

JAPAN - NORWAY ENERGY SCIENCE WEEK 2015 HYDROGEN AND FUEL CELLS; END USE AND STORAGE



HEXAGON
COMPOSITES

Storage and transport of compressed hydrogen

Tokyo May 28th 2015, Per S. Heggem, Director, Hexagon Global Hydrogen Team





HEXAGON COMPOSITES IN BRIEF

- Headquartered in Ålesund, Norway
- Global market leader in lightweight composite pressure cylinders (Type 4) for Compressed Natural Gas (CNG), Compressed Hydrogen Gas (CHG) and Liquefied Petroleum Gas (LPG)
- Manufacturing facilities in Norway(2), in United States (2) and Russia (1-JV)
- Listed on the Oslo Stock Exchange under ticker: HEX



HEXAGON COMPOSITE GROUP



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- Hexagon administration and production sites
- Sales representatives: Sweden, Denmark, Spain, India, Singapore, Chile and the US
- Represented in Japan by Mitsui



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HIGH-PRESSURE CYLINDERS DEVELOPMENT AND PRODUCTION

Hexagon Lincoln, Lincoln, NE and Hexagon Raufoss, Raufoss, Norway



- 50 years experience in development and fabricating advanced filament-wound composites.
- More than 20 years experience building Type 4 cylinders
- Global leader in the industry with Type 4 that has demonstrated excellent combination of safety, efficiency and durability.

Most of our business today is related to composite high-pressure cylinders for passenger and commercial vehicles, buses, bulk transportation and storage of CNG and Hydrogen and accumulators for Hydrogen Refueling Stations world wide.

HEXAGON LINCOLN



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2010-2015



- World largest capacity for composite cylinder manufacturing.
- World largest direct purchaser of high strength carbon fiber.
- 2015 expansion project underway to support continued growth.

2015-





COMPOSITE MATERIAL IN CYLINDERS FOR TRANSPORT OF COMPRESSED GAS

Utilizing Carbon Fibre in large and high pressure T4 cylinders represents the ultimate use of composite materials

- **Low weight**
- **Produce reliable structures over lifetime**
- **T4 cylinders are corrosion free**

Hexagon Composite cylinders has demonstrated to be safe in normal service operations over more than 20 years in use.

Issues/incidents with composite cylinders over the years has been related to non-functioning fire protection equipment or abnormal use of the cylinders.



STEEL TO COMPOSITE – THE EVOLUTION

Weight of storage per scf NG



Steel bottle trailer
140,000 scf



Steel tube trailer
190,000 scf

TITAN4™
364,000 scf



TITAN™ T5M
473,000 scf

TITAN™ XL
521,000 scf

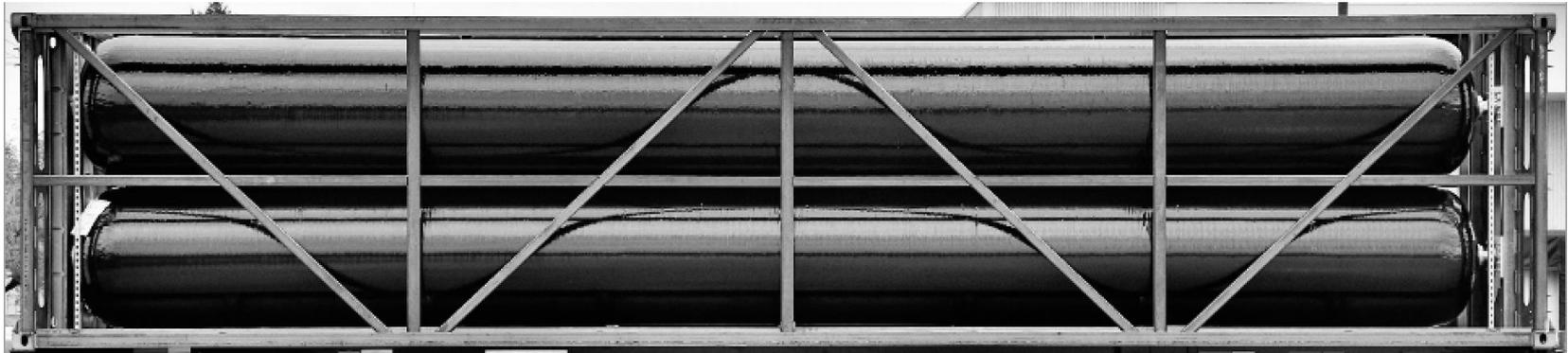


Portable volume in scf NG



HEXAGON FIRST GENERATION (TITAN4™)

- **364,000 scf of CNG**
- **617 kg of H₂ [CHG]**
- **34,000 liter volume**
- 4 large composite tanks
- Intermodal ISO 40' container
- GVW
 - <80,000 lbs with CNG
 - ~65,000 lbs with CHG
- DE-FG36-08GO18062
- **US DOT approval in 2012**



HEXAGON 2ND GENERATION TRAILERS (TITAN™ XL)



**Several hundreds Hexagon TITAN modules on the roads worldwide for distribution of CNG.
First TITAN-T4 Hydrogen module under final testing**



HEXAGON LINCOLN T-4 CYLINDERS IN SWAP BODY MODULES



- 450L/250bar cylinders approved for use in Europe (CNG).
- 450 – 650L/525-700 bar cylinders under development for hydrogen. (Available 2015)
- Hexagon Lincoln has concepts ready for bulk hauling modules for more than 1.2 Mt compressed hydrogen base on Type 4 cylinders.

