Results from RBMI Workshop

London
29-30th January 2004

Sub-task 2.4: Health Environment and Safety (HES)

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Sub-task 2.4: objectives (recap)

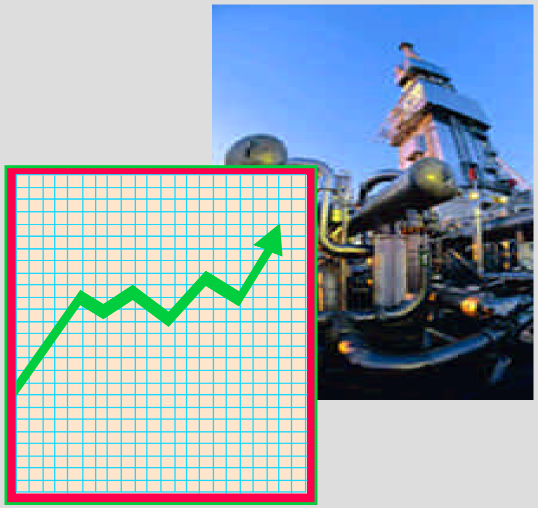
- Apply a risk based method to develop input to maintenance and inspection guidelines for a generic hydrogen refuelling station

Risk Based Maintenance & Inspection

- The RBMI method is based on the philosophy that maintenance efforts should be focused on items that constitute the largest risk
- Risk is considered to be dependent on probability and consequence of failures, where consequences may be
  - Additional costs or lost income
  - Potential injuries
  - Environmental emissions

Risk Based Maintenance & Inspection

- Optimise resources needed to operate, inspect, maintain and improve installations
- Do not compromise on safety, reliability or environmental standards.



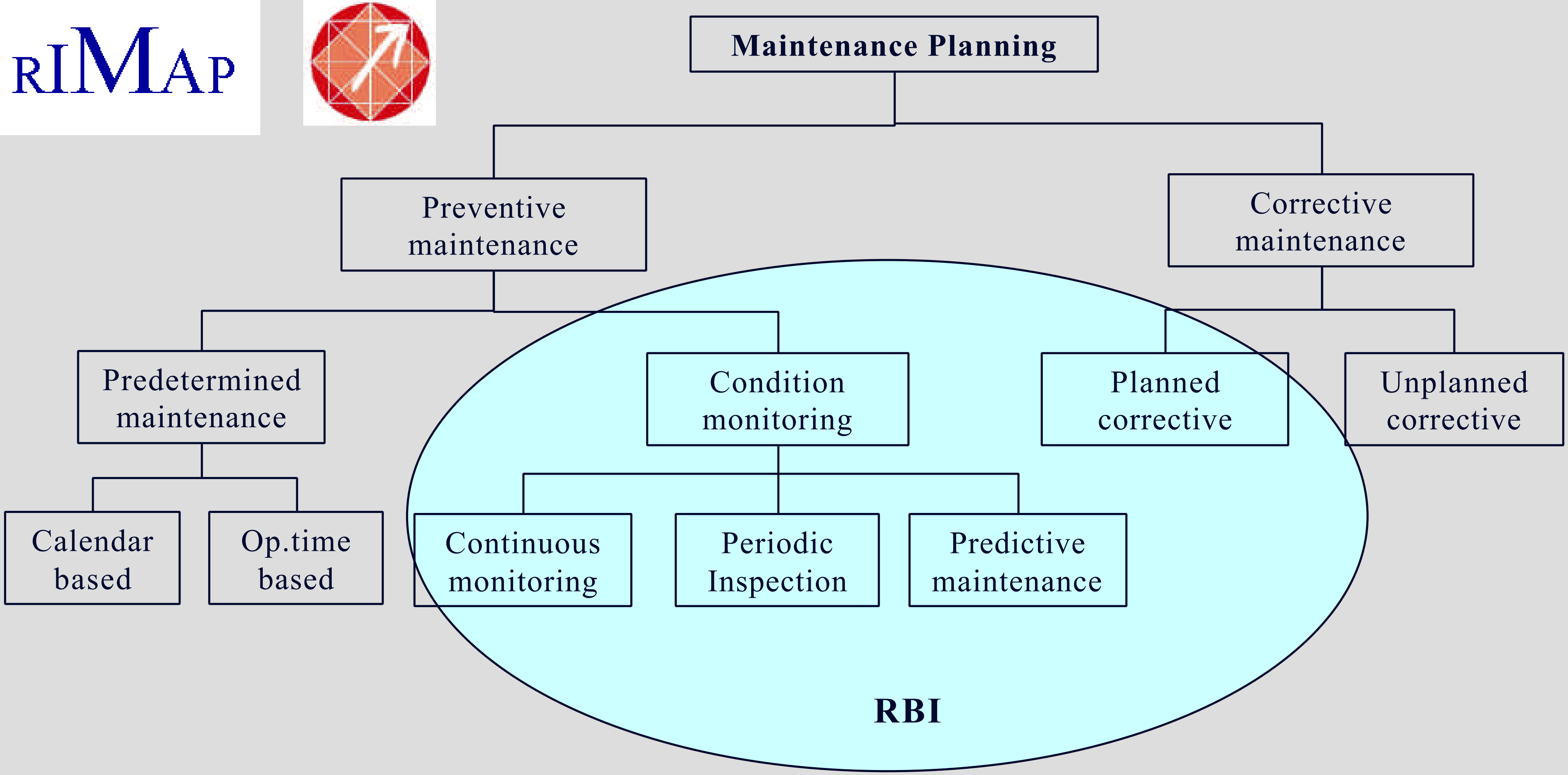
Link: The EU project RIMAP (2001-2004)

