Health and Safety
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HSE

Recognising and managing the risks from hydrogen in conventional and nuclear workplaces

Gordon Newsholme

Peter Donnelly

Presentation overview

- Duties under law
- Hydrogen hazards in conventional workplaces
- Managing the risk
- **H_2 in the nuclear sector**
- Incidents at nuclear sites
- Learning
- Sources of advice and guidance
- Questions

H_2: a hazard in the workplace – so what!!

The law holds certain parties accountable – *dutyholders*

Who are the main dutyholders?

Employers,

Managers,

Employees,

Manufacturers/suppliers,

Designers/consultants,

i.e. You !!!!!!!!

Overarching legal duty

To ensure that work activities do not adversely affect the health and safety of:

- Employees
- The general public

By reducing risk – “the likelihood of danger”

So far as is reasonably practicable

The H_2 hazard in conventional workplaces


LFL


EXIDE

Managing the risk

The ATEX hierarchy:

- Eliminate the risk, e.g. replace the dangerous substances
- Control the risk
  - Reduce the inventory of dangerous substances
  - Prevent flammable atmospheres forming
  - Avoid ignition sources
  - Control access
- Mitigate the risk
  - Reduce the number of people at risk
  - Provide explosion relief, suppression or containment

Avoid forming flammable mixtures

- Suitable containment
- Appropriate location/orientation of equipment
- Effective ventilation

Reduce the likelihood of ignition

- Carry out a hazardous area classification
- Locate electrical/mechanical sources in safe areas
- Use appropriate equipment in hazardous zones
- Use bonding, earthing and anti-static clothing
- Control hot work, smoking, mobile phones etc
- Consider protection against lightning

Mitigate the effect of an explosion

- Reduce the number of people at risk
- Contain the explosion
- Relieve the overpressure
- Suppress to progress of the explosion

Security and access control

- Security provisions should be appropriate to location
- Appropriate balance between ventilation & security
- Perception of Regulator is likely to exceed the real risk
- “Precautionary principle” should be used

The story so far

- You are responsible!
- People will get hurt if you are careless/incompetent
- People like you are key to the safe use of hydrogen

Embrace the learning,

meet the challenge!

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Hydrogen in nuclear workplaces

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The plants

Large plants with significant inventories of material
Variety of conditions
Variable operating histories

Sources of hydrogen

Radiolysis :-

Radiation + $H_2O \rightarrow H_2 + ½O_2$

Reactive Metals:- typically Corrosion

$M + xH_2O \rightarrow M(OH)_x + xH_2$

Are they really a problem?

Radiolysis - Brunsbuettel BWR

- Occurred 14th Dec 2001
- Investigated February 2002
- Reactor pressure vessel spray head pipeline within secondary containment
- 100 mm diameter pipe.

Radiolysis - Brunsbuettel BWR

3m long section lost.
Plant out of action for 12 months.
No activity released.

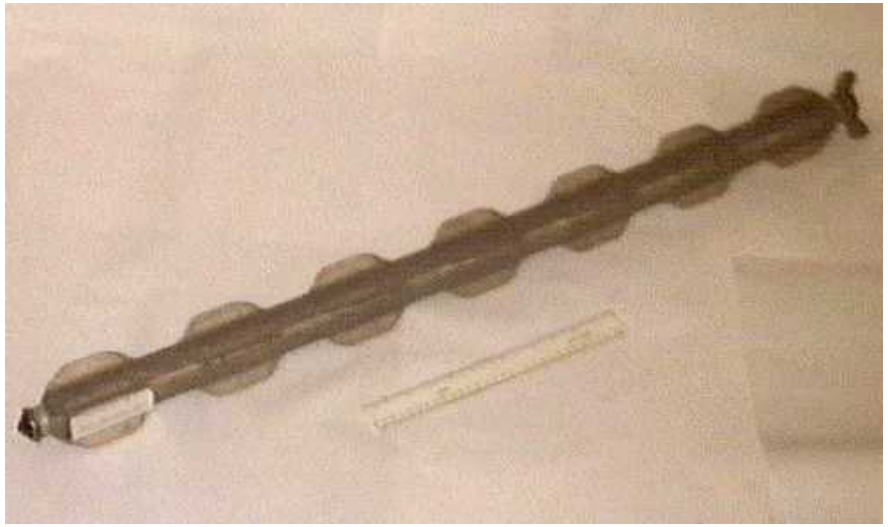
Corrosion issues

- Reactive metals are an issue

(Mg, Al, U, Na and K)

- The most significant of these is Mg.
- Mg is a significant component of Magnox fuel cladding.

