GTEN 2021 Virtual Symposium

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Industrial Gas Turbine Test Facility; Present and New Engineering Challenges

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With special thanks to our numerous colleagues

Present Test Needs

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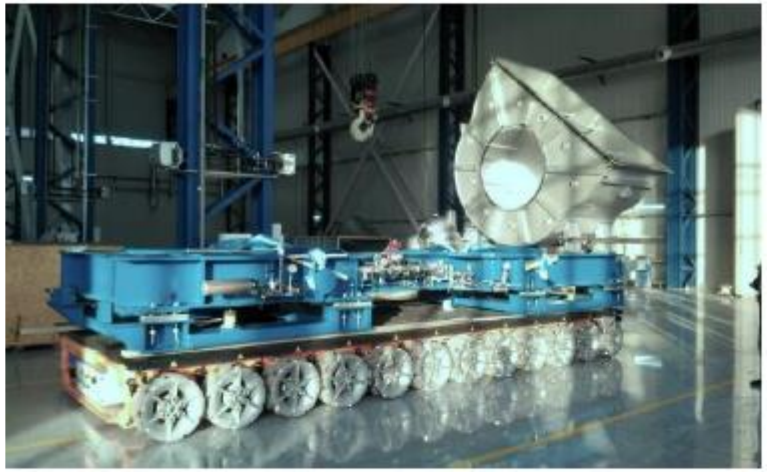
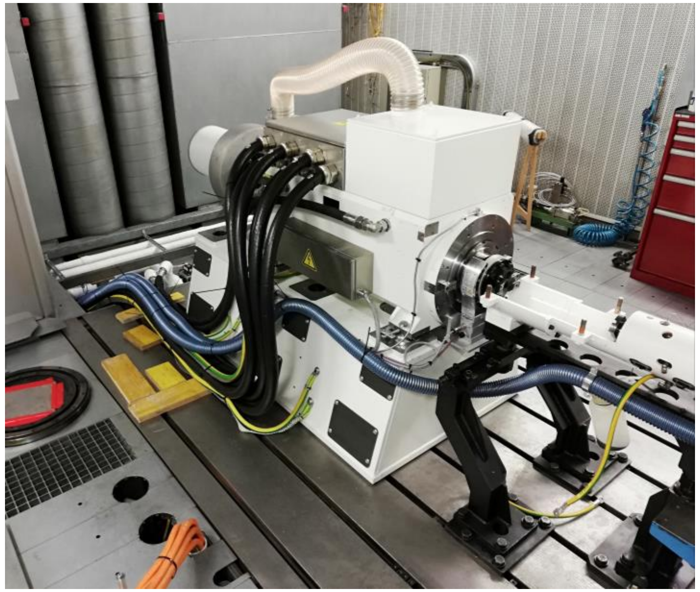
Present Test Needs

- Minimizing the time for engine setup



Present Test Needs

- Providing multi-engine capability



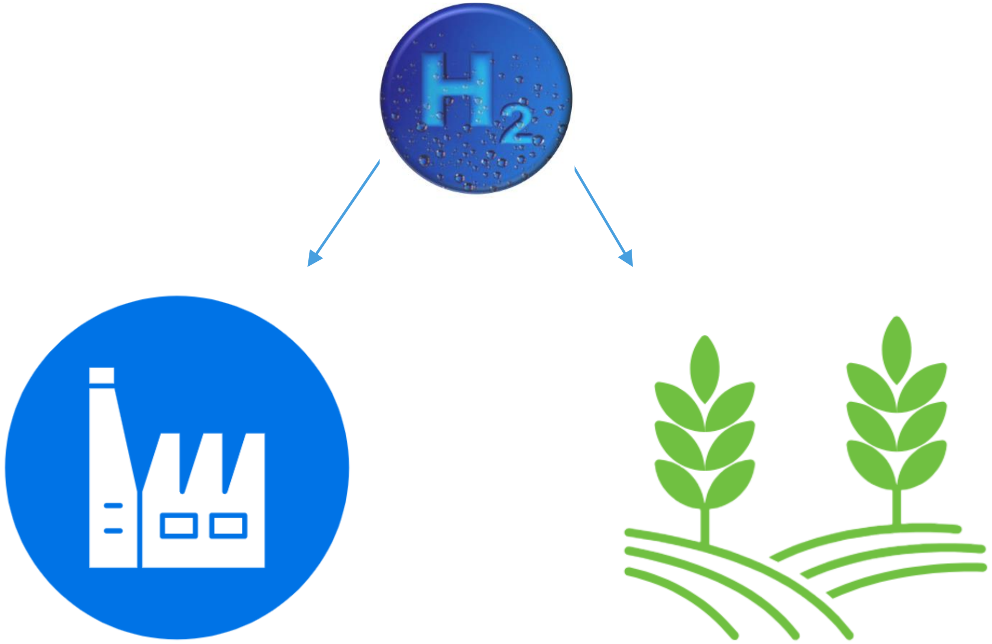
Present Test Needs

- Aero gas turbine test

Photo credit: Rolls-Royce

New Test Needs

We are preparing ourselves for a gas turbine test future which involves hydrogen fuel blends.