- **Objective:**
  - To develop a unified approach for making risk based decisions within inspection and maintenance planning.
- **Main deliverables:**
  - A guideline for developing and maintaining a risk based inspection and maintenance plan.
  - Industry specific workbooks for the **steel, chemical, power** and **petrochemical industry**.
  - The technical basis for a future European standard in this area.
- **Partners:**
  - **DNV (Co-ordinator),** BV, Corus, DOW, ESB (Ireland), EnBW, ExxonMobil Chemical, Hydro Agri, JRC-Petten, MBeL, MPA, Siemens, Solvay, TNO, TÜV Süddeutschland, VTT
- **For more:**

  http://research.dnv.com/rimap

RIMAP

Maintenance Planning

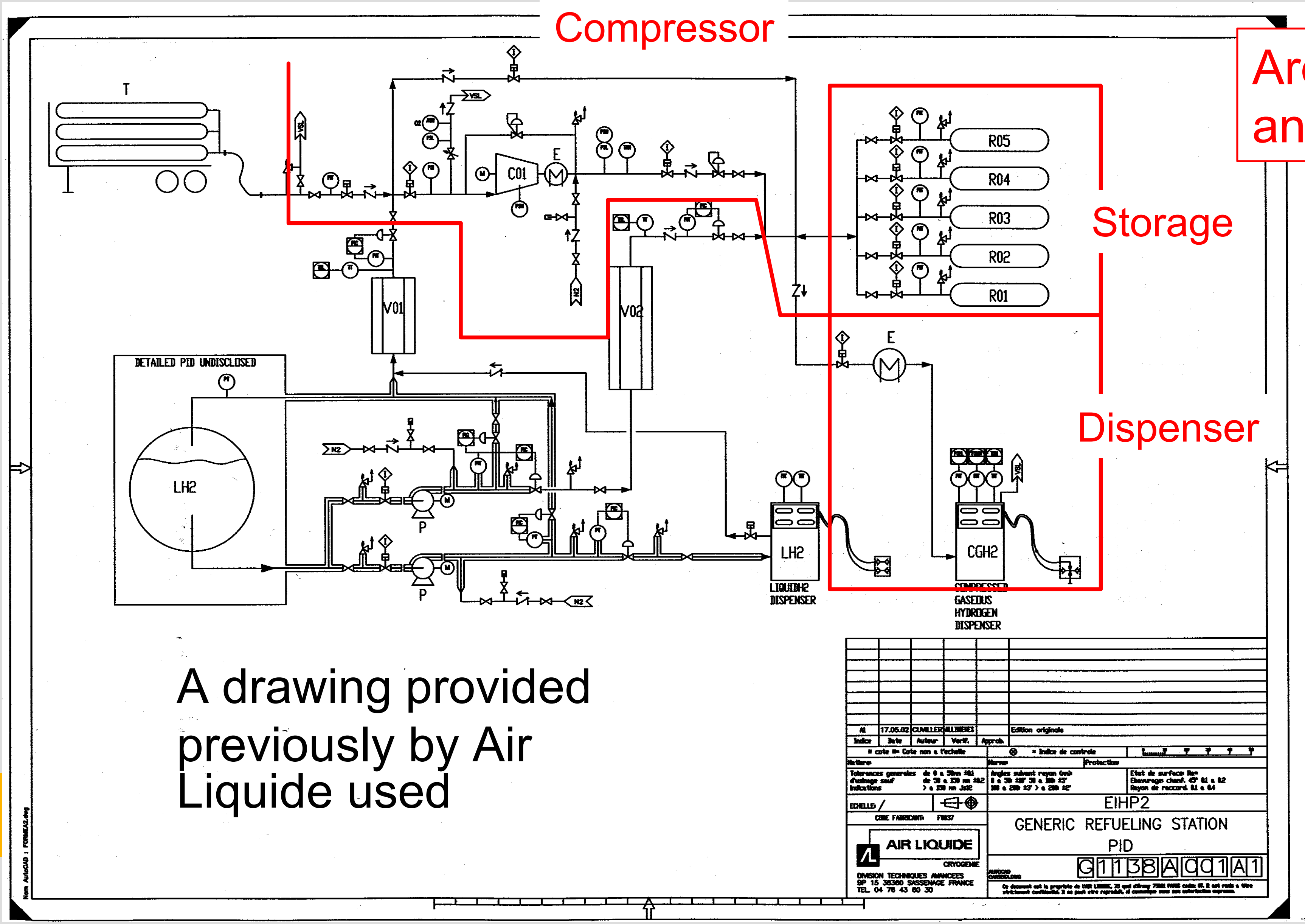


WP 2.4 Workshop 19-20th January, Høvik

- The exercise:
  - RBMI on generic hydrogen refuelling station based on WP5.2
  - Risks associated with malfunction of each of the individual components of the refuelling station.
  - Some guidance on focus for maintenance efforts tfor an acceptable level of safety and operational reliability in a cost effective way.

