Hydrogen Station- Allentown, PA, USA

Hydrogen Codes and Standards Workshop

New Delhi- India

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Review of Critical Component and System Standards

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Who Is Air Products?

- Global atmospheric, process and specialty gases, performance materials, equipment and services provider
- Serving industrial, energy, technology and healthcare markets worldwide
- Fortune 500 company
- Operations in over 40 countries
- ~21,000 employees worldwide
- Known for our innovative culture and operational excellence
- Corporate responsibility commitment

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INOX AIR PRODUCTS

Joint Venture

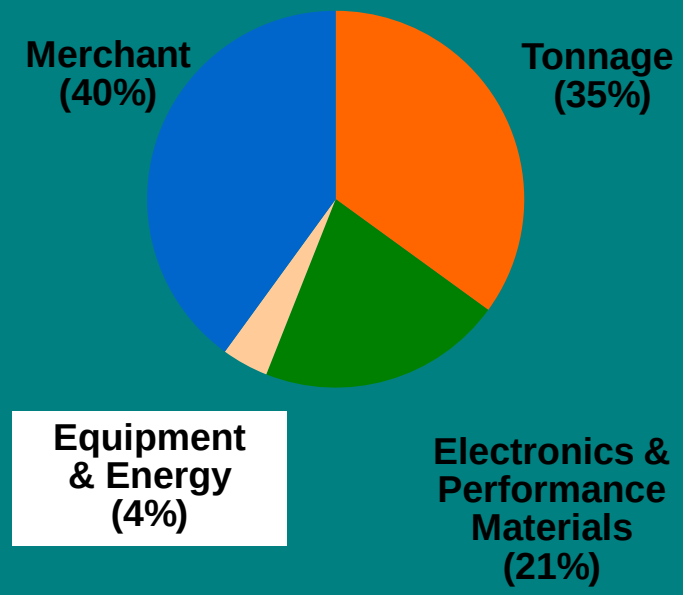
INOX in India

AIR PRODUCTS of USA

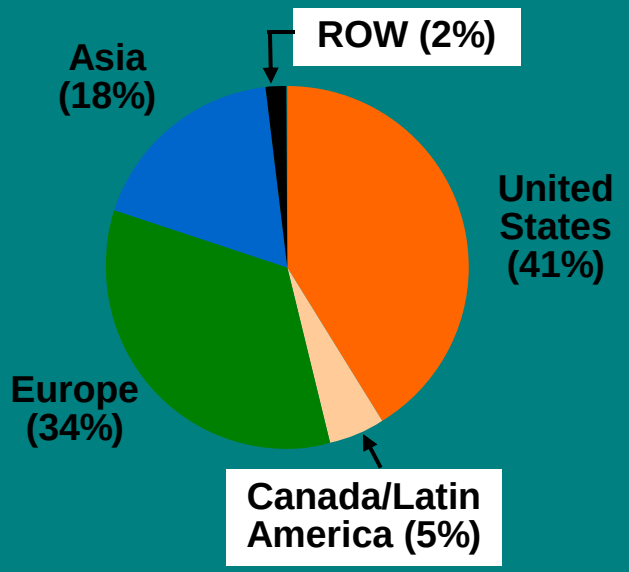
Air Products
Sales into Diverse Markets

- $10.4 billion company
- Diverse markets and geographies
- Positioned for continued long-term value creation

FY'08 Business Segment Sales



FY'08 Geographic Sales



Leadership in Hydrogen Infrastructure

- 50+ years of hydrogen experience
- Worlds largest producer of merchant hydrogen
- Our capacity ~1.75 million TPY
- Plants with Capacity from 100 kg/day to 200,000 kg/day
- 2B cu ft per day H_2 production
- Bulk, liquid, and pipeline distribution
- 1000's H_2 customers

Reformer - 200,000 KG/DAY

Reformer – 100 KG/DAY

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Leadership in H2 Fueling Infrastructure

- Active since 1993
  - 100+ H2 fueling projects
  - Stations in 16 countries
  - Over 100,000 fueling/yr
- Major role in H2 fuel safety codes and standards
- Broad technology base and intellectual property position
- Helping pave the way for a future hydrogen economy