Retrofit of existing test facilities

New greenfield test facilities

Identification of hydrogen fuel delivery process

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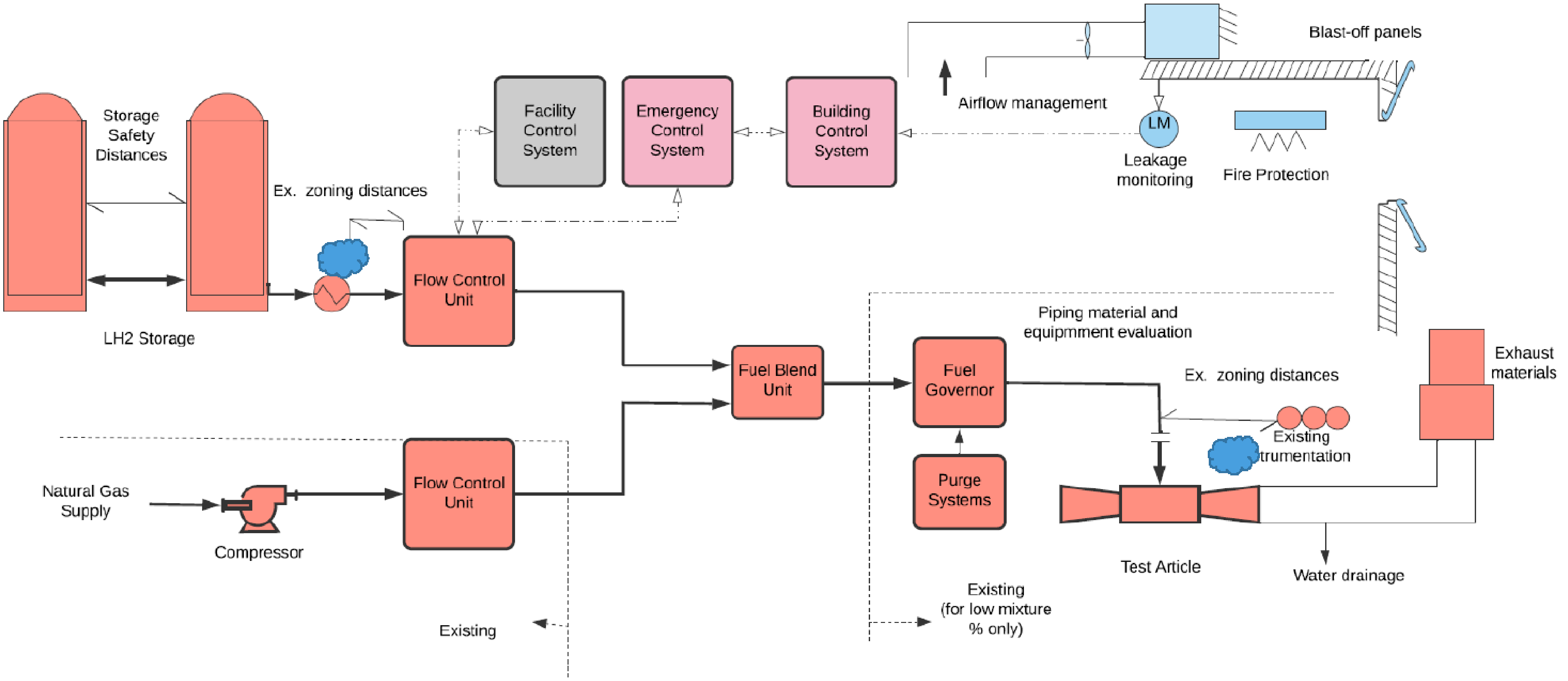
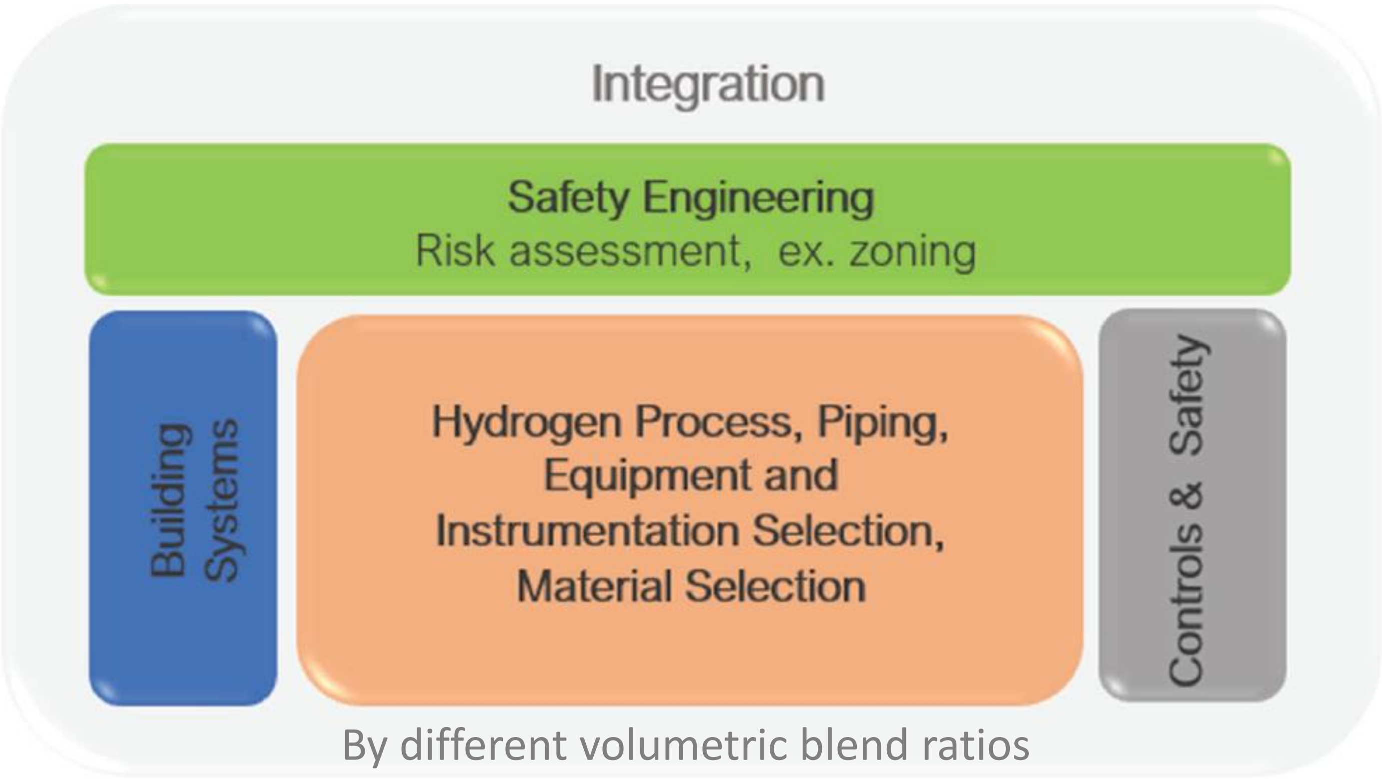


