

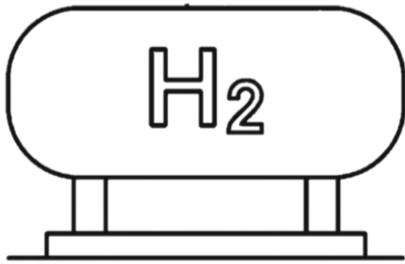


# Operational Safety for Hydrogen Fueling Installations

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AcuTech Group, Inc.

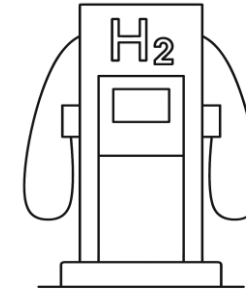
# Hydrogen Fueling System



(1) Storage



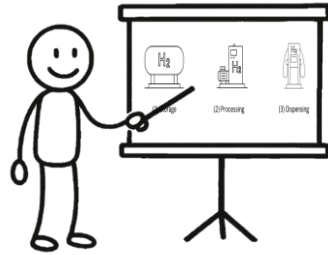
(2) Processing



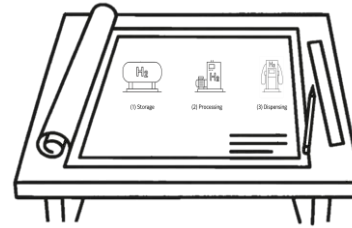
(3) Dispensing

- 1) Bulk Storage system – receive deliveries, store fuel, supply process equipment
- 2) Processing Equipment – provide fuel to dispenser at pressure, temperature and flow rates required
- 3) Dispensing Equipment – interact with user to establish fueling request, control fuel transfer within safe operating boundaries

# Hydrogen Fueling Systems Project Phases



Concept & Funding



Detailed Design Engineering



Permitting



Construction



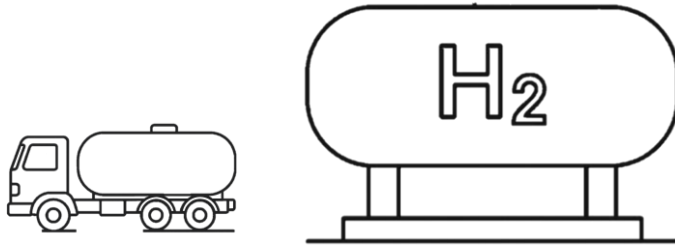
Commissioning



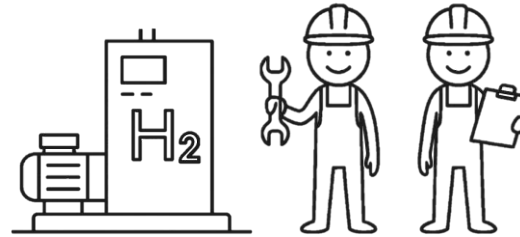
Operations

# Operational Safety Goal: Plan for **normal** & **abnormal** operational scenarios:

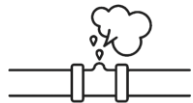
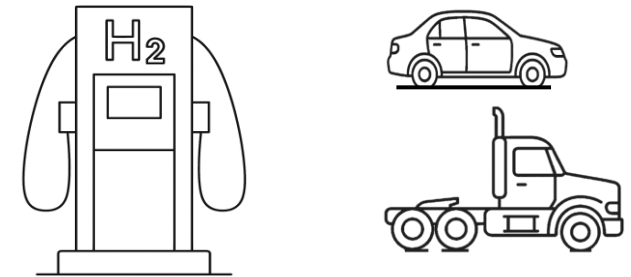
## Deliveries



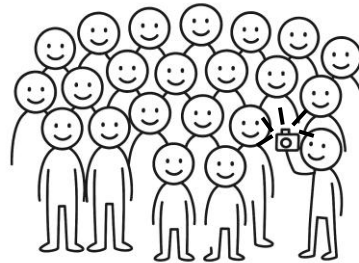
## Maintenance



## Fueling



## Loss of Containment (leaks)



## Site Tours



## Natural Disasters

# Operational Safety - Prepare and Maintain

## Operational Readiness (prepare for safe operations)

**Purpose:** Ensures that facilities, equipment, and personnel are fully prepared before starting or restarting operations.