Corrosion issues



Dungeness Magnox

Bradwell Magnox

Corrosion issues

Magnox corrodes

$Mg + 2\ H_2O \rightarrow Mg(OH)_2 + H_2 + \text{energy}$

Corrosion issues

Active Sludge

Corrosion issues

Energy released by corrosion in the form of heat.

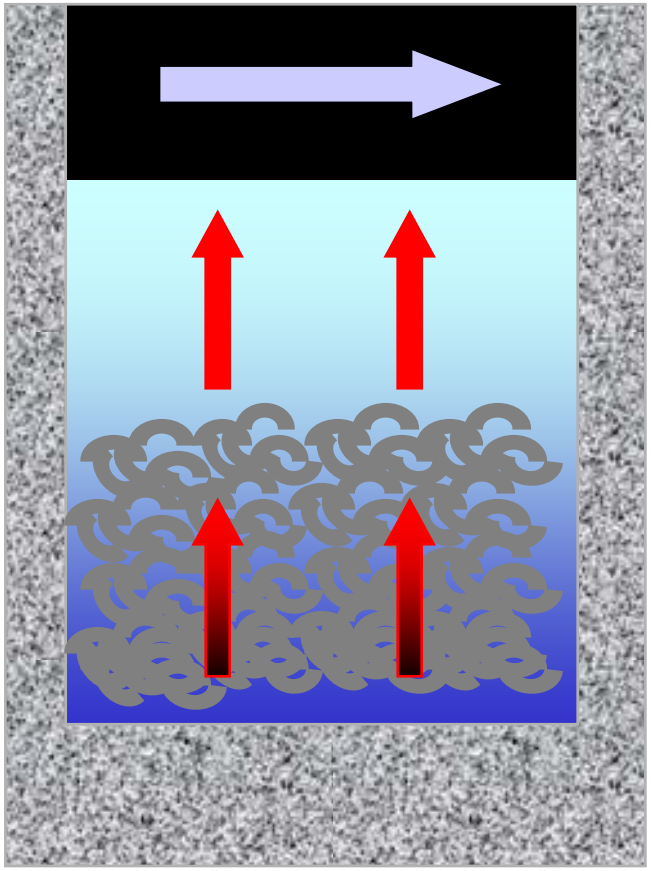
Corrosion of Magnox is temperature dependant – Rate doubles per 8-10°C increase above 22°C.

Magnox is a good conductor of heat away from corrosion point.

Magnesium Hydroxide is a good insulator.

Hotspots possible in the waste. - EXCURSIONS!