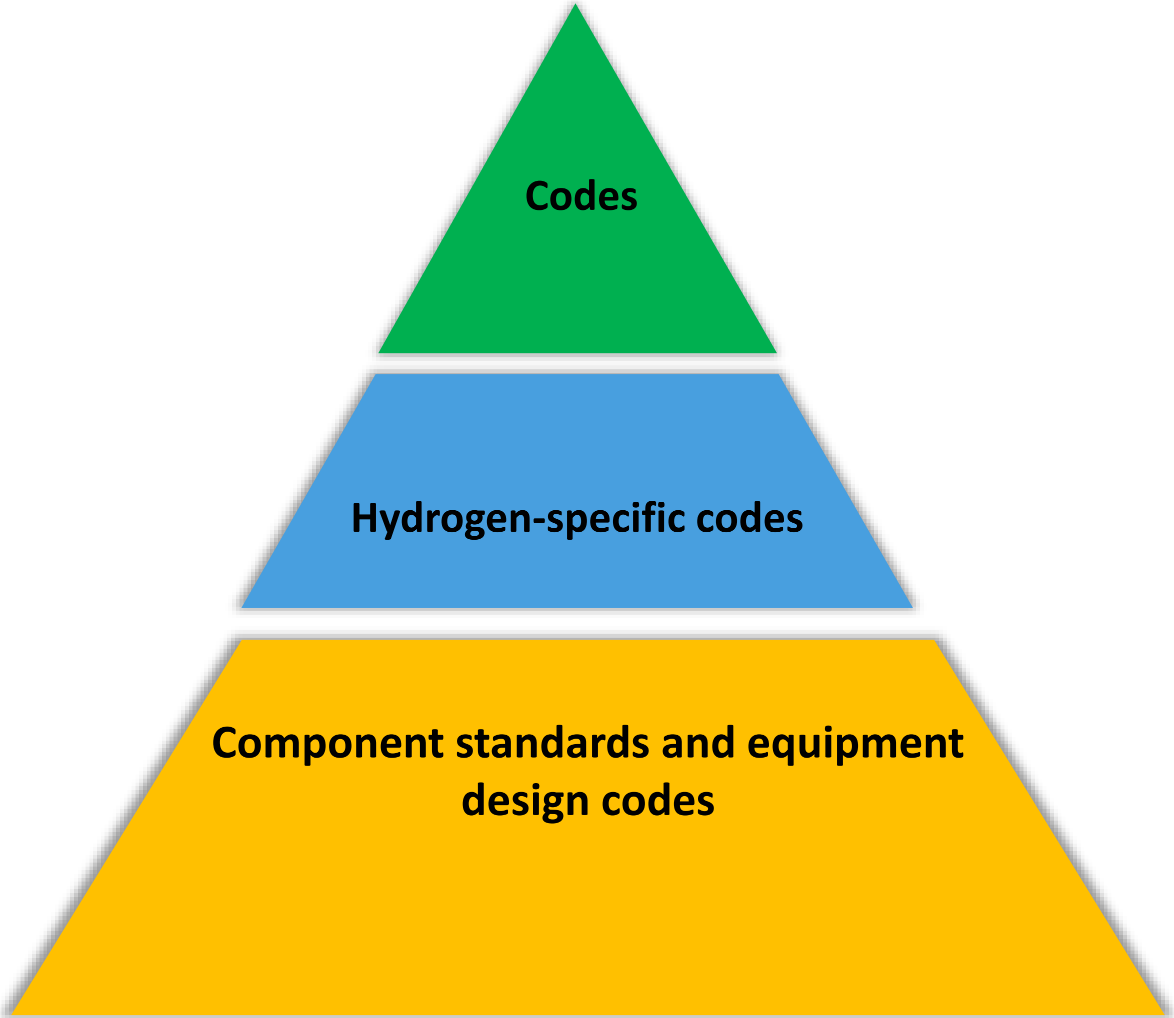
Safe Integration of Hydrogen Fuel

Safe Integration of Hydrogen Fuel