- **Focus Areas:**

- Pre-startup safety reviews (PSSR)
- Verification of procedures, training, and equipment
- Compliance with design and safety standards

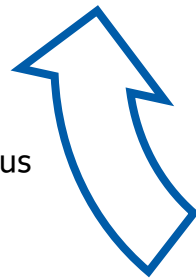
- **Examples:**

- Development of PSSR checklists for repeated processes AND escalation process
- Develop personal gas monitors calibration process, plan calibration equipment use and maintenance
- Ensuring operators are trained on new control systems before restarting operations

Project Execution Driven



Management & Continuous  
Improvement Driven



## Conduct of Operations (maintain safe operations)

**Purpose:** Ensures consistent, disciplined execution of tasks during ongoing operations.

- **Focus Areas:**

- Operational discipline and adherence to procedures
- Shift handovers and communication
- Monitoring and control of process parameters

- **Examples:**

- Using a checklist for startup and shutdown procedures
- Developing a clear and easy to follow approach to purging processes in and out of service
- Responding to alarms according to standard operating procedures (SOPs)

# Risk Based Process Safety - RBPS

How can we be sure we prepare and maintain safety?

- AcuTech recommended Process Safety Management (PSM) system
- 20 Elements of AIChE Center for Chemical Process Safety (CCPS) Risk Based Process Safety Management system
- Organized by 4 Pillars:
  - Commit to Process Safety
  - Understand Hazards & Risks
  - Manage Risk
  - Learn from Experience
- “Plan-Do-Check-Act”
  - Demming style continuous improvement & culture focused

AcuTech Model Process Safety Management System



Based on four underlying pillars supported by the 20 elements of the Center for Chemical Process Safety (CCPS) Risk Based Process Safety Model.

# RBPS Element Responsibility – Operations Perspective

## RBPS Elements – Management

- Safety Culture & Stakeholder Involvement
  - Commitment to Process Safety
- Competence & Workforce Involvement
- Management Review & Continuous Improvement
  - Operational Readiness
  - Conduct of Operations
  - Decommissioning
- Auditing

*Pillars: Commit to Process Safety & Learn from Experience*

## RBPS Elements – Prior to Operations

- Hazard Identification and Risk Analysis
- Compliance with Standards
- Operational Readiness (prepare)

*Pillar: Understand the Hazards and Risks*

## RBPS Elements – Operations

- Conduct of Operations (maintain)
  - Emergency Management
  - Operating Procedures
  - Safe Work Processes
  - Management of Change
  - Contractor Management
  - Asset Integrity and Reliability
  - Measurement and Metrics
  - Incident Investigation
  - Training and Performance Assurance
  - Process Knowledge Management

*Pillar: “Manage the Risk”*

- Decisions regarding RBPS elements occur prior to Operations Phase
- Operations and Management share ongoing responsibilities
- The PSSR is the end of preparing for operations, not the starting point

# Safety Opportunities in Concept & Funding Phase

| Project Phase     | Safety “Tools”                                                                                                                                                                         | Relationship to Operations                                                                                                                                                              |
|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Concept & Funding | <ul style="list-style-type: none"><li>• Project Risk Assessment, Hazard Identification (HAZID)</li><li>• Simple compliance assessment</li><li>• CHS Safety Planning Guidance</li></ul> | <ul style="list-style-type: none"><li>• Overall site safety and security expectations</li><li>• Process safety and performance expectations</li><li>• Compliance requirements</li></ul> |

Goal: Concept and Funding efforts evaluate the project viability

If a project risk assessment process is conducted, then:

- Worst case scenarios identified
  - informs **Emergency Management**
  - identifies **Stakeholders**
- Process safety and performance expectations established
  - establishes **Safety Culture** expectations and **Commitment to Process Safety**
  - establishes **Management Review and Continuous Improvement** expectations