DEVELOPMENT OF HIGH CAPACITY HYDROGEN TRAILERS



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SAFETY RELATED TO USE OF COMPOSITE CYLINDERS FOR TRANSPORT OF HIGH PRESSURE GAS



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- Trailers with Composite Cylinders has been in several incidents
 - Roll overs
 - Off road
 - Fire
 - Grenade attack

No release of gas or safety issues related to the composite cylinders



COLOMBIA- NOVEMBER 2014



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R&D IS THE KEY TO THE SUCCESS

In addition to internal R&D and product development, Hexagon is actively participating in external R&D programs and in national and international Regulation, Code and Standard work.

EXAMPLES ON EXTERNAL HYDROGEN R&D ACTIVITIES AT HEXAGON



- **European based (FCH-JU and Enova)**
 - General understanding on how Composite behave (**HyComp**)
 - Optimization of Hydrogen transport (**DeliverHy**)
 - Effect of Impact on Composite performance (**HyFactor**)
 - Effect of Fire on Composite performance (**FireComp**)
 - Transfer of Hydrogen from one to another receptacle - temperature effects (**HyTransfer**)
 - Electrochemical compressors and optimization of Hydrogen Refueling Stations (**Phaedrus**)
 - Prototype and testing of high pressure hydrogen trailer in Norway (**HyTrans**)
 - Development of cost effective and reliable hydrogen refueling station components and systems for fuel cell vehicles (**H2Ref**)
- **US-based (DOE):**
 - Several projects related to cost optimization of composite structures and liner material/production technology.

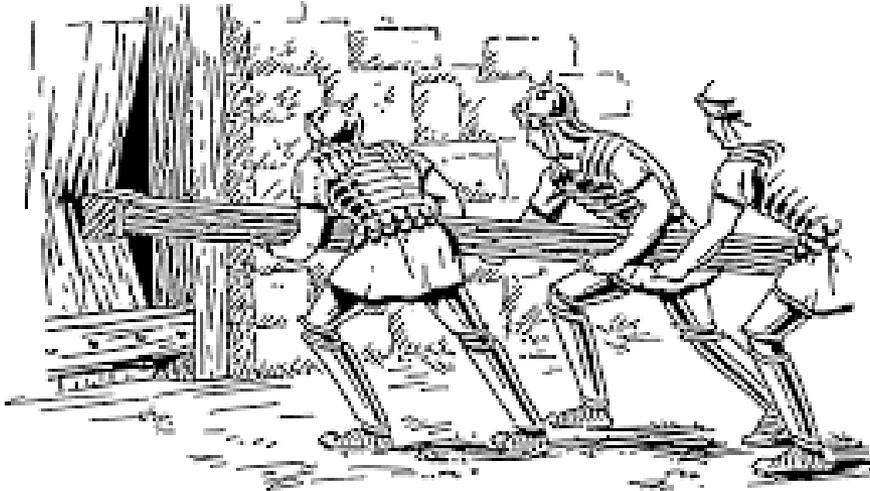


IMPACT TESTING OF HEXAGON TYPE 4 – 70MPA CYLINDERS





REGULATION, CODES AND STANDARDS FOR TRANSPORT OF COMPRESSED GAS



- Technology is ready
- Lack of relevant Regulation, Codes and Standard is an hinder for international market development
- The industry need a break through on RCS topics related to Composite Cylinders

Hexagon has taken initiative through Standard Norway for developing an adequate ISO standards for transport of larger quantity of Hydrogen (ISO 17519). This Committee is today convened by Hexagon.



DEVELOPMENT STATUS – ISO/DIS 17519

Gas cylinders — Refillable permanently mounted composite tubes for transportation

- Approved as New Work Item 9/2011
- Scope revised
 - Added Type 3
 - Pressure limited to 1000 bar
- WG agreed to limit energy to 3,000,000 bar-liters (i.e. 3,000Liters in combination with 1000bar or 10,000Liters in combination with 300bar or any other combination equivalent to 3,000,000 bar-liters)
- 2nd Committee Draft circulated 3/2013,
- DIS ballot voting from 19 Feb 2015 to 19 May 2015
- 19 May 2015 DIS was approved with comments. (Japan abstained from voting or making comments)
- FDIS expected to be circulated by end 2015

HEXAGON COMPOSITE CYLINDERS FOR HYDROGEN REFUELING STATIONS



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50 MPa – 531L

Bulk/Cascade storage for Hydrogen Refueling Station.

