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Review on Industrial Hazards and its Prevention

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Abstract

Indian pharma industry has been making tremendous progress not only in creation of excellent infrastructure but also attending to the global needs of the supply of APIs as well as quality medicines in addition to entering into growing fields of contract research and manufacturing and clinical trials. Like most chemical industries, the Pharma industry also has various environmental issues especially in manufacture of APIs. This review provides technical information regarding hazards in the pharmaceutical sector and our aim is to bring awareness about hazards, avoidance of hazards, be in preparedness mode to suitably respond to the effects and impacts of hazards including Disaster Management in the pharmaceutical industry.

Keywords: Pharmaindustry, Pharmaceutical sectors, Hazards, Disaster management.

Contents

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1. Introduction

Hazard is a situation that possesses a level of threat to life, health and property or environment. Industrial hazard may be defined as any condition produced by industries that may cause injury or death to personnel or loss of product or property. The accidents in various types of industries like manufacturing, power production etc. and in storage and transportation of various hazardous materials used in these industries fall under this category. The risk involved under this category is defined as the chances of death or injury per person per number of hours exposed. The major disaster threats have emerged in the chemical and nuclear industries. The manufacturing, processing, transportation, distribution/storage and the application/use of many products of these two areas are hazardous. The following paragraphs highlight some aspects under these two major groups.

2. Description

Types of Industrial Hazards

- **Physical**: Noise, vibration, heat, cold, pressure, radiation, fibres.
- **Chemical:** Flammable or explosive materials, toxics, sensitizing agents.
- **Biological:** Dust, pathogens.

- **Psychological:** Work place practices and systems, payment systems.

General hazards in industries

- Fire hazards
- Mechanical hazards
- Electrical hazards
- Chemical hazards
- Pharmaceutical hazards
- Radiation hazards
- Dust explosion

Fire hazards

Fire is an exothermic chemical reaction between oxygen and fuel. This is the most frequent of the hazards however the consequences are generally less. The effect of fire on people usually takes the form of skin burns and is usually dependant on the exposure time and the intensity of the heat. Fire can also produce toxic fumes like Acrolein, Carbon monoxide and Cyanides. Physical structures can be damaged either by the intensity of the heat or combustion. It may also have an effect on essential services like power and instrumentation which can cause an escalation of the incident.

Sources of fire hazards

- Hot surfaces
- Combustible and flammable liquids
- Heat utilization equipments (over heating)
- Chemical process equipments
- Lightening
- Gas cylinders
- Ovens and furnaces
- Reactor
- Welding and cutting
- Spark from metal to metal contact
- Carelessness

Types of fire

The National Fire Protection Association (NFPA) categorizes fires by class.The relevant graphics and letter designations that accompany these classes are specified by NFPA 10, the standard for portable fire extinguishers.

Class A fires involve solid materials of an organic nature such as wood, paper, cloth, rubber and plastics that do not melt.

Fig.1 Class A fire

Class B fires involves liquids. They include petrol, diesel, thinners, oils, paints, wax, cooking fat and plastic that melts.

Fig.2 Class B fire

Class C fires involve electricity.

Fig.3 Class C fire

Class D fires involve flammable metals such as magnesium, aluminium, titanium, sodium and potassium.

Fig.4 Class D fire

Cooking media (vegetable or animal oils and fats)

Classification of hazards

In accordance with NFPA, areas are typically classified as being light (low) hazard, ordinary (moderate) hazard, or extra (high) hazard.

Light (low) hazard areas are locations where the quantity and combustibility of Class A combustibles and Class B flammables is low. In these areas, expected fires have relatively low rates of heat release. Light hazard areas may include offices, classrooms, meeting rooms etc.

Ordinary (moderate) hazard areas are locations where the quantity and combustibility of Class A combustible materials and Class B flammables is moderate. Fires with moderate rates of heat release are expected in these areas. Ordinary hazard locations could be offices, malls, light manufacturing or research operations, parking garages, workshops, or maintenance/service areas.

Extra (high) hazard areas are locations where the quantity and combustibility of Class A combustible material is high or where high amounts of Class B flammables are present. Quickly developing fires with high rates of heat release are expected. These locations could be sites for cars repair, aircraft and boat servicing, painting, dipping, and coating, storage areas (tanks, containers etc).