Safe Integration of Hydrogen Fuel

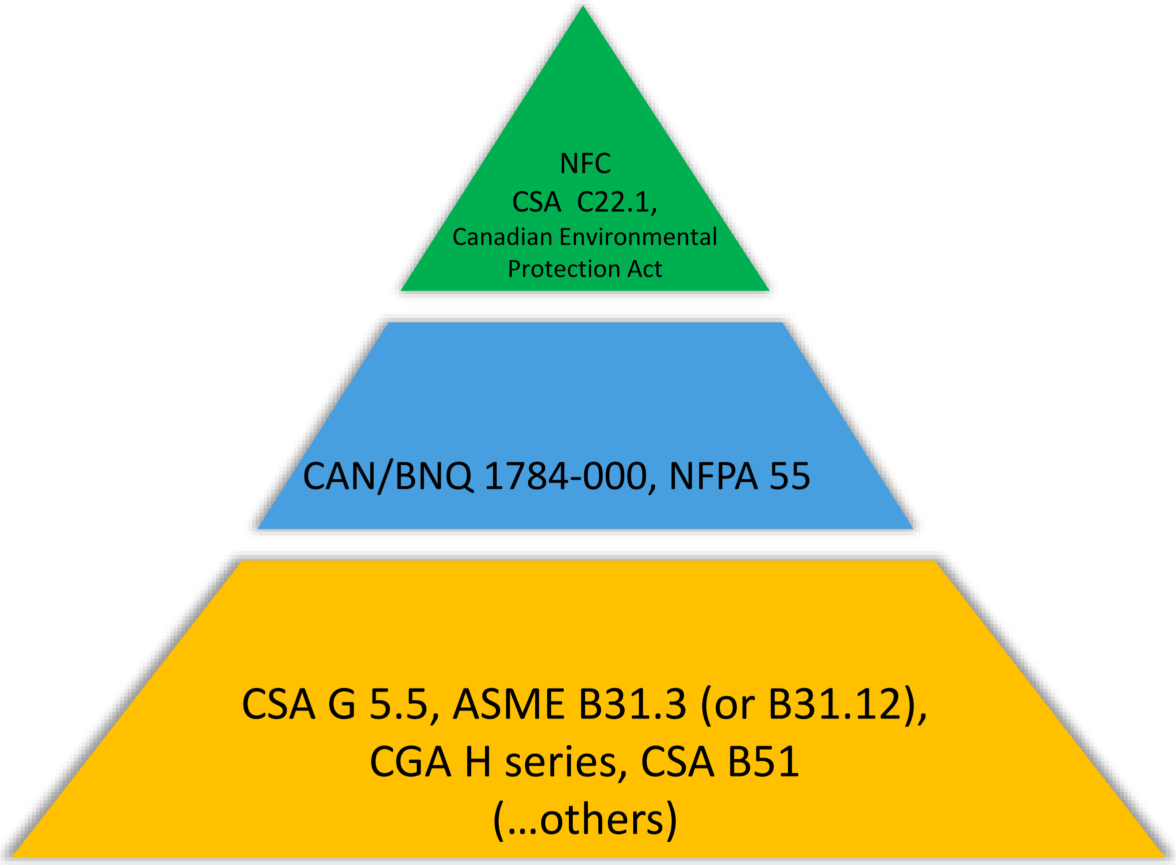
- Hierarchy of Canadian codes and standards



