Explosion Replication Test of a FCEV Hydrogen Tank (ID:188)

2023. 9. 21.

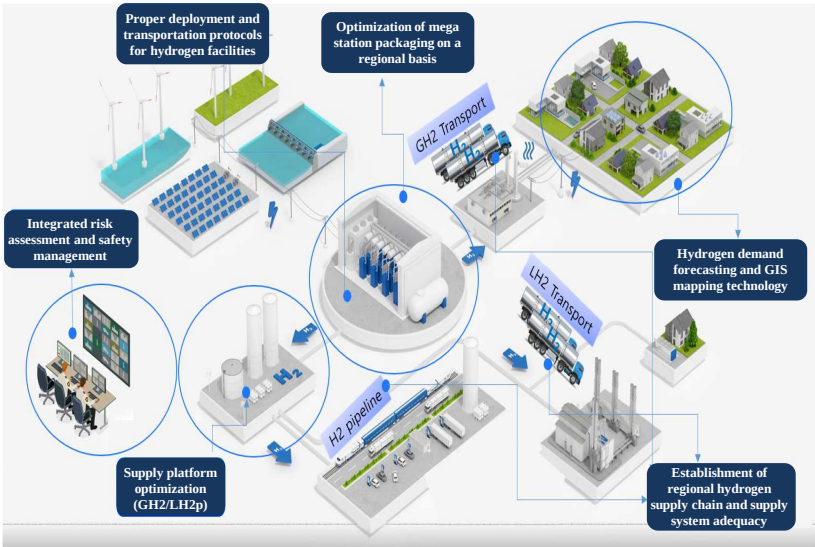
KICT KOREA INSTITUTE of CIVIL ENGINEERING and BUILDING TECHNOLOGY

Park, Byoungjik / Kim, Yangkyun

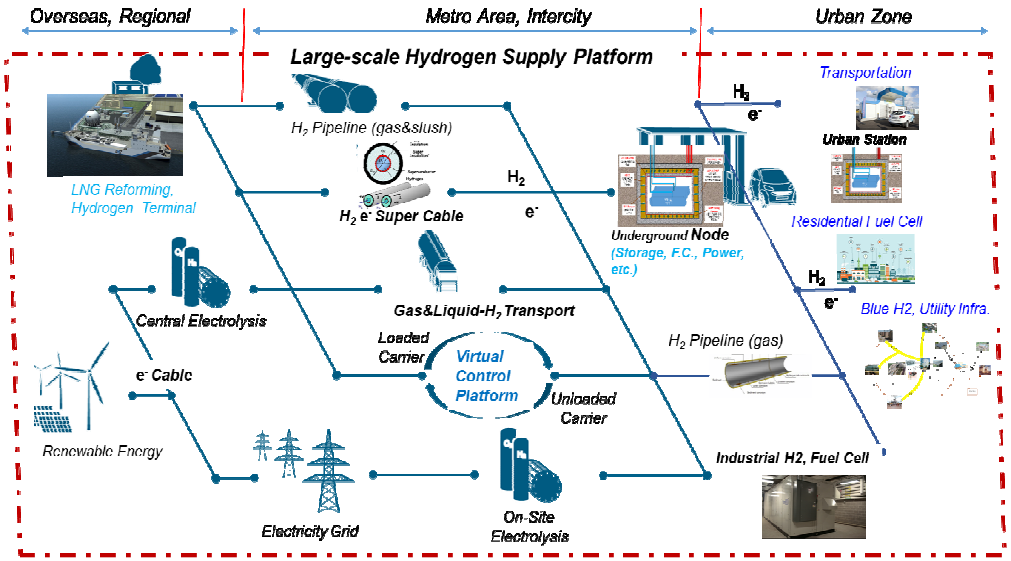
1. Getting Started

KICT Hydrogen infrastructure Research Cluster, H_2iRC

- Members (total 60 researchers, PhD 80%)
- R&R : Developing technology in planning, design, construction, maintenance of as well as national Act. and policy



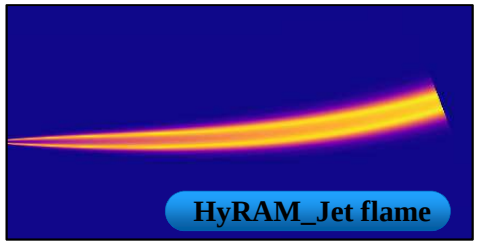
- **Hydrogen City : A city that uses hydrogen as the main energy source to maintain urban functions and has a clean circulation system in connection with available resources in the region**
- **Full cycle of hydrogen infrastructure : Infrastructure for hydrogen production and supply (transportation, storage, distribution, etc.) and utilization**

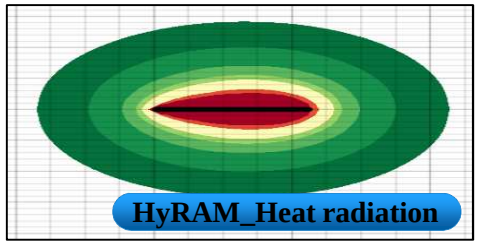


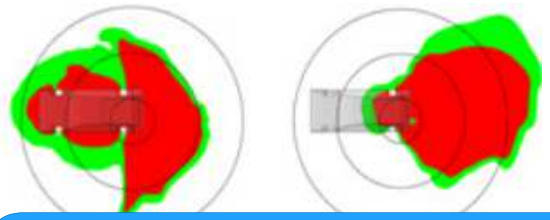
1. Getting Started

Let's get started…

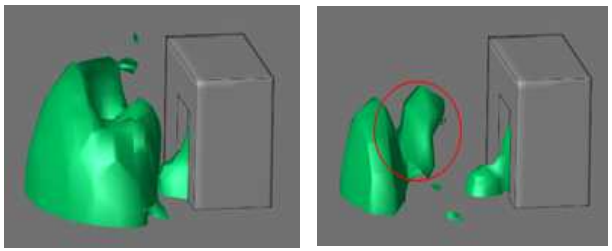
[Numerical Analysis]