Excursions – normal corrosion

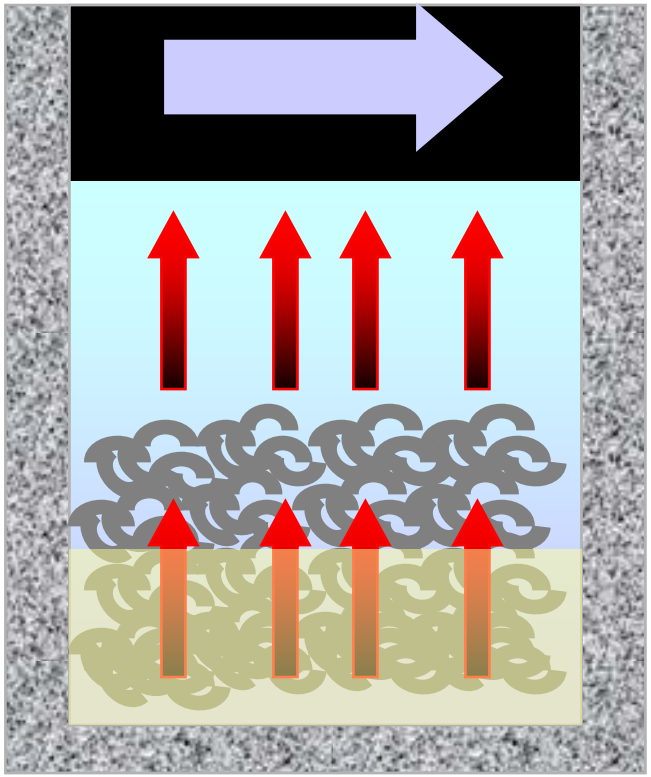


Heat removed by evaporation

Heat dissipated through cover water

Reaction produces heat

Excursions – corrosion progresses

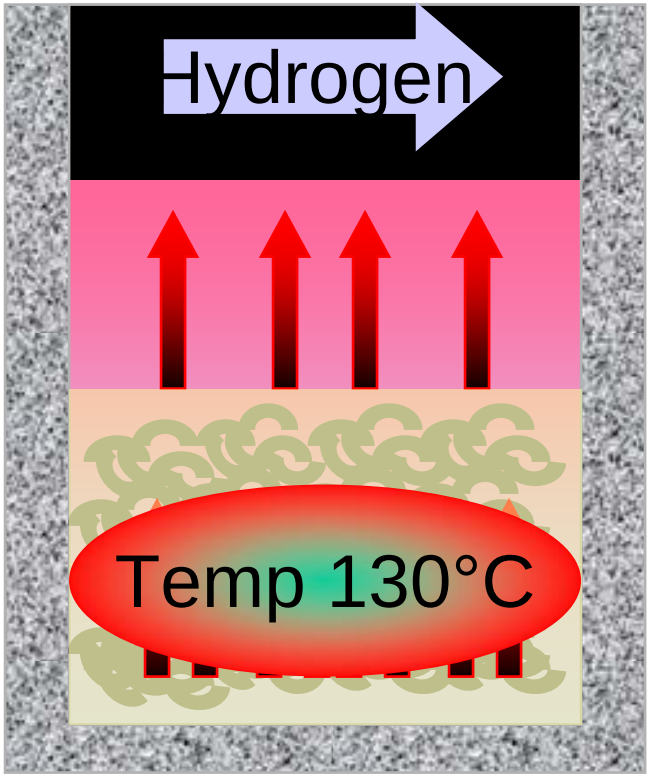


Heat output rises

Temperature rises

Sludge build up restricts heat loss

Excursions – the limit



High hydrogen concentration

Water reaches boiling point at depth

Sludge builds up further. Heat loss less than heat generated

Corrosion - Dounreay shaft

- 1959 – used to dispose of radioactive wastes, including sodium contaminated items.
- Shaft is wet owing to ground water ingress.
- 1971 – Other storage available so shaft use limited to unconventional items.