NFPA (National Fire Protection Association)

NFPA 704: Standard System for the Identification of the Hazards of Materials for Emergency Response is a standard maintained by the U.S. based National Fire Protection Association. First "tentatively adopted as a guide" in 1960, and revised several times since then, it defines the colloquial "fire diamond" used by emergency personnel to quickly and easily identify the risks posed by hazardous materials. This helps determine what, if any, special equipment should be used, procedures followed, or precautions taken during the initial stages of an emergency response.

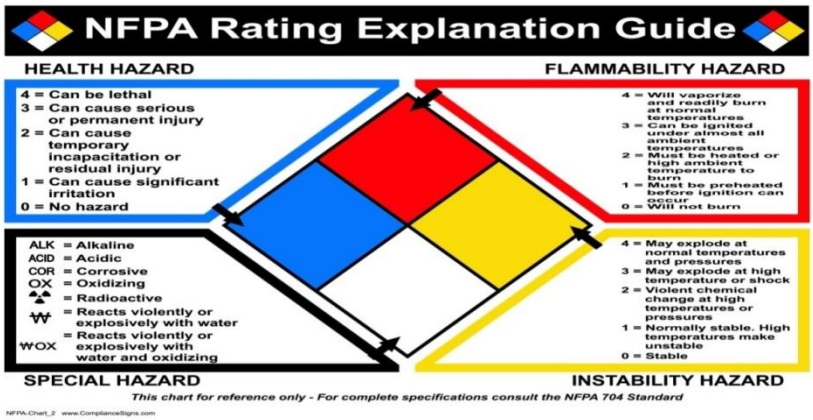

Fig.5 NFPA Rating Explanation Guide

Symbolism

The four divisions are typically color-coded, with blue indicating level of health hazard, red indicating flammability, yellow (chemical) reactivity, and white containing special codes for unique hazards. Each of health, flammability and reactivity is rated on a scale from 0 (no hazard) to 4 (severe risk).

These NFPA diamonds are found on,

- Product labels
- Material safety data sheets

The flammability of a chemical can be determined by its flash point. The flash point of a liquid is the lowest temperature at which the liquid gives off enough vapor to be ignited. The lower the flash point, the greater the risk of ignition. Flash point information may be found on the product labels or MSDS sheets.

Non-standard symbols

These hazard symbols are not part of the NFPA 704 standard, but are occasionally used in an unofficial manner. The use of non-standard symbols or text may be permitted, required or disallowed by the authority having jurisdiction (e.g., fire department).

COR: Corrosive; strong acid or base (e.g. sulfuric acid, potassium hydroxide) **ACID** and **ALK** to be more specific
BIO : Biological hazard (e.g., smallpox virus)
POI: Poisonous (e.g. Strychnine)
RAD: Radioactive (e.g., plutonium, uranium)
CYL or **CRYO**: Cryogenic (e.g. Liquid Nitrogen)

Flammable and combustible liquids

Flammable and combustible liquids are potential fuel sources for fire and are present in almost every work place. The vapor created by flammable and combustible liquids ignites and burns. The flash point of flammable liquids is less than 100^0 F. This means that flammable liquids burn easily at normal working temperatures. Combustible liquids have a flash point at or above 100^0F.These liquids are less hazardous than flammable liquids but still pose a risk. The volatility of flammable and combustible liquids requires special storage and handling requirements.

Storage of flammable and combustible liquids

Flammable liquids must be stored away from ignition sources in cool, well ventilated areas away from incompatible materials. The amount of these liquids is to be minimized. As a general rule, not more than 10 gallons of flammable materials should be outside of approved flammable liquid storage cabinets or approved storage rooms. Room storage limits of these materials depend on various factors such as sprinklers and storage cabinets.

Sources of fire

The fire triangle or combustion triangle illustrates the three elements a fire needs to ignite:

- Heat
- Fuel
- Oxidizing agent (usually oxygen).