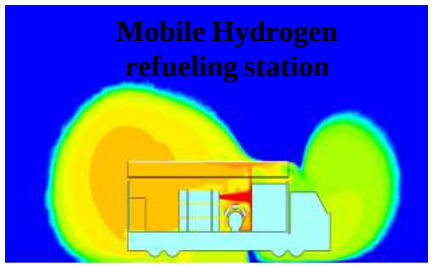


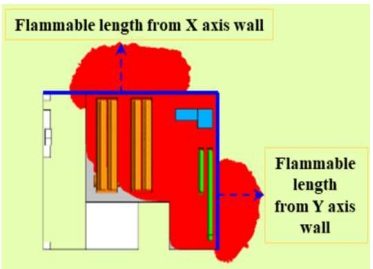


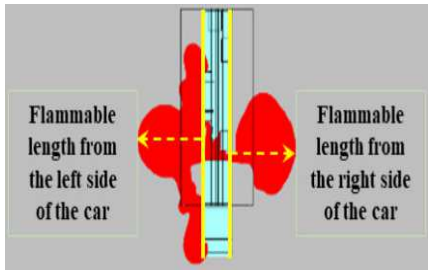
Heat flux profile around the vehicle at different TPRD discharge angles (90°vs45°)



3D shape of pressure in Hydrogen fuel cell room







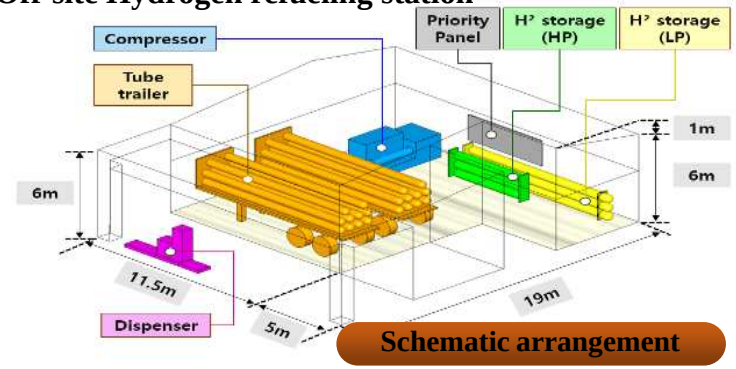
Hydrogen volume fraction distribution by jet release

1. Getting Started

Let's get started…

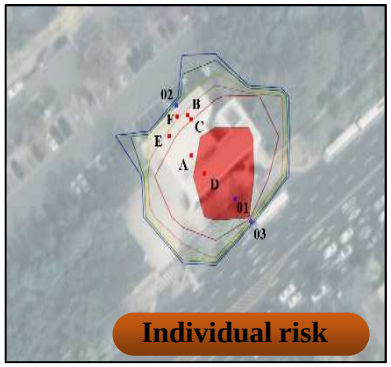
[Qualitative Risk Analysis]

