MODULE 1

Safety and Risk Assessment in Hydrogen Logistics

The cornerstone of a secure energy future

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Why Choose Hydrogen?
Why Prioritize Security?

I

The increasing significance of hydrogen: Accelerated advancement of the hydrogen economy, its potential as a clean fuel and energy carrier.

II

Presentation objective: Acquiring an understanding of hydrogen safety regulations and standards. Cultivating risk analysis and emergency response competencies.

III

Challenge: Hydrogen serves as a potent energy carrier; however, its unique properties necessitate specific precautions.

Hydrogen: Distinct Properties, Distinct Challenges

Lightness

The lightest element, it evaporates and disperses rapidly, reducing the risk of accumulation in open space while complicating detection.

Diffusivity

Effortlessly infiltrates materials.

Inflammability

A broad spectrum of explosive concentrations in the air (4-75% by volume).

Invisible fire

The hydrogen flame is devoid of color, nearly imperceptible in daylight.

No odor or color

No inherent warning signals for humans.

Minimal ignition energy

Requires a minimal spark (under 0.02 mJ) for ignition.

Cryogenic properties of liquid hydrogen

Liquefied hydrogen (LH2) possesses an extremely low temperature of -253°C, presenting a risk of frostbite and material embrittlement.

Security Foundation: Regulations, Standards, and Norms

Why are they essential?

They offer cohesive guidelines, mitigate risks, and safeguard individuals, the environment, and infrastructure.

Legislation

Compulsory, instituted by legislative authorities.

Norms/Standards

Voluntary in nature, they represent a collection of best practices and are frequently cited in regulations.

Global Standards: Key ISO and IEC Standards

ISO 14687 – "Hydrogen Fuel Quality – Product Specification"

Ensures that hydrogen utilized as fuel adheres to the necessary specifications. This is essential for optimal fuel cell performance and safety, preventing equipment damage, corrosion, and uncontrolled reactions.

IEC 60079 (series) – "Explosive Atmospheres"

Establishes criteria for equipment and systems utilized in potentially explosive environments (e.g., where hydrogen may be present). Specifies zone classification (ATEX) and equipment specifications.

Specialized Standards: Enhancing Security

ISO 19880 (series): Hydrogen Refueling Stations

Comprehensive guidelines for the design, construction, operation, and safety of hydrogen refueling stations.

ISO 22734: Hydrogen Generators

Safety standards for hydrogen generation systems (e.g., electrolysers).

Material specifications

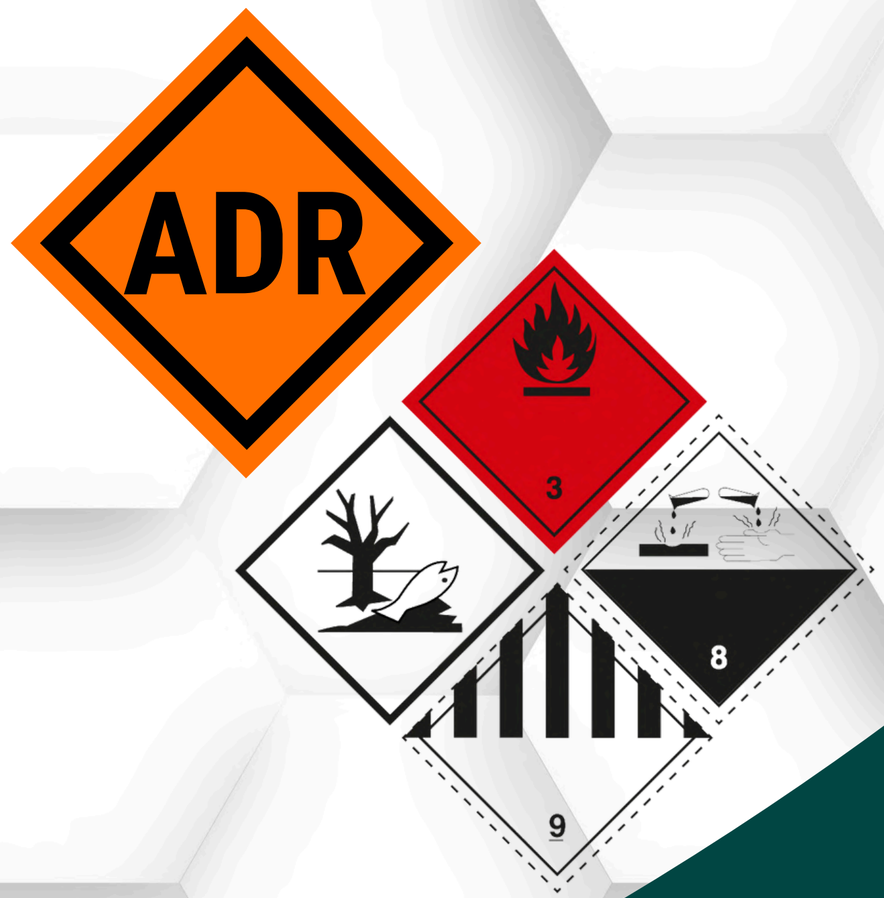
compatibility with hydrogen, resistance to hydrogen embrittlement in materials.