BTW: Lack of commitment  
is still a communication of  
commitment

# Safety Opportunities in Engineering & Permitting Phases

| Project Phase           | Safety “Tools”                                                           | Relationship to Operations                                                                                                                   |
|-------------------------|--------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| Detailed Design & Engr. | Process Hazard Assessment (HAZOP, QRA, etc.)                             | <ul style="list-style-type: none"><li>• Identification of safety critical components</li><li>• Process actions and procedure steps</li></ul> |
| Permitting              | Detailed compliance assessment<br>Quantitative risk analysis (as needed) | <ul style="list-style-type: none"><li>• Detailed compliance information</li><li>• Detailed site &amp; process safety and security</li></ul>  |

Goal: Engineering efforts establish design and operational intentions

If a Process Hazard and compliance assessments are conducted, then:

- Criteria for **Operational Readiness** are established (maint intervals, fluids, layout, etc.)
- Critical process safety components are identified which:
  - inform **Operating Procedures** and
  - provide inspection testing and preventive maintenance information for **Asset Integrity & Reliability**
- **Process Knowledge Management** processes are established (engineering document and project archive)
- Project may elect to establish **Management of Change** process for FEED, Construction and Commissioning

# Safety Opportunities in Construction Phase

| Project Phase | Safety “Tools”                                                                                                | Relationship to Operations                                                                                                                          |
|---------------|---------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| Construction  | Contractor Safety Program<br>Safe Work Processes (Permits, Hot Work, LOTO)<br>Change Management (Project MOC) | <ul style="list-style-type: none"><li>• As built process safety information</li><li>• Contractor safety and work permit program templates</li></ul> |

Goal: Construct the planned process and record changes

If safety management continues during Construction efforts, then:

- Processes for **Contractor Safety** and **Safe Work Processes** are established
- Project may elect to establish **Management of Change** process for FEED, Construction and Commissioning

# Summary of process safety management opportunities

## Project Phase Activities

### Concept and Funding Phase:

- Safety Plan, Project Risk Assessment, HAZID
- Compliance Assessment
- Management reviews (funding consideration and approval)

### Engineering Phase:

- Process Design Documentation
  - P&ID, Bill of Materials, Controls Narrative
- Equipment Design and Operations Documentation
  - User Manual, Troubleshooting, Repair instructions, Spare Parts lists
- Process Hazard Assessment

### Construction Phase:

- Construction contractor management
- Construction change management
- Construction safe work processes

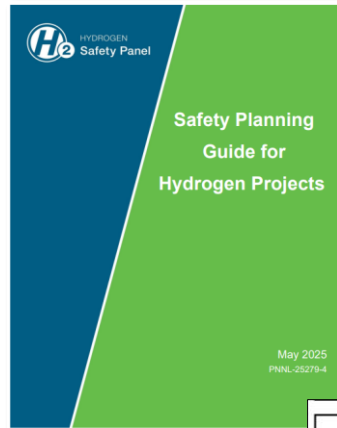
## RBPS Element Opportunities

Commitment to Process Safety  
Emergency Management  
Stakeholder Engagement  
Management Review and Continuous Improvement

Process Knowledge Management  
Asset Integrity and Reliability Management  
Operating Procedures

Contractor Management  
Management of Change (MOC)  
Safe Work Processes

# Commissioning – PSSR – Operational Readiness



## Safety Planning for Hydrogen and Fuel Cell Projects

| Manage Operations | Approach                          | Examples of Actions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|-------------------|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                   | Establish and document procedures | <input type="checkbox"/> Responsibilities for each of the parties involved.<br><input type="checkbox"/> Operating procedures.<br><input type="checkbox"/> Emergency procedures.<br><input type="checkbox"/> Preventive maintenance schedules for equipment services, sensor calibrations, leak checks, etc.<br><input type="checkbox"/> Safe work practices such as lock-out/tag-out, hot work permits, and hydrogen line purging.<br><input type="checkbox"/> Review and approval of design and procedural changes. |
|                   | Train personnel                   | <input type="checkbox"/> MSDS awareness for hydrogen and other hazardous materials.<br><input type="checkbox"/> Applicable procedures and work instructions for bottle change-out, deliveries, operation, maintenance, emergencies, and safety work practices.                                                                                                                                                                                                                                                       |
|                   | Monitor                           | <input type="checkbox"/> Track incidents and near-misses, and establish corrective actions.<br><input type="checkbox"/> Monitor compliance to all procedures and work instructions.                                                                                                                                                                                                                                                                                                                                  |