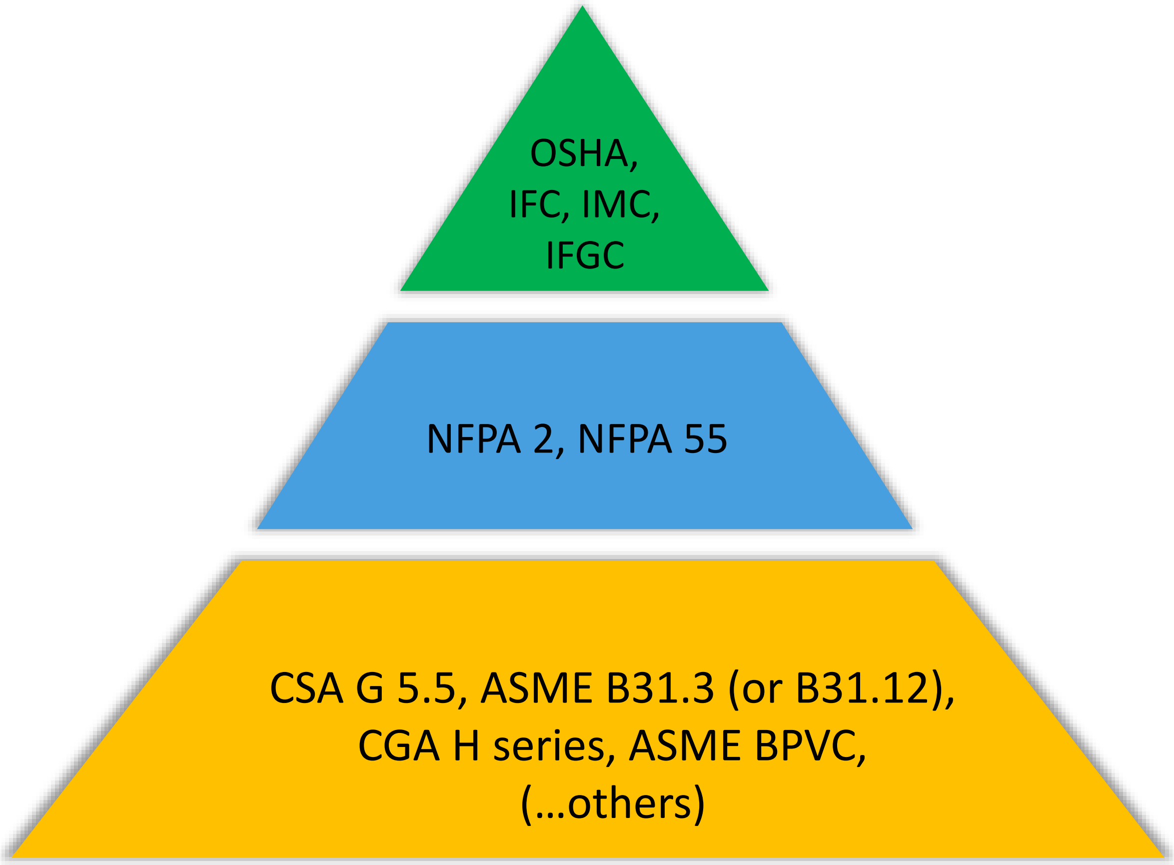
Safe Integration of Hydrogen Fuel

- Some relevant codes and standards

Canada

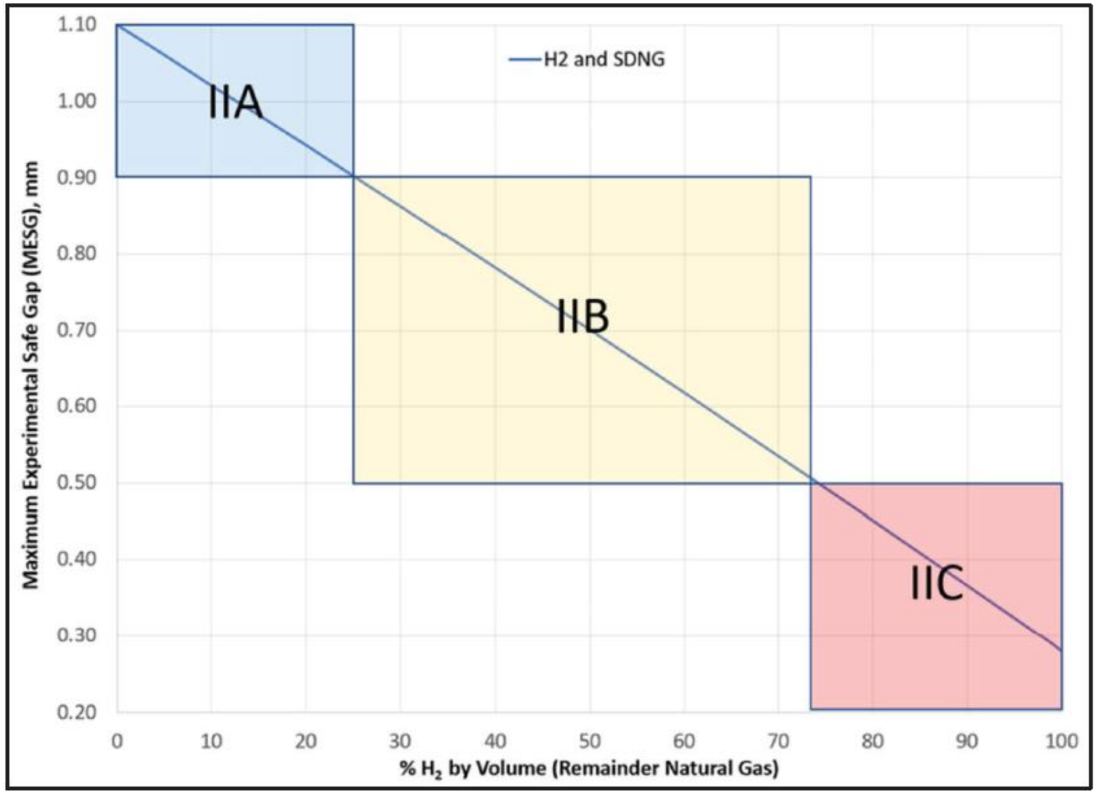


US



Safe Integration of Hydrogen Fuel

- Safety Engineering
  - Hazardous Area Classification



[11] Review of Hydrogen to Reduce Carbon Emissions (Presentation slides), Chris Lyons and Terry Tarver, Solar Turbines & International District Energy Association, 2020

