Approach – Composite Data Products

Bundled data (operation & maintenance/safety) delivered to NREL quarterly

Internal analysis completed quarterly

Detailed Data Products (DDPs)
- Individual data analyses
- Identify individual contribution to CDPs
- Only shared with partner who supplied data every 6 months\(^1\)

Composite Data Products (CDPs)
- Aggregated data across multiple systems, sites, and teams
- Publish analysis results without revealing proprietary data every 6 months\(^2\)

1) Data exchange may happen more frequently based on data, analysis, and collaboration
2) Results published via NREL Tech Val website, conferences, and reports
Infrastructure consistently delivering 250 and 350 bar fills even though the majority of the sites have a MTBF of 25 days or less.
MISC includes the following failure modes: ambient temperature too low, broken wire, cavitation, debris infiltration, failed closed, flow high, flow low, fluid leak, non-hydrogen, inspect trouble alarm or report, maintenance error, manufacturing defect, metal fatigue, moisture infiltration, network malfunction, operator protocol, other, pressure high, software bug, vandalism, voltage low, other.

* Percentage of total events or hours, reference CDP 66.
Hydrogen Compressor Failures By Mode

Classified Events = 137
98% unscheduled
5%

17%
21%
26%
14%
9%
9%

Total Hours = 1,572
97% unscheduled

12%
36%
14%
7%
12%
22%

MISC includes the following failure modes: cavitation, debris infiltration, failed closed, flow high, manufacturing defect, moisture infiltration, operator protocol, preventative maintenance, maintenance error, upgrade, replace failed parts, other

Event Count
Hydrogen Leaks - Detailed

Hydrogen Leaks By Equipment Category: Infrastructure

- **Classified Events = 49**
  - 100% unscheduled
- **Total Hours = 442**
  - 100% unscheduled

- **16%**
- **18%**
- **6%**
- **6%**
- **6%**
- **47%**

- **hydrogen compressor**
- **fittings&piping**
- **dispenser**
- **valves**
- **seal**
- **reformer**

misc 0
classified events 49
Approach – Process Hazard Analysis

- A PHA was conducted for the installation of 2nd H₂ fueling station at NREL (Internally funded)
- Hazards were identified by NODE and analyzed for SEVERITY, LIKELIHOOD to obtain the overall RISK (H, M, L, R)

<table>
<thead>
<tr>
<th>SEVERITY</th>
<th>Category</th>
<th>Descriptive Word</th>
<th>A Frequent</th>
<th>B Reasonably Probable</th>
<th>C Occasional</th>
<th>D Remote</th>
<th>E Extremely Remote</th>
<th>F Impossible</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Catastrophic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>Critical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>Marginal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>Negligible</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LIKELIHOOD</th>
<th>A Frequent</th>
<th>B Reasonably Probable</th>
<th>C Occasional</th>
<th>D Remote</th>
<th>E Extremely Remote</th>
<th>F Impossible</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Frequent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B Reasonably Probable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C Occasional</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D Remote</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E Extremely Remote</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F Impossible</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PHA Weighted Results

- Each node was analyzed for process upset conditions (pressure high, flow low, etc...)
- In the context of safeguards, the consequences were ranked by SEVERITY and LIKELIHOOD to arrive at a RISK level
- High risks were weighted by 4, Medium by 3, and so on

<table>
<thead>
<tr>
<th>Node Description</th>
<th>RISK</th>
<th>Node Total Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Compressor</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hose</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Nozzle</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cascade Tanks</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Control Electronics</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Air System</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cryo Storage</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
RD&D Challenges

Compressor reliability (Cost)
  • Lifetime of diaphragms, CV and seals

Hose reliability (Safety, Cost)
  • Improve lifetime to avoid frequent hose replacement

Nozzle (Cost)
  • Lifetime of diaphragms, CV and seals
More information available

- www.nrel.gov/hydrogen/proj_tech_validation.html
- or search for “NREL CDP”