Off-site Hydrogen refueling station



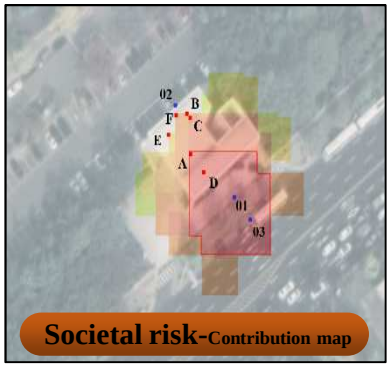
Schematic arrangement

Geometry

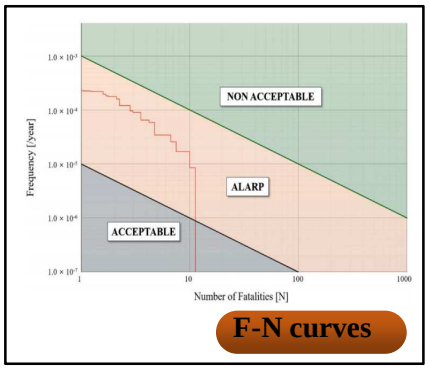


Individual risk

Societal risk-Contour map



Societal risk-Contribution map

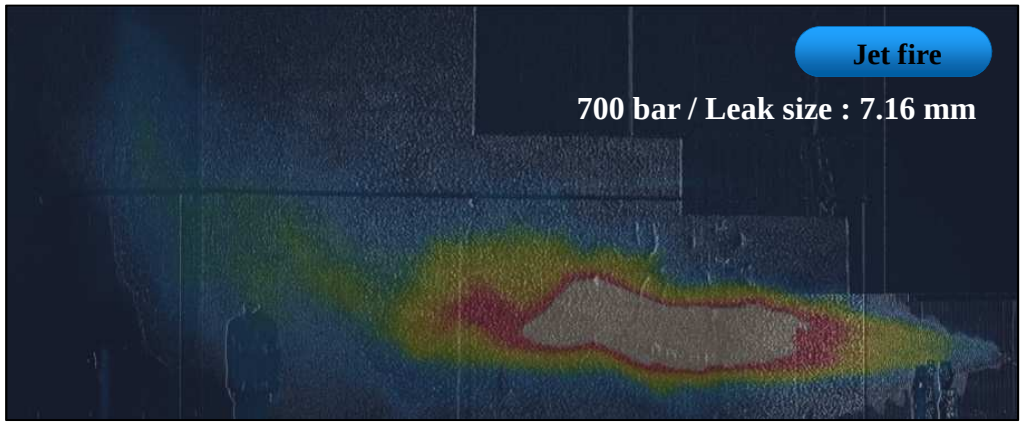


F-N curves

1. Getting Started

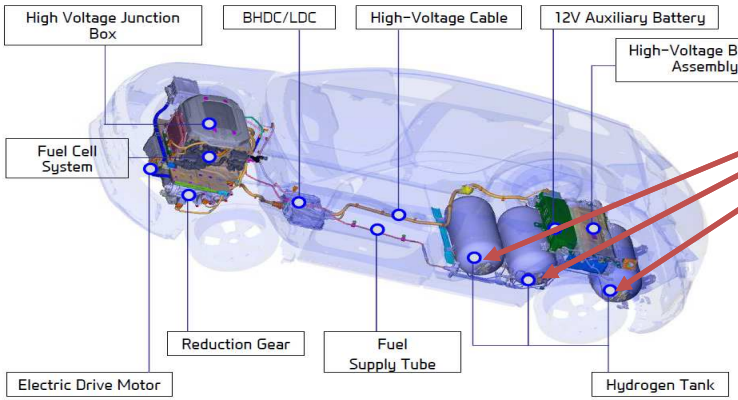
Let's get started…

[Experimental Analysis]



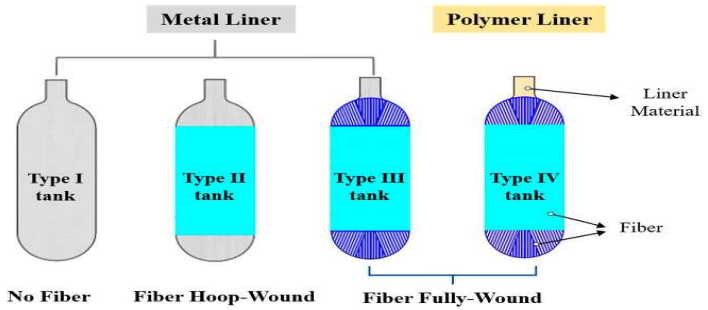
2. Test Preparation

FCEV structure



<FCEV structure>

<Structure of FCEV tank>



<Types of FCEV tanks>

Volume (L)	Pressure (MPa)	Nozzle Size (mm)
52.2	70	1.8

Flow Rate (kg/s)	Length (mm)	Diameter (mm)
0.102	870	363

<Hydrogen tank model parameters>

* IFA, Extract from the rescue data sheets for the Hyundai NEXO, https://www.ifa-swiss.ch/en/magazine/detail/what-to-dowhen-hydrogen-vehicles-burn (December 22, 2020).
* Carbon Fiber Composite Material Cost Challenges for Compressed Hydrogen Storage Onboard Fuel Cell Electric Vehicles (energy.gov)
* Review of Decompression Damage of the Polymer Liner of the Type IV Hydrogen Storage Tank, Zeping Jin et. all, Polymets(MDPI), 15(10), 2258, (March, 2023)

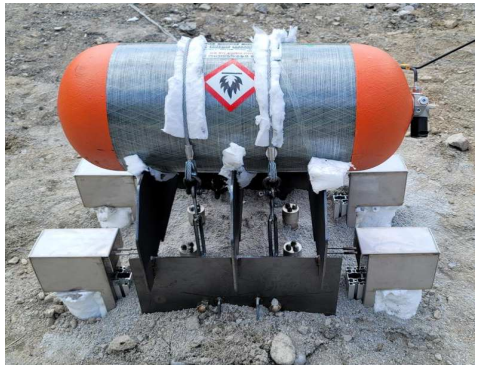
2. Test Preparation

Test Preparation (1)

<Test Site: Outdoor Explosion Site of R.O.K. Army Engineer School>

2. Test Preparation

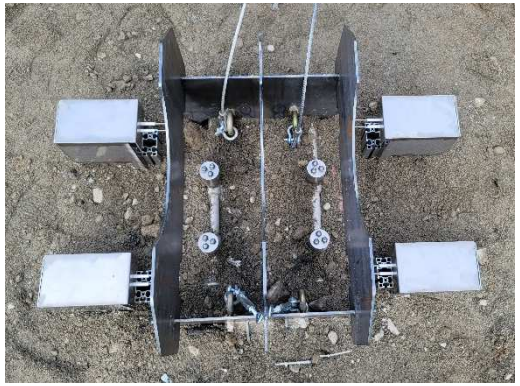
Test Preparation (2)



