon disulphite
- Carbon monoxide
- DDT
- Diethyl stibostrol (DES)
- Diphenyl-hydantoin
- Ethylene dibromide
- Ethylenethiourea (ETU)
- Lead
- Methyl mercury
- Nicotine
- Oxtedazole
- Polychlorinated biphenyls (PCBS)
- Thalidomide
- Vinyl Chloride Monomer (VCM)
- Wartarin

2.11.9. Chemicals Causing or Suspected of Causing Cancer

The International Agency for Research on Cancer (IARC), an arm of the World Health Organization, has listed several categories in which chemicals may be placed, depending on the quality of the evidence that links them with cancer.

There is a group of 21 chemicals, groups of chemicals or industrial processes which are definitely carcinogenic for humans.

- 4-aminobiphenyl
- Arsenic and certain arsenic compounds
- Asbestos
Finally there is a much larger list of substances, for which there is sufficient evidence that the material causes cancer in well conducted animal tests, but for which human evidence is inadequate or lacking entirely. The IARC says that these materials should be treated, for all practical purposes, as if they present a carcinogenic risk to humans.

2.11.10. Chemicals Affecting the Skin

The most common of the occupational diseases caused by chemicals are skin irritation in the form of causing dermatitis or eczema. The chemicals act as primary irritants, producing lesions by direct action at the site of exposure, or as sensitisers, producing an allergic reaction deep inside the skin. Sensitisers cause contact dermatitis.

Primary irritants and sensitisers produce a similar effect. The first change noted is redness (erythema) and swelling, followed by residues which burst to produce a red weeping sore. The sore heals by crusting over.

Primary irritants which affect, mainly through direct chemical reaction or by removing the fat from skin (solvents), include:

- Alkaline sulphides
- Ammonium and barium hydrate and carbonate
- Alcohols
- Coal tar solvents
- Calcium oxide
- Chlorinated hydrocarbons
- Esters
- Ethanolamines

Elements and their salts such as antimony, arsenic, chromium, copper, mercury, nickel, zinc, silver solvents, inorganic acids.

- Inorganic alkalis
- Ketones
- Methalamines
- Organic acids
- Petroleum solvents
- Sodium and potassium salts
- Trisodium phosphate
- Terpenes

Other irritants penetrate the sweat glands and produce swelling of the glands, accompanied by a discharge called acne.

- Chloronaphthalene
Skin sensitisers are found throughout industries. Chemical sensitisers act by penetrating the upper skin barrier and reacting with proteins in the lower skin layers. The principal skin sensitisers in industries include a number of chemicals. Hence, they are classified as the specific groups.

- Dye intermediates
- Dyes
- Photographic developers
- Rubber accelerators and antioxidants
- Insecticides
- Oils
- Natural resins
- Synthetic resins
- Coal tar and its direct derivatives
- Explosives
- Plasticisers

2.12. **Threshold Limit Values (TLVs)**

American Conference of Governmental Industrial Hygienists (ACGIH) which publishes these values (TLVs) annually, defines airborne concentrations to which, it is believed, most workers may be repeatedly exposed without adverse effects. It includes concepts like:

(a) Time Weighted Average Concentrations (TWACs) : Applicable to repeated exposure of workers for an 8 hour duration per day, during a normal working week without adverse effects.

(b) Short Term Exposure Limits (STELs) : Applicable to workers with an exposure for a period upto 15 minutes, with no more than four such exposures per day (during 8 hour shifts), and at least 60 minutes between them.

(c) Ceiling Values (CV) : Exposure should never exceed any of the above periods.