Important: Standards are dynamic and continually evolving alongside technological advancements.

Control of Major Accident Hazards: Seveso III Directive

- **Objective:** To prevent serious industrial accidents (fires, explosions, leaks) involving hazardous substances, including hydrogen, and to mitigate their impacts.
- **Scope:** Pertains to facilities where substantial amounts of hazardous substances are present or may potentially be present (hydrogen has defined quantitative thresholds).
- **Key requirements:** Formulation of a comprehensive accident prevention policy, safety assessments, and both internal and external emergency response plans.

Safe Transport of Hydrogen: ADR and IMDG Regulations



ADR (European Agreement on the International Carriage of Dangerous Goods by Road)

It delineates the regulations governing the international road transport of hazardous materials, including hydrogen, encompassing classification, packaging, marking, documentation, driver training, vehicle approvals, and vehicle equipment.

IMDG Code (International Maritime Dangerous Goods Code)

Comparable regulations for maritime transport, tailored to the unique characteristics of the marine environment.

Regulations in Poland: Execution and Distinctiveness

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EU execution

EU regulations are incorporated into Polish law (e.g., the Act on the Transport of Dangerous Goods, occupational health and safety regulations, and Construction Law concerning hydrogen installations and storage facilities).

Office of Technical Supervision (UDT)

A crucial function in the oversight of pressure equipment (tanks, cisterns, pipelines) and hydrogen installations. UDT grants operational approvals, conducts inspections, and provides certification.

National standards and guidelines

Supplementary documents enhancing the regulations.

Emergency Events: Hazard Scenarios

- Despite stringent standards, the risk of emergency incidents remains ever-present.
- Due to its characteristics, hydrogen presents particular hazards: leaks, fires, and, in the most severe cases, explosions.
- Comprehending their mechanics is essential for efficient prevention and response.

Hydrogen Emissions: Unseen Hazard

Sources of leaks

Leaks in installations, valves, connections, and damage to transport tanks.

Hydrogen behavior following a leak

Due to its low density, hydrogen ascends rapidly and disperses upward, thereby reducing accumulation in low-lying areas while posing a risk in confined spaces or beneath roofs.

Risk

Formation of explosive mixtures with air (4-75% H2). Risk of frostbite upon contact with liquid hydrogen.

Hydrogen Fires: Specifics and Impacts

Flame Attributes

Invisible in daylight, devoid of color, complicating identification and location.

Temperature

Extremely elevated flame temperatures (reaching up to 2000°C) result in significant thermal radiation.

Burn rate

Hydrogen combusts at a rapid rate.

Secondary risk

A hydrogen fire can ignite other materials and inflict damage on structures and equipment.

Hydrogen Explosions: Shockwave and Devastation

Deflagration versus Detonation

Deflagration: A swift combustion process occurring at subsonic speeds, resulting in the generation of a pressure wave.

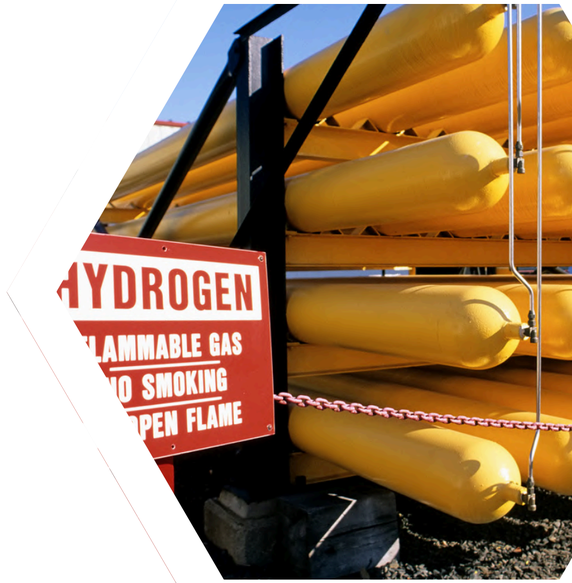
Detonation: Propelling at supersonic velocity, producing a significantly more powerful shock wave and increased devastation.

Explosion parameters

Accumulation of hydrogen within explosive concentration limits (4-75% H2 in air) alongside the presence of an ignition source.

Consequences

Shockwave, fragment dispersion, structural impairment, human injuries.



Case Studies:
Logistical Threat Scenarios

1

Scenario 1:
Leak in an enclosed storage area

Risk of swift development of an explosive mixture, challenges in ventilation.

2

Scenario 2:
Fire at hydrogen refueling facility

Threats to operators and the environment, along with potential damage to infrastructure.

3

Scenario 3:
Hydrogen tanker collision incident

Risk of significant leakage, fire, and explosion in a public area, necessitating prompt evacuation and management.

Threat Preparedness: Fundamental Response Principles

01 **Detection and Alarming:** Rapid identification of the threat (detectors, trained personnel) and prompt activation of the alarm.