95 MPa - 255L

Tanks for quick top-fill make the Refueling Stations complete.

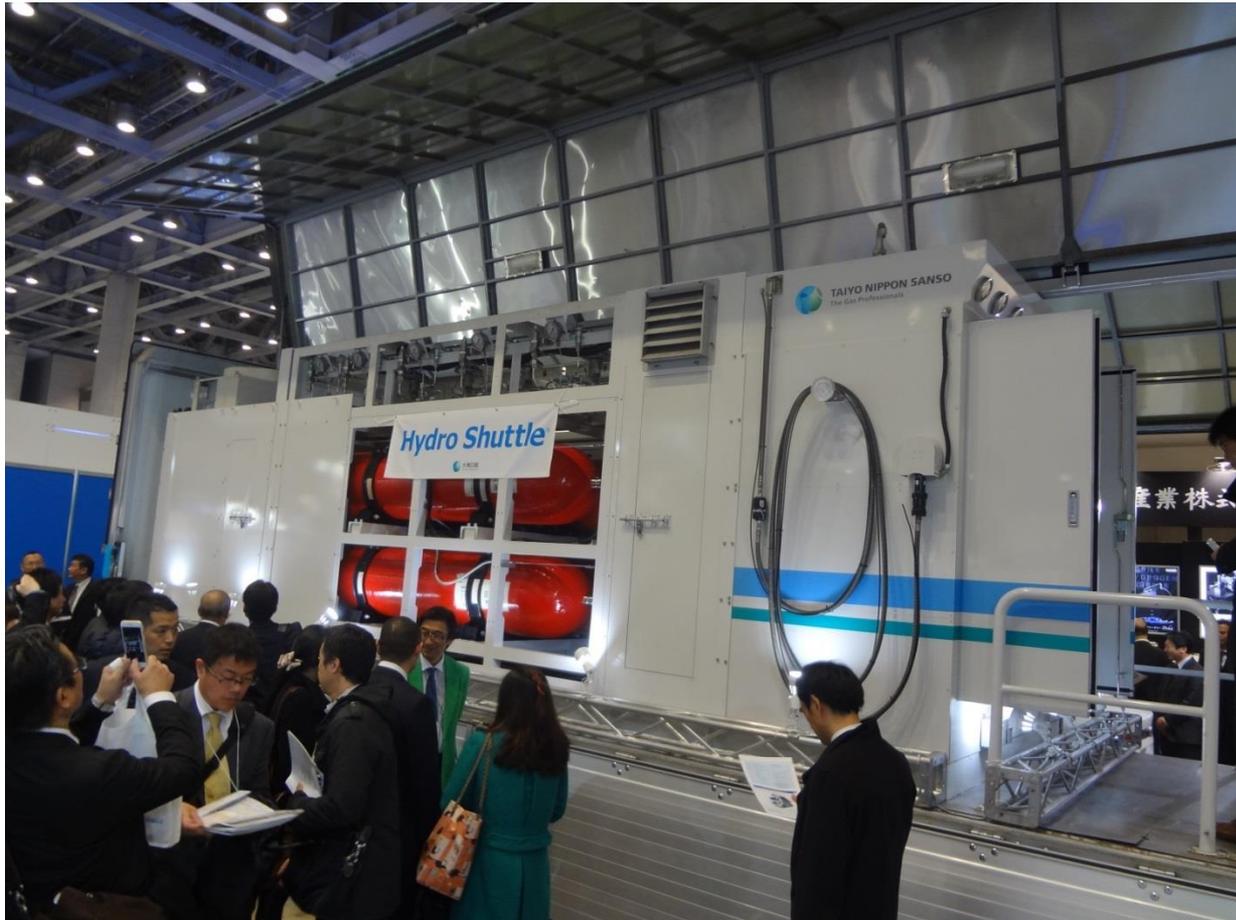


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95MPa CYLINDERS FOR MOBILE HYDROGEN REFUELING STATIONS IN JAPAN



Hexagon Lincoln 95MPa KHK-approved cylinder for mobile hydrogen refueling stations presented on the Tokyo FC EXPO 2013 in a Taiyo Nippon Mobile Hydrogen Refueling Station.



**MOBILE
HYDROGEN
REFUELING
STATION
WITH
HEXAGON
LINCOLN
95MPA KHK
APPROVED
STORAGE**



CONCLUSION

Composite cylinder technology and cylinder products for safe and efficient introduction of compressed hydrogen is available.

Regulation, Code and Standards are not ready yet.

World Wide Harmonization of Regulation, Codes and Standards will reduce the cost for implementation of hydrogen

Continued development of National Regulation, Codes and Standard will increase the cost for implementation of hydrogen. Might solve a local challenge, but complicate Global Harmonization.

Composite cylinder technology is ready. The rest is related to Regulation, Codes and Standards and paperwork and high test/qualification cost.



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THANK YOU FOR YOUR ATTENTION

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