Threshold Limit Values (TLVs) are derived from experience and experimental work and are supported by published material of the ACGIH, stating the sources used to define each value and the underlying objective, whether it is protection of health or comfort and amenity. In India, TLVs, published by ACGIH, are adopted as
<table>
<thead>
<tr>
<th>Industrial Hygiene and Chemical Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Amino resins, Polyacrylonitrile fibres, Polyfluorines, Rubber, Vinyl and Poly Vinyl chloride, Particulates of plastics, Cadmium, Carbon Disulphide, Xylene, Sulphuric Acid, Formaldehyde.</strong></td>
</tr>
<tr>
<td><strong>Solvents industry</strong></td>
</tr>
<tr>
<td>Hydrocarbons, Hydrogenated Hydrocarbons, Aldehydes and Ketones, Alcohols, Ether, Glycol derivatives, Esters and Miscellaneous Solvents.</td>
</tr>
<tr>
<td><strong>Sugarcane industry</strong></td>
</tr>
<tr>
<td>Fumes and Gases of Carbon Dioxide, Sulphur Dioxide, Carbon Monoxide, Hydrochloric Acid.</td>
</tr>
<tr>
<td><strong>Automobile industry (iron and steel works and foundries)</strong></td>
</tr>
<tr>
<td>a) Fumes and Dust of iron oxide, Carbonates, Silicates, and free silicab) Gases of Carbon Monoxide, Carbon Dioxide, Sulphur Dioxidec) Fumes of Phosphorus, Lead, Fluorine, Manganese, etc.</td>
</tr>
<tr>
<td><strong>Glass industry</strong></td>
</tr>
<tr>
<td>Silica, Lead, Alkaline dust, Sulphur dioxide, Vanadium, Arsenic, Potassium carbonate.</td>
</tr>
<tr>
<td><strong>Paper and pulp industries</strong></td>
</tr>
<tr>
<td>Sulphur dioxide, Chlorine, Ammonia, Sodium Hydroxide, Organic thio compounds.</td>
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<tr>
<td><strong>Construction industry</strong></td>
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<tr>
<td>● Asbestos sheet Asbestos dust.</td>
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<tr>
<td>● Glass Metals such as Chromium, Cobalt, Cadmium, Manganese, Nickel, Arsenic, Antimony, etc., Silica dust.</td>
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<tr>
<td>● Bricks Dust, Carbon Monoxide, lubricants.</td>
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<tr>
<td>● Stone Dust Free Silica.</td>
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<tr>
<td>● Cement Dust Free Silica, Carbonmonoxide and Nitrous Gases during blasting.</td>
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<tr>
<td>● Wood Zinc, Boron, Mercury, Chromium, Copper, Mineral oil, Lignite oil, Metal salts, Organic compounds, Tetrachlorophenol, Pentachlorophenol, Chlorinates Naphthalenes, Chlorinated Methane and Ethane derivatives, Nitro compounds, Organo Mercury compounds.</td>
</tr>
<tr>
<td><strong>Printing industry</strong></td>
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<tr>
<td>Benzene, Oil mist, Solvents, Dyes, Cadmium and Lead.</td>
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<td><strong>Gas industry</strong></td>
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<tr>
<td>Benzopyrene, Coal Carbonisation products, a/b-Naphthylamine.</td>
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<tr>
<td><strong>Rubber industry</strong></td>
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<tr>
<td>Benzene, Aromatic amines, 1,3-Butadiene, Styrene, Acrylonitrile, Isoprene, Chloroprene, Di-isocyanates,</td>
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<td>Industry</td>
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<tr>
<td>Cement Industry</td>
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<td>Tanning &amp; Leather Finishing Industry</td>
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<td>Engineering Industry</td>
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<td>Furnace operations</td>
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<td>Galvanising</td>
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<td>Paint spraying</td>
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<td>Solvent degreasing</td>
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<tr>
<td>Electroplating</td>
</tr>
<tr>
<td>i) Pickling</td>
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<td>ii) Plating</td>
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<tr>
<td>Welding, gas or electric arc (Brazing)</td>
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<td>Electro-tinning (alkaline)</td>
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<td>Smelting and refining</td>
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<tr>
<td>Forming and forging</td>
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<tr>
<td>Handling Operations</td>
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<tr>
<td>Refractories handling</td>
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<tr>
<td>Ferromanganese handling</td>
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