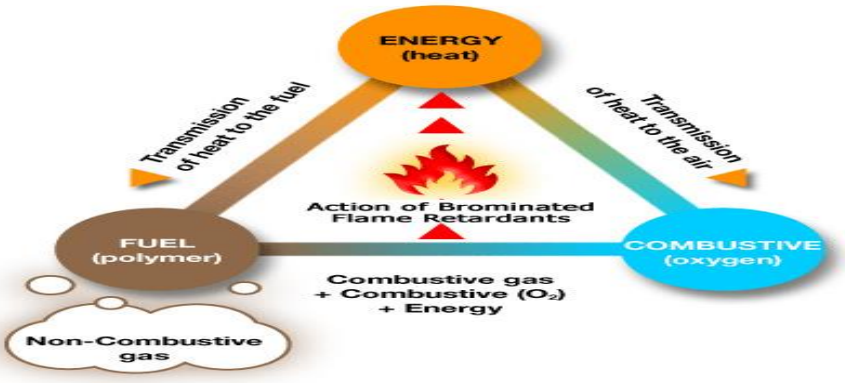

Fig. 6 Fire triangle

A fire naturally occurs when the elements are present and combined in the right mixture, and a fire can be prevented or extinguished by removing any one of the elements in the fire triangle. For example, covering a fire with a fire blanket removes the "oxygen" part of the triangle and can extinguish a fire.

Table.1 Sources of Fire

Ignition	Fuel	Oxygen
• ARSON • Smokers materials • Naked flames • Electrical, gas, Portable heating equipment • Hot processes-paint stripping, welding • Lighting equipment.	• Flammable liquid based products • Packaging materials • Waste products • Stationary • Soft furnishings and furniture • Some construction materials.	• The air around us • Air conditioning • Some chemicals • Oxygen supplies cylinder storage • Pyrotechniques

Table.2 Classes of Fire and Types of Extinguishers

Fuel Sources	Class of Fire	Type of Extinguisher(Extinguishing Agent)
Ordinary Combustibles (e.g., trash, wood)	A	chemical foam; dry chemical
Flammable liquids (e.g., oils, grease, tar, gasoline, paints, thinners)	B	Carbon dioxide (CO2); halon2; dry chemical; aqueous film forming foam (AFFF)
Electricity (e.g., live electrical equipment)	C	CO2; halon; dry Chemical
Combustible metals (e.g., magnesium, titanium)	D	Dry powder (suitable for the specific combustible metal involved

1. Dry chemicals, CO_2 and halon can be used on Class A fires, but may not be effective on their own. They need to be supplemented with water.
2. Halon extinguishers are no longer made, but some may still be in use. Dangerous gases are formed when halon is used to put out fires. Wear proper respiratory equipment, particularly in enclosed spaces. After use, do not allow anyone to enter the area until it has been well ventilated.

Electrical hazards

The electrical hazards are categorized into three types

- The first type and most commonly recognized hazard is electrical shock
- The second type of hazard is electrical burns
- The third is the effects of blasts which include pressure impact, flying particles from vaporized conductors and first breath considerations.

Electrical hazards are caused by the following reasons:

- Contacting overhead power lines
- Faulty insulation
- Improper grounding
- Loose connections
- Defective parts
- Ground faults in equipment
- Unguarded live parts
- Failure to de-energize electrical equipment when it is being repaired or inspected
- Intentional use of obviously defective and unsafe tools
- Use of tools or equipment too close to energized parts.

Table.3 Effects of Electrical current on the human body

Current in milli amperes	Effects
1 or less	no sensation; probably not noticed
1 to 3	mild sensation not painful
3 to 10	painful shock
10 to 30	muscular control could be lost or muscular clamping
30 to 75	respiratory paralysis
75 mA to 4 amps	ventricular fibrillation
Over 4 amps	Tissue begins to burn. heart muscular clamp and heart stops beating

Table.4 Resistance value

Type of resistance	Resistance value
Dry skin	100,000 to 600,000 ohms
Wet skin	1,000 ohms
Hand to foot	400 to 600 ohms
Ear to ear	100 ohms

Protection and prevention

- **Insulation-** glass, mica, rubber and plastics are put on conductors to prevent shock, fires and short circuits.
- **Guarding –** live parts of equipment operating at 50 volts or more must be guarded against accidental contact
- **Grounding-** "conductive body(earth)" by grounding a tool or electrical system, offers low resistance and sufficient current carrying capacity.
- **Circuit protection devices** – automatically limit or shut off the flow of electricity in the event of a ground fault, overload or short circuit in the wire systems eg: fuses, circuit breakers
- Safe work practices
- Training

Symbol for electrical hazard

Fig. No: 7 symbol for electric hazard

Mechanical hazards

There exist a several mechanical systems in the accelerator complex that could have potential hazards associated with them if they were to fail. Failure of any mechanical systems, could lead to implosion (in vacuum chamber) or explosion (in gas or liquid filled pipes). Other mechanical hazards may exist from machine shop tools, metal grinding, industrial vehicles, etc.