<Hydrogen tank>

<Site view>

<Fuel tank and fuel supply system)>



<Nozzle and igniter>

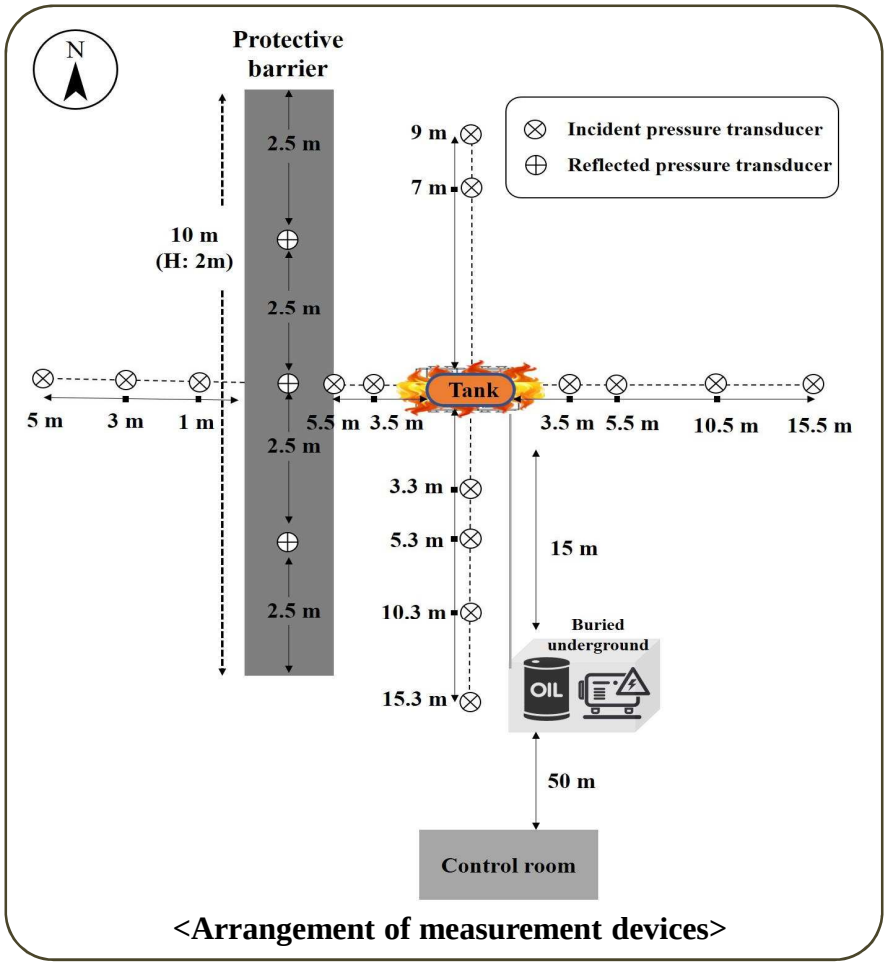
<Protective barrier>

<Pressure sensor (incident pressure)>

<Displacement gauge and accelerometer>

2. Test Preparation

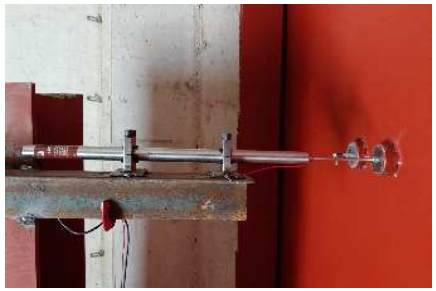
Test Preparation (3)