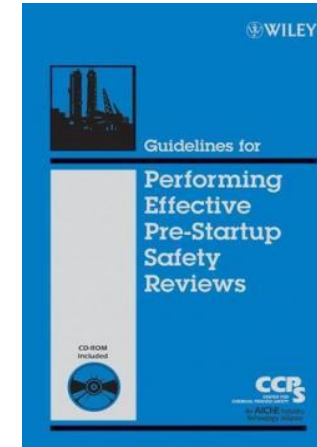
## Operational Readiness

### *How does the project ensure it is safe to begin hydrogen operations?*

The project team should evaluate and document the organizational tools used to formally ensure that the HIRA and all safety action items have been completed and implemented using checklists or a more formal independently-reviewed process. The readiness review should ensure that MOC has been properly addressed for any changes that might impact HIRA results.

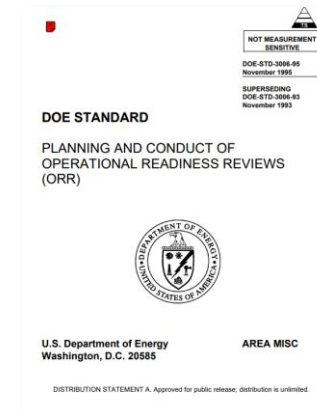
A formal operational readiness process should include an authorized and trained reviewer/approver, and results documented and maintained in project records.

*DOE has published a thorough operational readiness standard that can be applied to any project on a graded approach: "Planning and Conduct of Operational Readiness Reviews (ORR)," DOE-STD-3006-95.*



## Introduction to Operational Readiness | AIChE

## Guidelines for Performing Effective Pre-Startup Safety Reviews | AIChE



## DOE-STD-3006-95; DOE Standard Planning and Conduct of Operational Readiness Reviews (ORR)

# Conduct of Operations

**Goal:** Adaptable and resilient systems that go beyond compliance

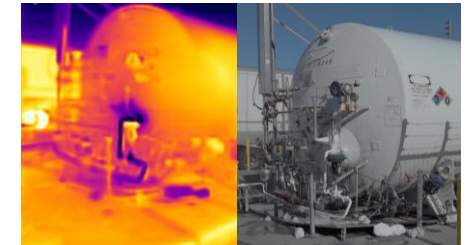
Resources: [Lessons Learned | H2tools | Hydrogen Tools](#) & [Introduction Conduct of Operations | AIChE](#)

Topics to consider:

- Emergency, Maintenance & Operating Procedures
  - Resources: competent staff, proper tools & a sense of vulnerability
  - Purging procedures, site visitor procedure, fuel quality testing
  - Consider adverse working conditions & natural disasters
- Competence and Workforce involvement
  - Establish competency requirements – **H2 Credential**
  - MOC, PSSR and Safe Work Permit processes
- Training and Performance Assurance
  - Develop training, validation and recordkeeping
- Measurement and Metrics
  - Establish performance metrics, recordkeeping and reporting
  - MOC, PSSR, Safe Work Permit, Action Item workflow efficiency
- Incident Investigation
  - Establish leak criteria for characterization and reporting
- Audit & Management Review
  - Self audit and action item recordkeeping
  - Management Review & Continuous improvement



[Credential in  
Hydrogen Safety |  
AIChE](#)



Example Thermal Image of LH2 tank –  
phone attachment



Example of adverse conditions –  
recovery from snowstorm at HRS



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