Mechanical hazards by type of agent:

- Impact force
- Collisions
- Falls from height
- Struck by objects
- Confined space
- Slips and trips

- Falling on a pointed object
- Compressed air/ high pressure fluids (such as cutting fluid)
- Entanglement
- Equipment related injury

By type of damage:

- Crushing and cutting
- Friction and abrasion
- Shearing
- Stabbing and puncture
- Poor maintenance or house keeping

Safety measures for mechanical hazards

- All machinery must be fenced or mechanical inter locking or photocell.
- Machine should be fitted with emergency shutdown system.
- Control system override should be monitored
- Turnkey system for cleaning and for repairing
- Operator must have a safe distance from the machine
- Strictly following SOP
- Stop and lock button for machines

Preventive measures: It includes

Building planning

- Floors must be non slippery
- Enough space to move easily
- Easy access of workers to the safety switches

Safe material handling

- All material handling equipments should be repaired and maintained properly

Personnel protective devices

- Protection of head by using hard hats and helmets
- Ears by using ear muffs and plugs
- Face by using face masks

Chemical hazards

Chemical hazards are toxic, corrosive, irritant, carcinogenic, flammable and mutagenic.

According to WHMIS (Workplace Hazardous Materials Information) chemical hazards are classified as,

Class A:

- Compressed gas
- Dissolved gas or liquefied gas

Class B:

- Flammable gases
- Flammable and combustible liquids
- Flammable solids
- Flammable aerosols
- Reactive flammable material

Class C:

- Oxidizing materials- oxidizer and organic peroxide

Oxidizer: Chlorates, nitric oxide, peroxides, permanganates, per chlorates, nitrites, nitrates, easily oxidize metal powder.

Organic peroxide: Tetra hydro furan, diethyl ether, dioxane, methyl iso butyl ether.

Class D:

Poisonous and infectious materials:

Eg: cyanides, tea salts, asbestos

Class E: Corrosive materials:

Eg: inorganic acids and bases, hydrogen fluoride

Class F:

Dangerous reactive materials:

Eg: ethylene dioxide, organic azides, Na, Li, Ca.

Pyrophosphoric materials:

Eg: white phosphorous, diethyl aluminium chloride, lithium

Effects of chemicals on exposure

- Skin burn
- Ache
- Anthrax
- Ulcer in hand, nose etc
- Cancer
- Irritation on wind pipe
- Many chemicals can cause severe burns, if they come in contact with living tissue
- Living tissue may be destroyed by following chemical reactions:
  - Dehydration by strong dehydrating agents
  - Digestion by strong acids and bases
  - Oxidation by strong oxidizing agents

Pictograms used in chemical hazards

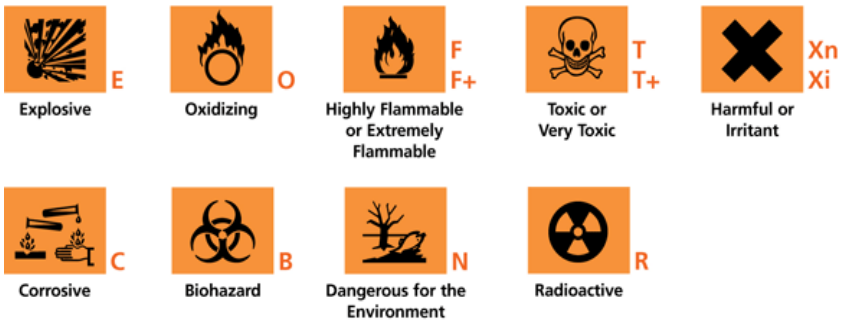

Fig.8 Pictograms used in chemical hazards

Table.5 Some clinical symptoms and hazard causing chemicals

organ	symptoms	chemicals
Eyes	corneal and conjunctival disturbances	Sulphur dioxide, Hydrogen sulphide
Nervous System	drowsiness	CNS depressants
Mouth and Throat	Green tongue salivation	Vanadium mercury