<Arrangement of measurement devices>

<Incident overpressure transducer>

<Reflected overpressure transducer>



<Displacement gauge>

<Accelerometer>

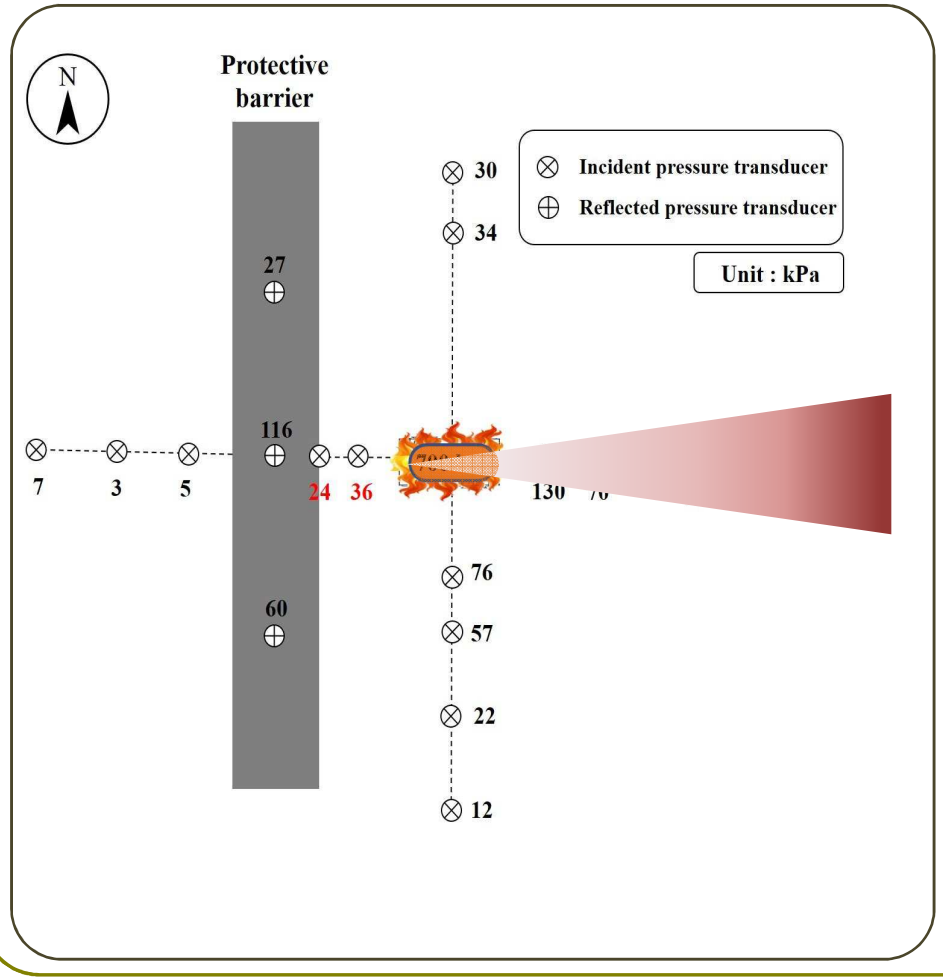
3. Details of Research

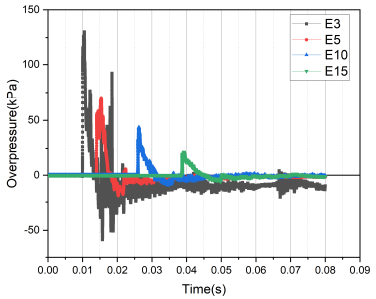
Hydrogen Tank (700 bar) Explosion Test (1)

<Video of hydrogen tank (700 bar) explosion test>

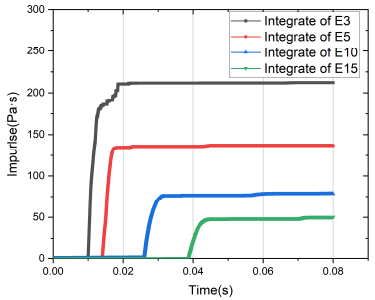
3. Details of Research

Hydrogen Tank (700 bar) Explosion Test (2) - Overpressure





<Incident overpressure (EAST)>



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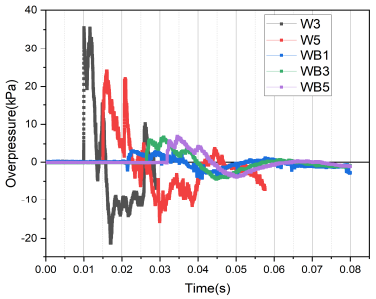

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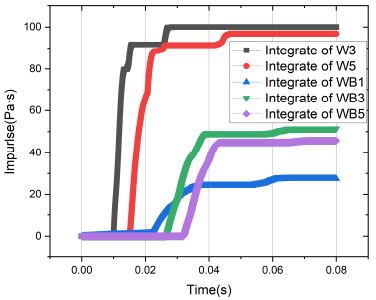