Delivery Encompasses the Entire H2 Value Chain






Produce and Purify → Prepare for Transport → Distribution → Site Storage → Prepare For Fueling → Dispense

- Optimizing value chain supply options based on advantages, trade-offs, costs of production, storage, transportation and dispensing of H2
- Creating solutions to satisfy customer needs throughout different stages of market life-cycle
- Active participation in developing Codes & Standards enabling innovation, introduction of new technology, products and services

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Capability - Air Products India

- Engineering Team - Staff of 60+ in Pune
- Multidiscipline Engineering Team
- Integrated with US and UK Eng Centers
- Operations Team all throughout India

Historical – 10 years back

- No Direct Code or Standards for H2 Fueling Stations
- No Prior Experience
- Limited knowledge on applicable Fire / Building Code
- Basis – Primarily on Industrial Practice
  - 1000+ LH2 / GH2 Installations
  - 50+ Hydrogen Compression Systems
- Since no Codes existed for H2 Fueling Stations:
  - Used and Exceeded Industrial Equivalents
  - Used Compressed Natural Gas as Reference
- Above Approach was successful

Codes and Standards Recent Development

- Large number of Codes & Standards developed over the last 10 yrs
- Roadmap for Codes & Standards heavily promoted by US Department of Energy
- Air Products is actively participating in developing:
  - Installation Codes: NFPA, I-Code, ISO
  - Components Codes: ASME, ISO, CSA, SAE
  - Interface Codes: SAE
- Where questionable safety or conflicting requirements arise…. Air Products can work to correct through code process

Installation Codes

Standards	Description
NFPA 55	For Storage, Use & Handling of Compressed Gases & Cryogenic Fluids in Portable and Stationary Containers, Cylinders and Tanks
NFPA 52	Vehicular Fuel Systems Code
NFPA 2 (Draft)	Hydrogen Technologies Code
ISO 20100	Gaseous Hydrogen Fueling Station
I-Code	International Fire Code- Chapter 22

The new NFPA 2 will consolidate requirements of all NFPA ‘s 20 different documents and address all areas of the Hydrogen fueling codes

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Component Codes

Standards	Description
SAE J2600	Compressed H2 Surface Vehicle Refuelling Connection Devices
SAE J2578	General Safety of H2 Fueled Vehicles
ASME BPVC	Section VIII Div 3
CSA	Canadian *Standards* Association
ASME / ASTM B31.1	Piping Specification

Canadian Standards Association (CSA)

Project	Title	Status
CSA HGV 4. 1	Standard for H2 dispensing systems	TIR
CSA HGV 4. 2	Standard for H2 Hose Assemblies	TIR
CSA HGV 4. 3	CSA HGV 4. 3 Standard for Temperature Compensation Systems for H2 Gas Dispensing Systems.	Early draft
CSA HGV 4. 4	Standard for H2 Break Away Devices	TIR
CSA HGV 4. 5	Standard for Priority and Sequencing Equipment	TIR
CSA HGV 4. 6	Standard for H2 Manual Valves	TIR
CSA HGV 4. 7	Standard for Automatic High Pressure Operated Valves for H2 Gas Dispensing Systems	TIR
CSA HGV 4 .8	Standard for H2 Gas vehicle Fueling Stations Compressor	TIR
CSA HGV 4. 9	Standard for Compressed H2 Dispenser System/Station	Draft
CSA HGV 4.10	Standard for H2 Fittings	Standard Published

Importance of Components Codes

- Component standards - critical for safe operation of stations
- Installation and interface codes have shown good progress
- Technology exceeding typical industrial requirements:
  - Cannot use “off the shelf” components for long term reliability as it provides min level of safety
  - Codes required for “listed” equipment & 3rd party certification
  - Requires testing to meet operating conditions
- Component standards are lagging (TIR to Standards)
  - A lot of effort, only few people involved
  - Few suppliers see the market today
  - Standards need to be performance based
  - Need to expand capable supplier base

Interface Codes developed by Society of Automotive Engineers (SAE)