Safe Integration of Hydrogen Fuel

- Safety Engineering (NFPA 2 and NFPA 30)
  - Storage Safety Distances (for US)

Outdoor Storage Type and Volume	Indoor Storage Allowed?	Minimum Distance to Place of Public Assembly	Minimum Distance to Sprinkled combustible building or structure
TK-201: Liquid Hydrogen, Outdoors, Bulk 12m^3	No	23 m	15 m
TK-101: Gas Hydrogen, Outdoors, Bulk 20m^3 @700Bar, or 34,000 scf	No, unless detached building with special requirements	4-6 m	4-6 m
Jet-A Fuel 12m^3	Yes, with special requirements	1.5 m to street alley or public way	8 m to property line that is or can be built upon

Safe Integration of Hydrogen Fuel

- Safety Engineering
  - Deflagration and deflagration prevention (NFPA 68 & 69)

Table 26: Fundamental burning velocity*

Gas	Fundamental Burning Velocity (cm/s)
Methane (Natural Gas)	40
Propane	46
Hydrogen	312

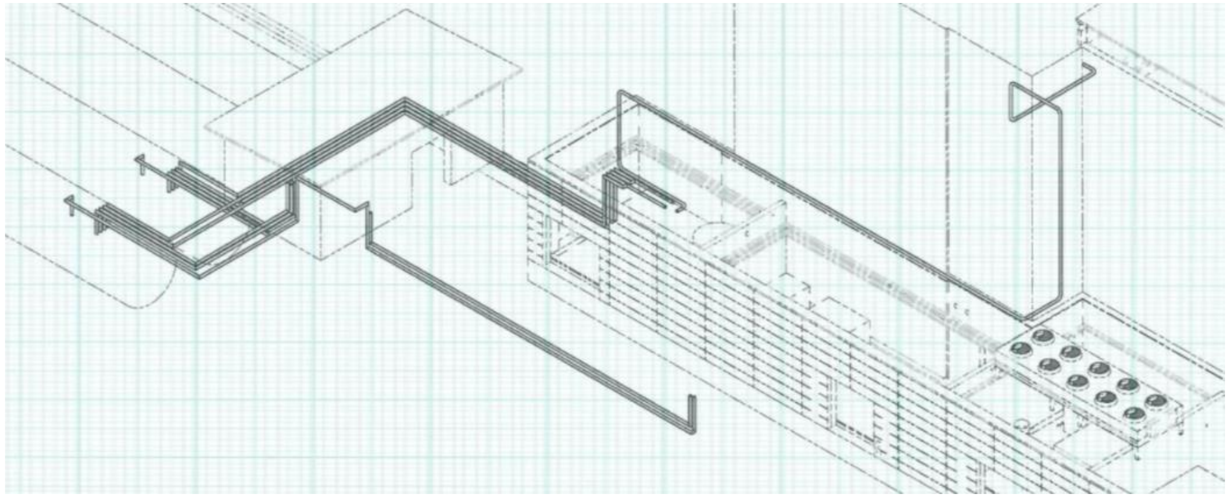
**Data taken from NFPA 68 Annex D*

Safe Integration of Hydrogen Fuel

Process Engineering

- Line Sizing

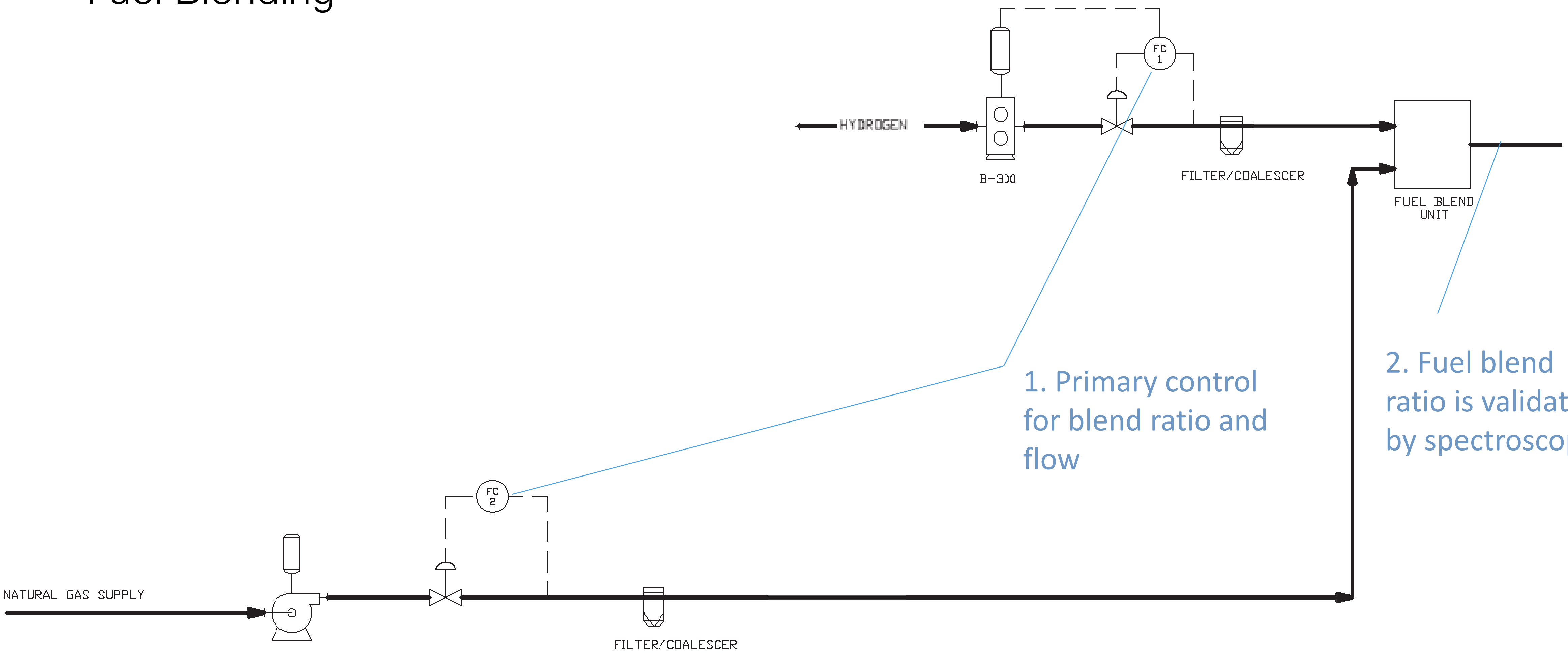