- Participants were:
  - Peter Newboult (Air Products)
  - Pål Kittilsen (Norsk Hydro)
  - Angunn Engebø (DNV)
  - Madeleine Brien (DNV)
  - Mikael Hägerby (DNV)

Generic Refueling Station



A drawing provided previously by Air Liquide used

Approach for RBMI: FMEA

- Failure Modes and Effects Analysis - a qualitative analysis that systematically examines each possible failure mode within a system.
- Failure modes of components are studied:
  - Probability of occurrence
  - Consequence
  - Prevention/detection
- Preventative actions may then be identified and prioritised

Consequence levels (ref. WP 5.2)

Level	Description	Definition		
		People	Environment	Material damage
1	CATASTROPHIC	Several fatalities	Time for restitution of ecological resource such as recreation areas, ground water >5 years	Total loss of station and major structural damages outside station area
2	SEVERE LOSS	One fatality	Time for restitution of ecological resource 2 - 5 years	Loss of main part of station. Production interrupted for months.
3	MAJOR DAMAGE	Permanent disability Prolonged hospital treatment	Time for restitution of ecological resource < 2 years	Considerable structural damage Production interrupted for weeks
4	DAMAGE	Medical treatment Lost time injury	Local environmental damage of short duration < 1 month??	Minor structural damage Minor production influence
5	MINOR DAMAGE	Minor injury Annoyance Disturbance	Minor environmental damage	Minor

Probability levels (ref. WP 5.2)

Level	Description	Definition	Frequency
A	IMPROBABLE	Possible, but may not be heard of, or maybe experienced world wide.	About 1 per 1000 years or less
B	REMOTE	Unlikely to occur during lifetime/operation of one filling station	About 1 per 100 years
C	OCCASIONAL	Likely to occur during lifetime/operation of one filling station	About 1 per 10 years
D	PROBABLY	May occur several times at the filling station	About 1 per year
E	FREQUENT	Will occur frequently at the filling station	About 10 per year or more.

Risk Matrix (ref. WP 5.2)

		PROBABILITY (per year)				
		A (<0.001)	B (0.01-0.001)	C (0.1-0.01)	D (1-0.1)	E (10-1)
Consequence severity	1 (Catastrophic)	H	H	H	H	H
	2(Severe loss)	M	H	H	H	H
	3 (Major damage)	M	M	H	H	H
	4 (Damage)	L	L	M	M	H
	5 (Minor damage)	L	L	L	L	M

Results

➢ Based on the risk corresponding to each component and the redundancy available, three different maintenance intervals were proposed:

- **Frequent maintenance-**
  - (High risk) routine process by operators, which could be even more often than manufacturer recommendation.
- **Regular maintenance-**
  - (Medium risk) reflects the frequency of use or wear on the equipment and at a minimum meets manufacturer requirements.
- **Intermittent maintenance-**
  - (Low risk) Maintenance meets manufacturer requirements but the frequency of interventions reflects consequence of equipment failure and frequency of use.

Results

- Maintenance actions and intervals were identified for every component or type of component (in the examined filling station)

	Frequent	Regular	Intermittent
Components	5	14	8

- The dispensing unit constitutes the greatest risk for two reasons:
  - Frequent public use and maltreatment (human error)
  - Likelihood of someone being in the vicinity upon failure

Comments

- Study Limitations:
  - Appropriate time to examine detailed design component by component
  - Examined one “generic” design
  - Component detailing not uniform

Conclusions

- Provided input to WP2.3 on issues related to inspection and maintenance.
- The main focus was on CGH2 compressor, storage and dispenser system.
- Issues related to on site hydrogen production and LH not covered.
- The results obtained in WP5.2 used as input.

Conclusions

- The RBMI approach is feasible for refueling stations, but…
  - Analysis should be installation-specific
  - More detailed maintenance procedures should be included

- The time required for a detailed and complete analysis for a specific location therefore will exceed what was spent in this workshop exercise under WP 2.4

Conclusions

- Maintenance scheduling should consider manufacturer recommendations along with risk based findings
- Dispenser system most critical. To be operated by trained users. Training users can reduce risks.
- It is recommended to develop a best industry practice (code) for RBMI of refueling stations based on a more complete and validated study. EIHP3 ?
- DNV Report No. 2004-0114 issued for comments. Main comments received are now included.