<Impulse (WEST)>

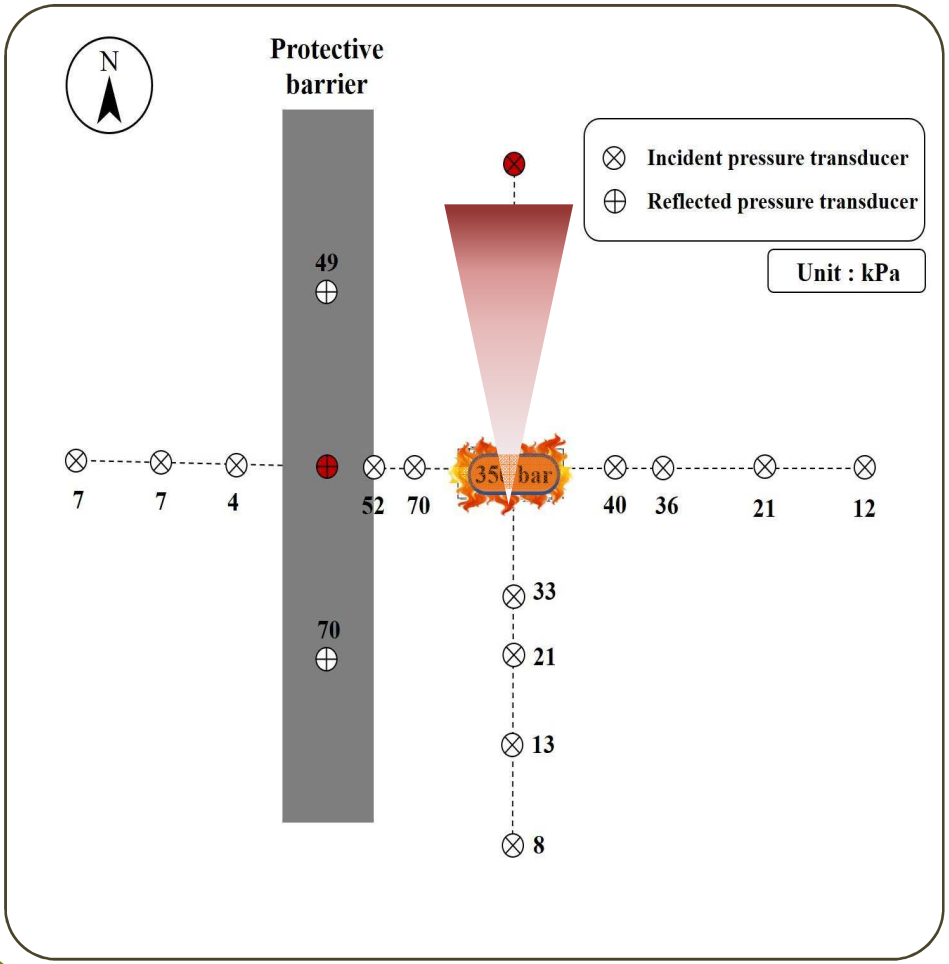
3. Details of Research

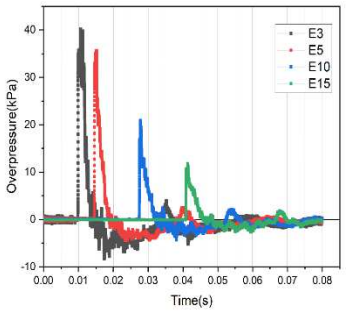
Hydrogen Tank (350 bar) Explosion Test (1)

< Video of hydrogen tank (350 bar) explosion test >

3. Details of Research

Hydrogen Tank (350 bar) Explosion Test (2) - Overpressure





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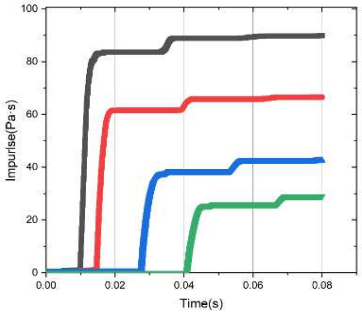

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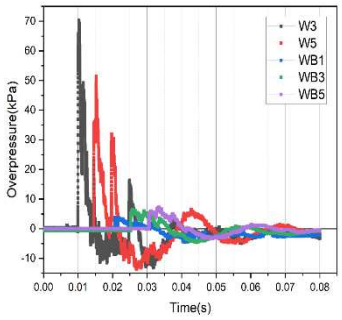

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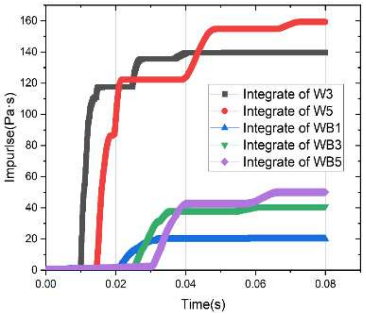
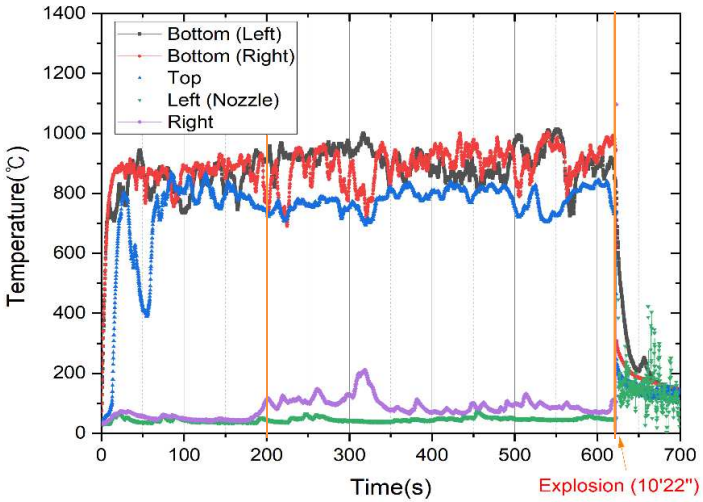
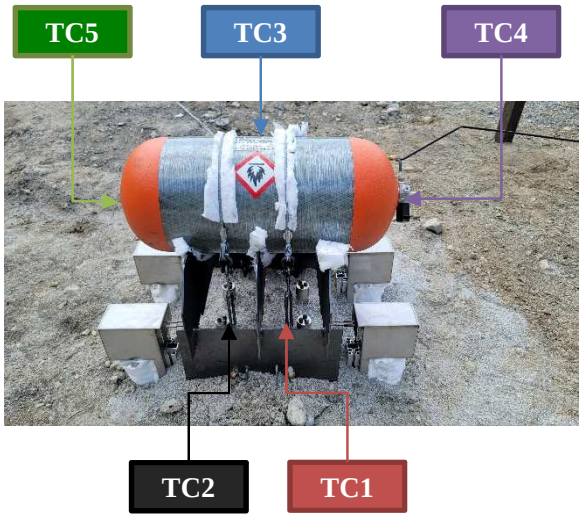