10 MW gas turbine	Flowrate (kg/s)	Design Flow Velocity	Calculated Nominal Pipe Size
Gas Hydrogen	0.25 kg/s	18 m/s	150 mm
Natural Gas	0.61 kg/s		80 mm
50/50 mixture by volume	0.43 kg/s		80 mm or 100 mm



Safe Integration of Hydrogen Fuel

Process Engineering

- Fuel Blending



1. Primary control for blend ratio and flow

2. Fuel blend ratio is validated by spectroscopy

Safe Integration of Hydrogen Fuel

Process Engineering

- Storage Sizing
  - Cryogenic storage: Suitable for larger volumes
  - Compressed gas storage: Suitable for smaller volumes
  - Pipeline: Available, but less abundant than NG. Limited for very high demands on special request

Access to hydrogen

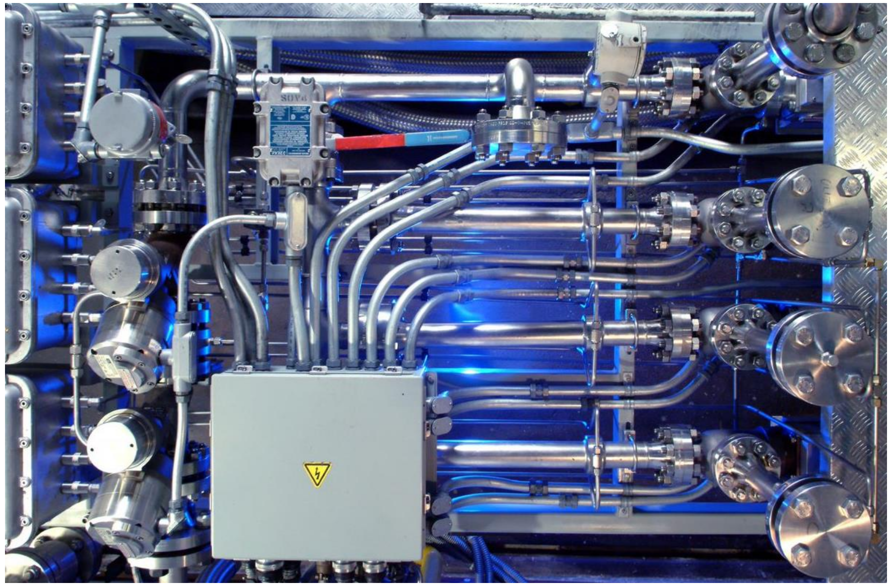
High cost and lower availability of hydrogen at large volumes is currently an important obstacle for test

A 20 MW Engine running 40 hours/week would require 60,000 m^3 liquid H_2, or 15 cryogenic trucks/week

Note: Grey hydrogen constitutes the majority of available hydrogen, green hydrogen is more expensive and scarce