Corrosion - Dounreay shaft

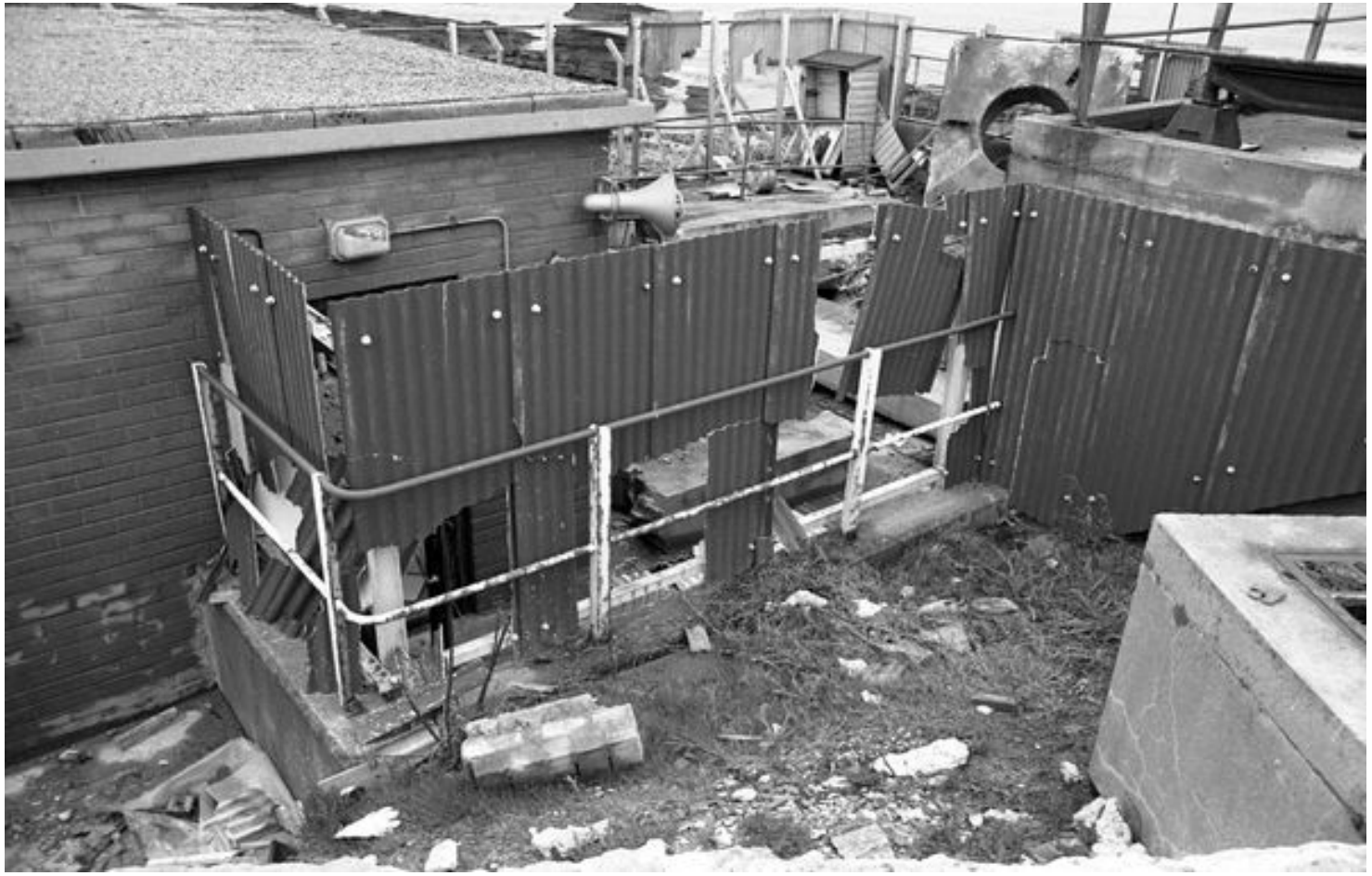
- Waste being loaded into shaft in 1960s

Corrosion - Dounreay shaft

- 10th May 1977 around 04.00
- Detonation in shaft
- Investigation considers Hydrogen explosion from Sodium – Water reaction to be the cause

Corrosion – Dounreay shaft

Corrosion – Dounreay shaft



Corrosion – Dounreay shaft

- No operators injured
- Ongoing monitoring and local community issues.
- Still have to recover the waste

Corrosion – Dounreay shaft

- Waste to be recovered
- Still possible hydrogen generation problems if disturbed.

Managing the issues

Principles similar to ATEX

- Eliminate
- Reduce
- Control
- Mitigate

- It can be difficult to do the first two points with existing hazards.

Managing the issues

- Manage using a hierarchy and multiple layers of protection
  - Redundancy
  - Diversity
  - Independence