Table.6 Additives and their Health Effects

Additives	Health effects
azo dyes	Bladder cancer
benzene	leukemia
Caustic soda	Blindness and respiratory damage
Zinc salts	Skin and eye damage
Chlorine ions	Lung and skin damage
lead	Lead poisoning

Preventive measures

- Solvents used in extraction, purification of synthetic drugs and chemical analysis should be handled with care.
- Flammable and explosive chemicals should be kept at proper distance.
- Tolerance levels for toxic chemicals set by federal regulation have to be followed.
- Suitable label to the chemicals for proper handling.
- Personal protective cloth.
- Application of cream before commencement of work.
- Use of goggles.

Pharmaceutical hazards

Some general health hazards in manufacture of pharmaceuticals include:

- Dust and noise exposures

- Exposure to UV radiation
- Exposure to formaldehyde
- Repetitive motion disorders
- Formaldehyde may cause lung cancer, prostate cancer. Acute exposure may cause pulmonary edema and pneumonia leading to death. Also causes allergic dermatitis.
- Repetitive motion disorder associated with packing and filling could lead to carpal tunnel syndrome or tendonitis.
- Hazards from handling crude drugs and its extracts eg: ipecacunha
- Solvents eg: benzene
- Alkaloids eg: scopolamine, emetine
- Toxic intermediate
- Final product eg: local anaesthetic
- Miscellaneous hazards : radiant energy, bacteria and viruses

Industrial Safety

Industrial safety is primarily a management activity which is concerned with reducing, controlling and eliminating hazards from the industries or industrial units. Industrial safety is the ability to manage the risks inherent to operations or related to the environment. Industrial safety is not a dislike of risks, rather it is a commitment to clearly identify them in relation to production operations, assess them in terms of quality and quantity, and manage them. For Total, that means, in practical terms, regularly looking at how risk management is addressed at the company's facilities and how much progress the company has made in its action plans to reduce them.

Total is exposed to three types of risk:

- Risks related to the products that we use or make
- Risks related to the processes and equipment used in our operations
- Transportation risks related to our operations.

Importance of Industrial safety

The danger of life of human being is increasing with advancement of scientific development in different fields. The importance of industrial safety was realized because every millions of industrial accidents occur which result in either death or in temporary disablement or permanent disablement of employees and involve large amount of losses resulting from danger to property, wasted man hours and wasted hours.

From managerial perspective the importance of industrial safety in any organization may be concluded by following facilitation:

- **Treatment:** Industrial safety management provides treatment for injuries and illness at the work place
- **Medical Examination**: Carries out medical examination of staff joining the organization or returning to work after sickness or accident.
- Hazards identification.
- Provision of protective devices.
- Consultancy: it provides medical advised on other condition potentially affecting health e.g. works, canteen etc.
- Education: it provides safety and health training.

Objectives of industrial safety:

- To prevent accidents in the plant by reducing the hazard to minimum.
- To eliminate accident caused work stoppage and lost production.
- To achieve lower workmen's compensation, insurance rates and reduce all other direct and indirect costs of accidents.
- To prevent loss of life, permanent disability and the loss of income of worker by eliminating causes of accidents.
- To evaluate employee's morale by promoting safe work place and good working condition.
- To educate all members of the organization in continuous state of safety mindness and to make supervision competent and intensely safety minded.

A safety programmed includes mainly following four E's.

- Engineering: i.e. safety at the design, equipment installation stage.
- Education: i.e. education of employees in safe practices.

- Enlistment: it concerns the attitude of the employees and management towards the programmed and its purpose. It is necessary to arouse the interest of employees in accident prevention and safety consciousness.
- Encouragement: i.e. to enforce adherence to safe rules and practices.

Industrial safety system

An industrial safety system is a counter measure crucial in any hazardous plants such as oil and gas plants and nuclear plants. They are used to protect human, plant, and environment in case the process goes beyond the control margins. As the name suggests, these systems are not intended for controlling the process itself but rather protection. Process control is performed by means of process control systems (PCS) and is interlocked by the safety systems so that immediate actions are taken if the process control systems fail. Process control and safety systems are usually merged under one system, called *Integrated Control and Safety System* (ICSS). Industrial safety systems typically use dedicated systems that are SIL 2 certified at minimum, whereas control systems can start with SIL 1. SIL applies to both hardware and software requirements such as cards, processors redundancy and voting functions.