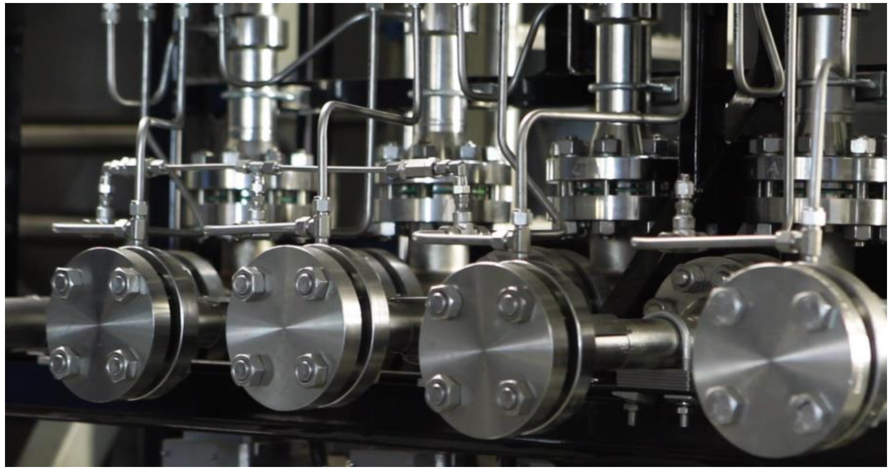
Safe Integration of Hydrogen Fuel

- Instrumentation
  - At cryogenic temperatures
    - Mostly available on special demand
  - In IIC (IECEx) gas group severity zones
    - Mostly available as SIL 2 or higher
  - Flow measurement
    - Coriolis flowmeters offer the highest accuracy



Safe Integration of Hydrogen Fuel

- Instrumentation
  - Hydrogen content monitoring; hydrogen blend ratio
    - Tunable diode laser spectroscopy (TDLAS) offers 15-25 second response time and accuracy
  - Leak detection
    - Catalytic lower explosive limit sensor (LEL) can detect hydrogen
    - Conventional Non-Dispersive Infrared (NDIR) is suitable for hydro-carbon gases only



Safe Integration of Hydrogen Fuel

- Electrical Equipment
  - In IIC (IECEx) gas group severity zones
    - Motors are available but considered special orders
    - Important attention required for the variable speed drives to be equipped with safe torque off and safe motor temperature monitoring

Safe Integration of Hydrogen Fuel

Materials Engineering (ASME B31.12 and API RP 941)

- Comparison of materials for hydrogen service

Material	Gas	Liquid / Slush	High Temperature (>400C)
Aluminum and aluminum alloys	Acceptable	Acceptable	Not Acceptable
Austenitic stainless steels with greater than 7% nickel (e.g. 304, 304L, 308, 316, 321, 347)	**Acceptable**	**Acceptable**	**Acceptable**
Carbon Steels	Acceptable	Not Acceptable	Acceptable
Copper and copper alloys	Acceptable	Acceptable	Not Acceptable
Gray, ductile, or case iron	Not Acceptable	Not Acceptable	Not Acceptable
Low-alloy steels	Acceptable	Not Acceptable	Acceptable
Nickel and nickel alloys (e.g. Inconel and Monel)	Not Acceptable	Acceptable	Acceptable

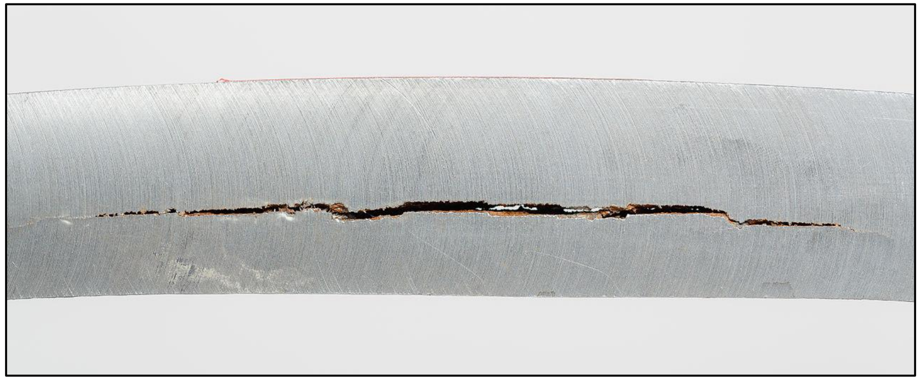


Figure 1: Hydrogen Induced Crack [Uwe Aranas, Wikimedia]

Safe Integration of Hydrogen Fuel

Materials Engineering

- General considerations for sealing
  - Silicon rubbers must be avoided
  - Flanged connections should be minimized
  - Threaded joints are not recommended for gaseous hydrogen
- Cryogenic considerations for sealing
  - Gasket selection should take into consideration thermal contraction and match materials to piping
  - Flanges should be retorqued periodically, especially for soft gaskets

Safe Integration of Hydrogen Fuel

To recap

	Any percentage of H2	25% H2/NG mixture	50% H2/NG mixture	73% H2/NG mixture	Cryogenic H2
Guidance	- Material and seal selection - Hydrogen storage (if pipeline unavailable) -Compressor evaluation -Static H_2/NG mixing control and equipment -Hazard assessment -Fire code safety compliance study -Hydrogen-capable leakage monitoring (depending on hazard assessment)	-gas group severity increase:	-Piping nominal size increase -Significant storage sizing increase	-Gas group severity increase: -Significant storage sizing increase -Piping nominal size increase	-Cryogenic mechanical equipment & instruments -material and seal selection -Increased storage safety distances -Cryogenic burn hazards
Impact	High	Medium	High	High	High

Thank you for your time