02 **Danger Zone Isolation:** Creation of an exclusion zone, restricting access.

03 **Evacuation:** Prompt and secure evacuation of personnel and nearby individuals.

04 **Emergency Services Contact:** Fire Department, Ambulance Service, Police, specialized units.

05 **Crisis Management:** Mobilizing Internal Response Teams emergency.

Technology in Security Services: Detection and Surveillance

- **The function of detectors:** Essential because of the invisibility and odorlessness of hydrogen.
- **Types of detectors:** Electrochemical, catalytic, semiconductor, optical.
- **Location:** Strategically positioned in areas susceptible to leaks (elevated, in recesses and crevices).
- **Alarm systems:** Early warning mechanisms (audible and visual alarms) and the automatic initiation of safety protocols (e.g., ventilation and shut-off).

Effective Measures: Fire Suppression Agents and Personal Protective Equipment

- **Hydrogen fires:** Challenging to extinguish directly. A controlled burn of the leak is frequently advised if it can be done safely.
- **Water:** Primarily utilized to cool surrounding components and water curtains to inhibit the propagation of fire and radiant heat.
- **Personal Protective Equipment (PPE):** Specialized protective garments, respiratory devices, cryogenic gloves, and eye and facial protection.

First Aid: Cryogenic Injuries

- **Cause:** Exposure to liquid hydrogen (LH2) or extremely cold system components.
- **Symptoms:** Discomfort, erythema, edema, vesicles, tissue necrosis (resembling frostbite).
- **Rescue protocols:**
  - Transport the injured individual to a secure location.
  - Remove contaminated clothing and jewelry, unless frozen.
  - Rinse the affected area with lukewarm water (neither hot nor cold) for 15 to 30 minutes.
  - Avoid rubbing or applying heat quickly.
  - Apply a sterile bandage.
  - Request medical assistance.

First Aid:
Risk of Asphyxiation and Other Gases

- **Hydrogen and asphyxia:** While hydrogen is not inherently toxic, elevated concentrations can displace oxygen in the atmosphere, resulting in hypoxia (asphyxia).

- **Symptoms of asphyxia** include dizziness, shortness of breath, loss of consciousness, and headache.

- **Other gases:** Hydrogen generated through various methods may contain impurities (e.g., hydrogen sulfide H2S, carbon monoxide CO) that are hazardous.

- **Rescue protocols:**
  - Ensure the rescuer's safety (breathing apparatus required!).
  - Relocate the injured individual to an area with fresh air.
  - Observe essential functions.
  - If there is no breathing or pulse, initiate cardiopulmonary resuscitation (CPR).
  - Request medical assistance.

Risk Management:
The Essential Element of Secure Logistics

1 Definition of risk

The probability of an adverse event transpiring and its possible ramifications.

2 The objective of risk analysis

Systematic identification, evaluation, and management of potential threats.

3 Stages

Hazard identification, risk analysis (evaluation of likelihood and outcomes), risk assessment (acceptability), risk management (mitigation strategies).

HAZOP: Systematic Identification of Operational Risks

- **Objective:** To identify potential deviations from the intended operation of a system (e.g., pipeline, tank) along with their possible causes and effects.
- **Characteristics:** A collaborative, systematic approach utilizing keywords (e.g., "none," "too much," "too little," "some," "more than").
- **Application of hydrogen in logistics:** An analysis of storage, pipeline transmission, transportation, and refueling processes.
- **Benefits:** Prompt threat identification, enhancement of design, heightened security.

FMEA: Failure Mode and Effects Assessment

- **Objective:** To identify potential failure modes of components or systems, evaluate their causes and effects, and prioritize preventive measures.
- **Characteristics:** Methodical "what-if" analysis for each component or function. Risk evaluation based on likelihood, severity, and detectability.
- **Applications in hydrogen logistics:** Evaluation of reliability for valves, pumps, detectors, tanks, and control systems.
- **Benefits:** Enhanced equipment reliability, diminished risk of failure, improved safety.

FMEA: Failure Mode and Effects Assessment

Effective Planning: Practical Risk Management

- **Risk management plans:** Formulating and executing strategies to mitigate identified risks.
- **Emergency plans:** Comprehensive protocols for addressing particular emergency situations (fire, leak, explosion).
- **Safety Management Systems (SMS):** A comprehensive approach to safety that includes policy, organization, planning, implementation, measurement, and evaluation.
- **Training and Exercises:** Consistent staff training and practical exercises are essential to the efficacy of the plans.

Key Messages: An Overview of Hydrogen Safety

- **Hydrogen** represents the fuel of the future; however, it necessitates an understanding of its particular risks.
- **Regulations** and standards constitute the cornerstone of secure operations in hydrogen logistics.
- **Comprehending** the dynamics of emergency situations facilitates efficient prevention.
- **Effective** response protocols and first aid measures preserve lives and reduce losses.
- **Risk analysis**, including HAZOP and FMEA, is crucial for proactive risk management.

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