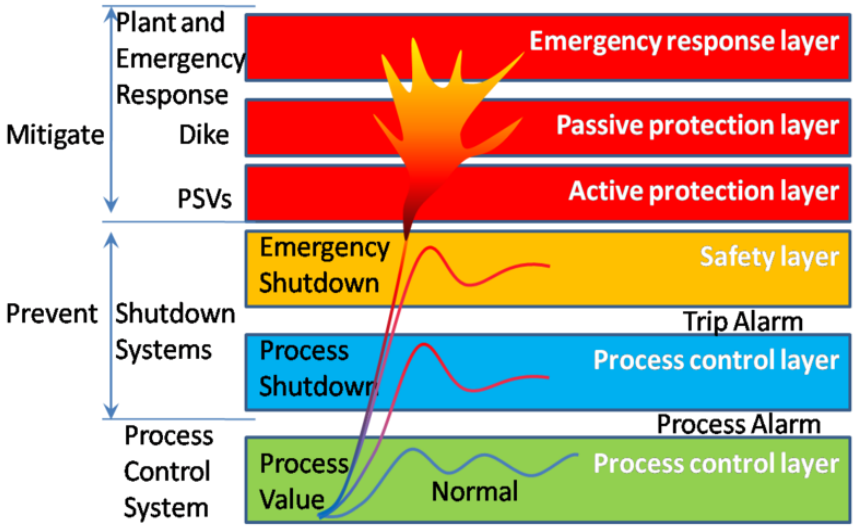

Fig. 9 Description of safety layer protection

Types of industrial safety systems

There are three main types of industrial safety systems in process industry

- Process Safety System or Process Shutdown System, (PSS).
- Safety Shutdown System (SSS):

  This includes Emergency Shutdown-(ESD) and Emergency Depressurization-(EDP) Systems.

ESD: These systems may also be redefined in terms of ESD/EDP levels as:

- ESD level 1: In charge of general plant area shutdown, can activate ESD level 2 if necessary. This level can only be activated from main control room in the process industrial plants.
- ESD level 2: This level shuts down and isolates individual ESD zones and activates if necessary EDP.
- ESD level 3: provides "liquid inventory containment".

SSS: The safety shutdown system (SSS) shall shut down the facilities to a safe state in case of an emergency situation, thus protecting personnel, the environment and the asset. The safety shutdown system shall manage all inputs and outputs relative to emergency shutdown (ESD) functions (environment and personnel protection). This system might also be fed by signals from the main fire and gas system.

FGS: The main objectives of the fire and gas system are to protect personnel, environment, and plant (including equipment and structures).

The FGS shall achieve these objectives by:

- Detecting at an early stage, the presence of flammable gas,
- Detecting at an early stage, the liquid spill (LPG and LNG),
- Detecting incipient fire and the presence of fire,
- Providing automatic and/or facilities for manual activation of the fire protection system as required,
- Initiating environmental changes to keep liquids below their flash point.
- Initiating signals, both audible and visible as required, to warn of the detected hazards,

- Initiating automatic shutdown of equipment and ventilation if 2 out of 2 or 2 out of 3 detectors are triggered,
- Initiating the exhausting system.

EDP: Due to closing ESD valves in a process, there may be some trapped flammable fluids, and these must be released in order to avoid any undesired consequences (such as pressure increase in vessels and piping). For this, emergency depressurization (EDP) systems are used in conjunction with the ESD systems to release (to a safe location and in a safe manner) such trapped fluids.

PSV: Pressure safety valves or PSVs are mechanical devices and are usually used as a final safety solution when all previous systems fail to prevent any further pressure accumulation and protect vessels from rupture due to overpressure.

3. Conclusion

This review suggests,

- Safety awareness and safety training requirements of plant employees with respect to hazards present in the plant
- Constructor safety awareness and recommend suitable improvement measures
- Systematic training of employees
- In addition, it suggests that there should be a committee in each department, responsible for safety in their departments.

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