Project	Title	Status	Date
J2574	Fuel Cell Vehicle Terminology	Pub	29Jan09
J2579	Technical Information Report for Fuel Systems in Fuel Cell and other H2 Vehicles	TIR	7Jan09
J2600	Compressed H2 Surface Vehicle Refueling Connection Devices	Pub	31Mar08
J2601	Compressed H2 Vehicle Fueling Communication Device	Draft TIR	3Aug04
J2719	Information Report on the Development of a H2 Quality Guideline for Fuel Cell Vehicles	TIR	29Jan09
J2799	70 MPa Compressed H2 Surface Vehicle Fuelling Connection Device & Optional Vehicle to Station Communications	TIR	29Jan09

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Examples of a few Gaps

- SAE Standards are primarily Automotive focused. Original Equipment Manufacturer (OEM) focus well suited for standards such as J2578, J2579. OEM focus not suitable for interface standards such as Purity & Fueling protocol
  - Purity Standard: Part of TIR J2719, includes seven constituents at detection limit, very difficult and expensive to measure
  - Fueling protocol: Draft TIR J2601 requires fuel to be delivered at or below hardware design temperatures
- Standards for H2 Vehicle Fuel Communication Device: SAE J2601 address this however standard does not apply to buses or off road vehicle:
  - Recognizes Air Products intellectual property suite
  - AP agrees to license universally

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Example of H_2/HCNG Station – Codes & Standards

- Reform 100 kg / day of H_2 from natural gas
- Dispense H_2 at 350 bar with communication fill to California Fuel Cell Partnership standard
- Blend and dispense 30% H_2 by volume with CNG at 250 bar non-communication fill as HCNG
- **HCNG not addressed yet in nearly all US and world wide Code and Standards**
- NFPA52: A Chapter was proposed but was rejected
- SAE and HGV left blend out of scope

H2/HCNG Station- Penn State

HCNG Blend Unit

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Learnings from C&S Development

- Utilize Codes available and customize appropriately for local markets. Avoid "Re-Inventing"
- Need experienced professionals to developing codes and standards
- Demonstrations are best laboratory for Codes and Standards development
- Avoid Codes and Standards being developed by interest groups; minimize one sided and narrow basis; potential conflict of interest
- Conflicting Codes can cause confusion. Need roadmap to direct completion

Conclusions

- Codes and Standards
  - Improves Safety, provides consistency
  - Assists with permitting process
  - Levels playing field for all participants
  - Enables market to develop in orderly fashion
- Codes and Standards work has progressed
  - C&S work is essential; it is time consuming
  - Feedback from demonstration is critical
- Properly developed Codes is valuable, however a poorly written Codes can be detrimental
  - Better to have none than a poor Standard

THANK YOU!

Mobile Fueling Station with solar panel

HCNG Dispenser- IOC, India

Hydrogen Station- DC, USA

Hydrogen Bus – Allentown, USA


H2/HCNG Station – State College, USA

H2 Station with onsite Reformer, California, USA

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Backup slides

Fuel System Equipment- Codes & Standards Compliance

- Liquid Tank
  - Portable : DOT, ADR
  - Stationary: ASME
- Hydrogen Gas Storage Tubes
  - Mobile application: DOT and DOT-SP
  - Onsite Storage: ASME
- Piping: ASME / ASTM B31.3
- Vaporizer: ASME
- Liquid Pump / Gas Compressor: ASME
- System : NFPA 52 , NFPA 55
- Vehicle Refueling Connection: SAE J2600
- Safety Standard For H2 Vehicle: SAE J2578

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National Institute of Standards and Technology (NIST)

- Handbook 44: Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices
- Desired accuracies based on experience with gasoline and CNG not consistent with available technology
  - Code Expectation of acceptable tolerance of +/- 1.5%
    - Current verification technology limited to +/- 6.0%
    - Current H2 measurement technology limited to +/- 5.0% to 10.0%

ASME Code For Storage Tanks / Tubes

- Boilers & Pressure Vessel Code (BPVC) Section VIII
  - Division 1- Pressure vessels
  - Division 3- High Pressure Vessels
- Code Case 2579
  - Hoop –wrapped Composite Reinforced pressure Vessel with Welded liners for Gaseous H2 Service; Section VIII Division 3
- Code Case 2569
  - SA-372 Steel Construction for use in High pressure H2 applications; Section VIII Division 3
- Code Case 2563
  - Aluminum Alloy 6061 construction for use in High pressure H2 application; Section VIII Division 3