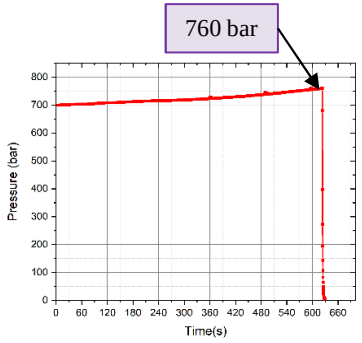
<Impulse (WEST)>

3. Details of Research

Hydrogen Tank (700 bar) Explosion Test (3) – Temperature & Internal Pressure



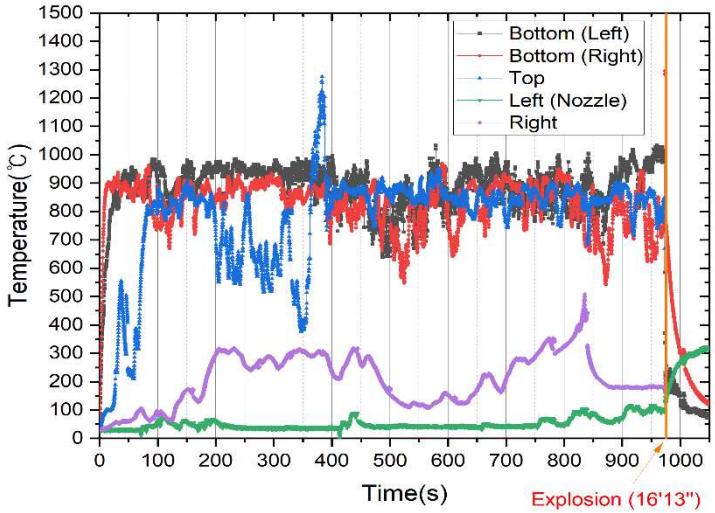


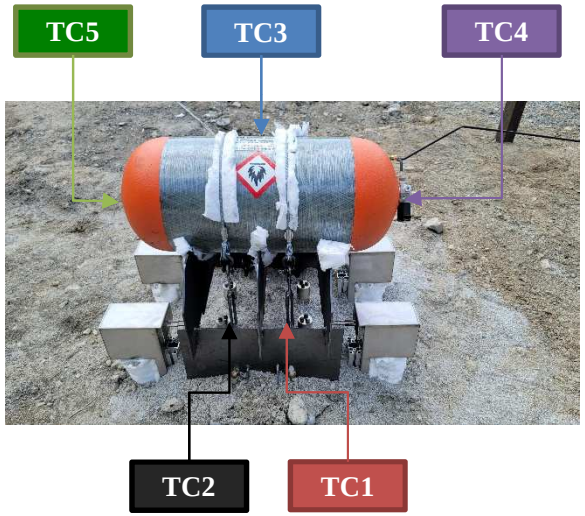


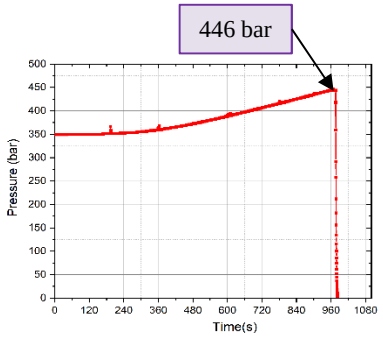
<Internal pressure> <Before explosion> <Exploding> <After explosion (burning finished)>

3. Details of Research

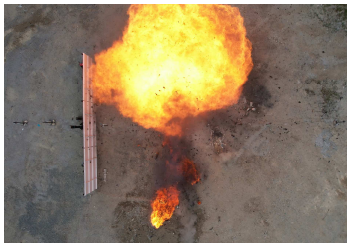
Hydrogen Tank (350 bar) Explosion Test (3) – Temperature & Internal Pressure