Managing the issues

- Set operational and design Limits

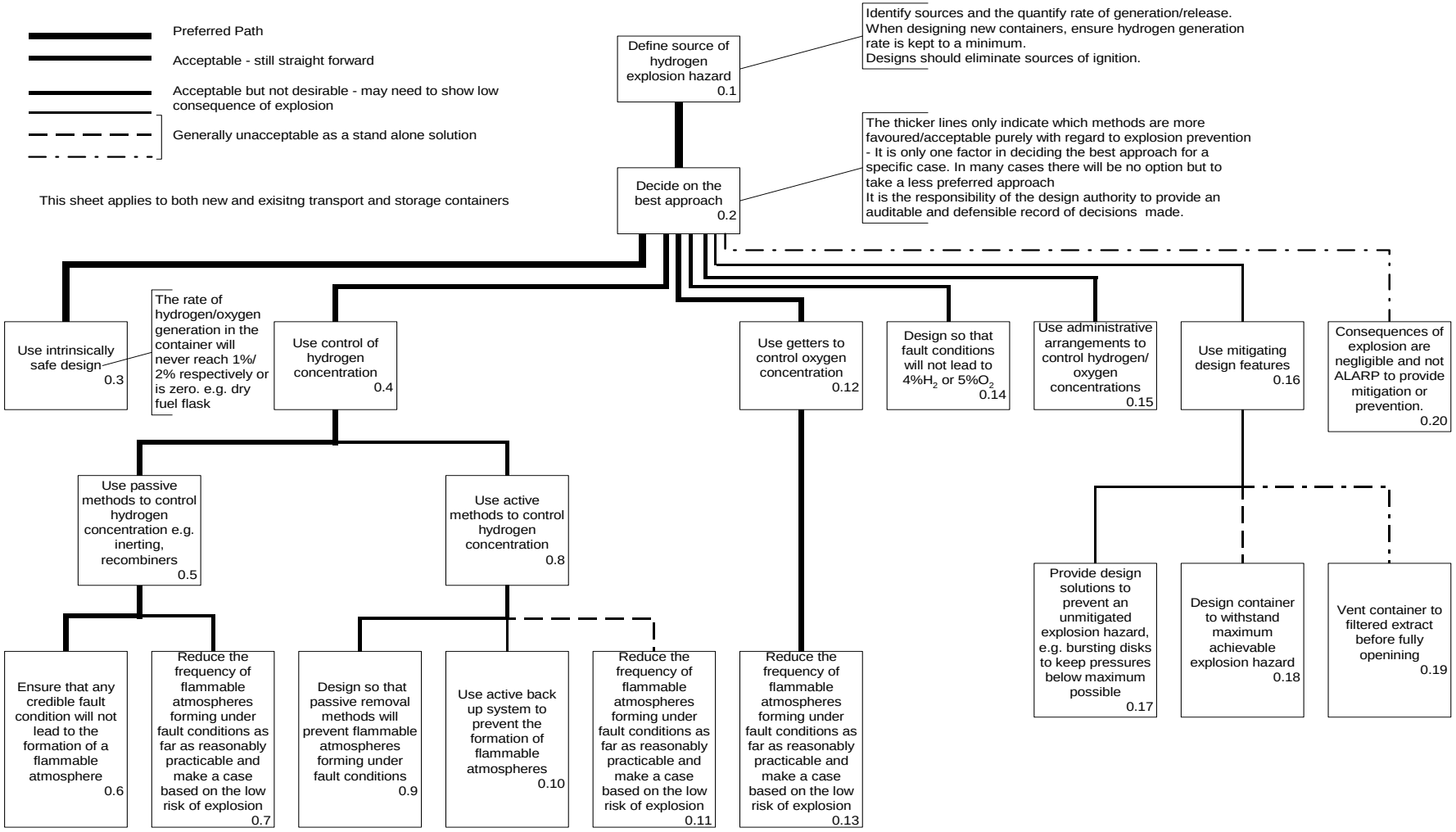
Typically:

< 1% H_2 normal operations

< 4% H_2 fault conditions

< 2% limiting O_2

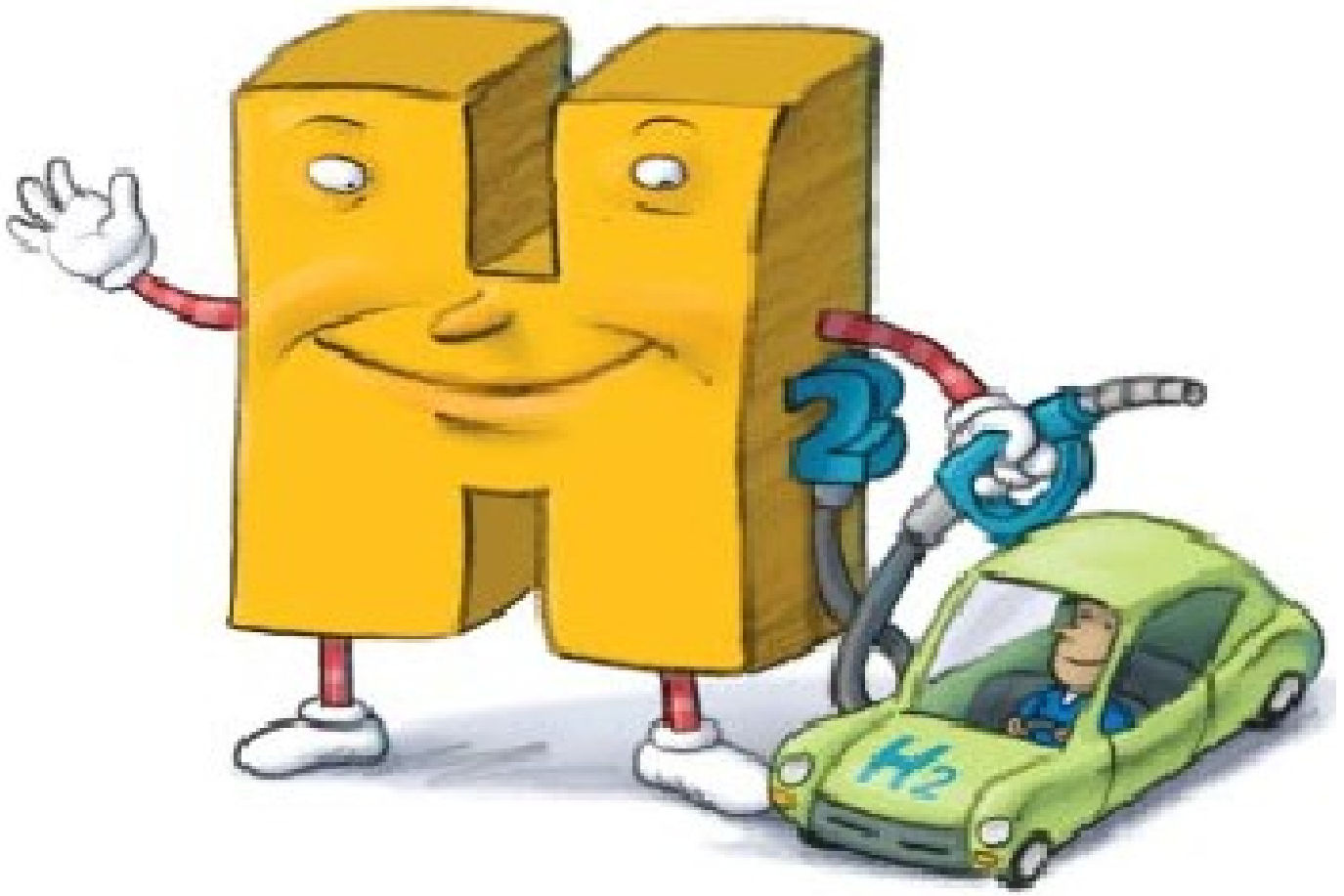
Managing the Issues



Information and guidance

- HSG 243: Fuel cells; understand the hazards, control the risks
- European Industrial Gases Assoc. (IGC Doc 15/05E)
- NASA (Safety std for hydrogen & hydrogen systems)
- ISO/DPAS 15916: Safety of hydrogen systems
- Installation permitting guidance for H_2 and fuel cell stationary applications (HSL RR715, 2009)
- HSE DSEAR ACOPs (L134-138 inc)
- BS EN 60079 Electrical app. for explosive gas atms

That’s all folks!



Questions?

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Acknowledgements

- Jem Sullivan: hydrogen man cartoon
- Fuel Cells Canada: selected images
- The Sellafield Ltd Hydrogen Technical Guide
- Sellafield Limited: Selected Images
- DSRL: Selected Images
- Mr P Vesey