< Internal pressure >

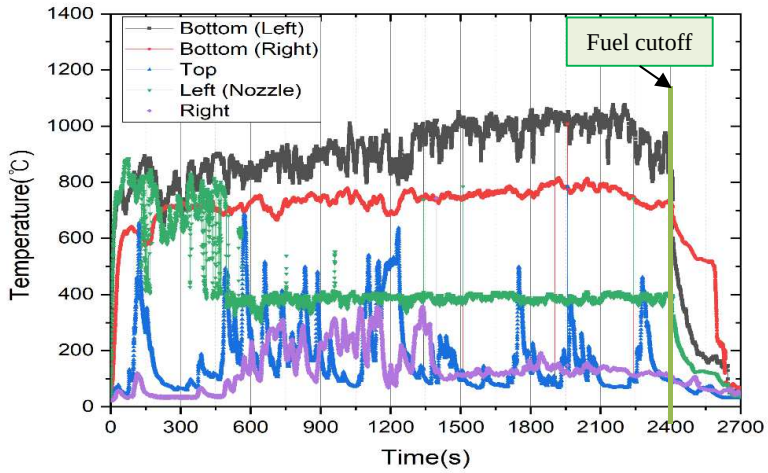


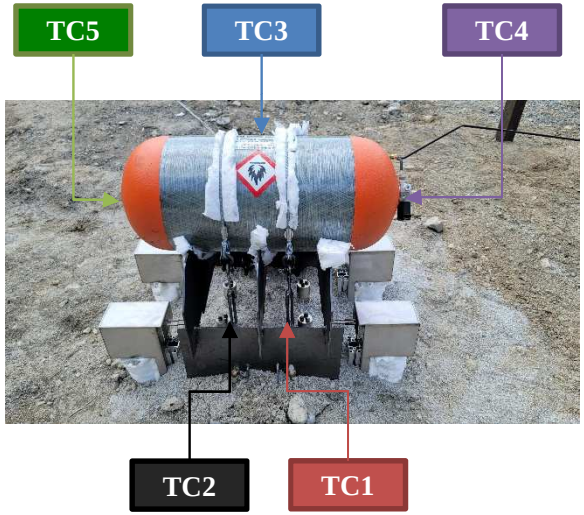
< Exploding >

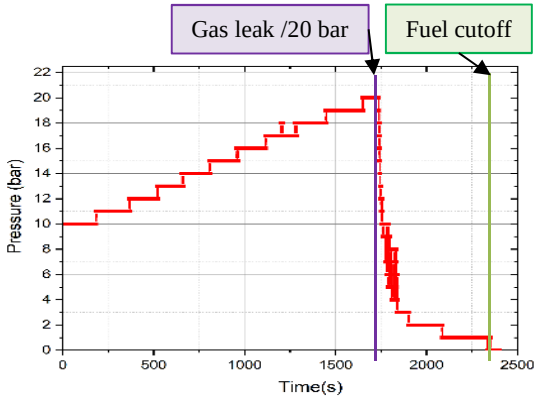
< After explosion (burning finished)>

3. Details of Research

Hydrogen tank (700 bar) explosion test (3) – Temperature & Internal Pressure







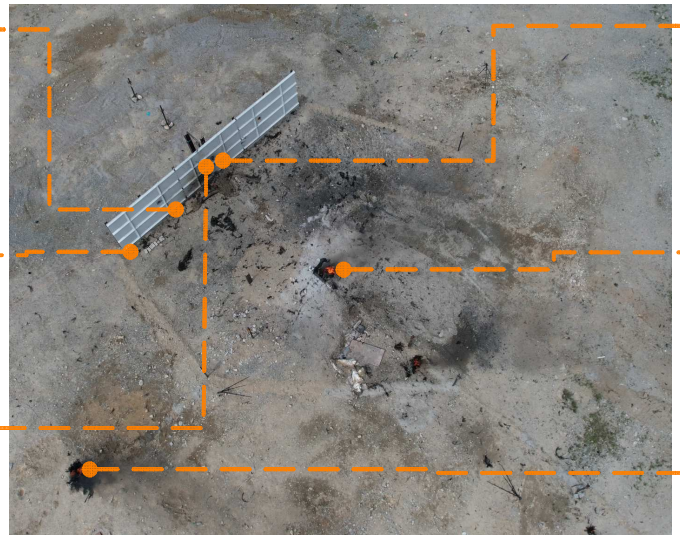
<Internal pressure>

<Testing>

<Test finished>

3. Details of Research

Hydrogen Tank Explosion Test (17) – Measurement of fragments and debris

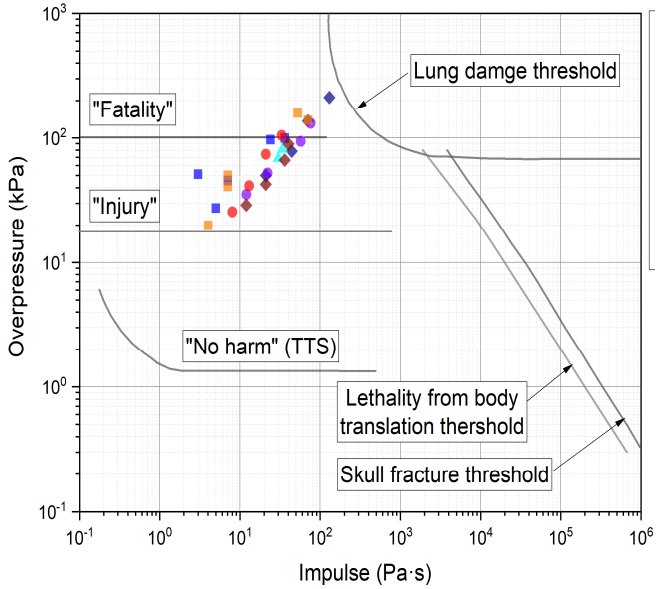


<Distribution of fragments and debris>

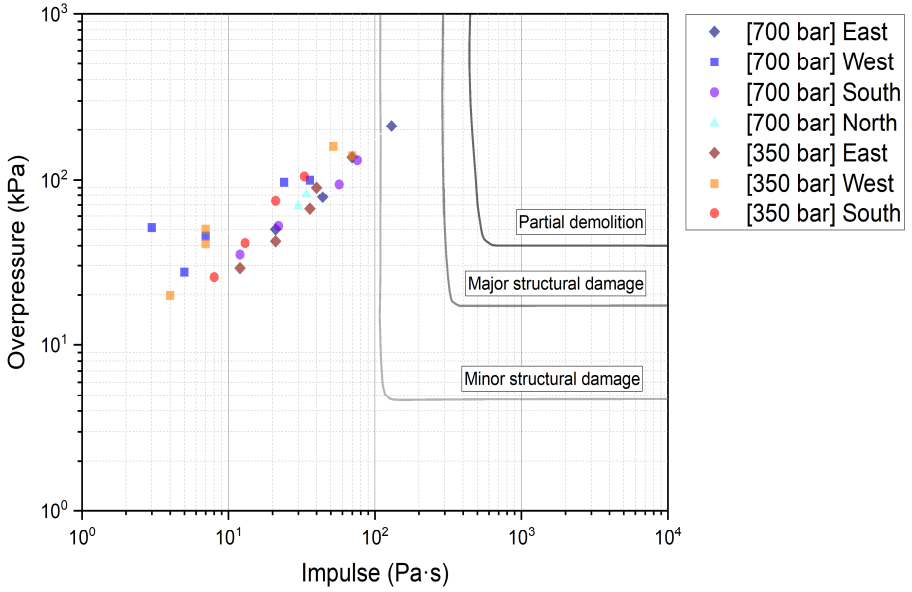
<Tank debris (700 bar) / 25.9 kg>

<Tank debris (350 bar) / 42.1 kg>

4. Conclusion



<Overpressure-impulse thresholds for harm criteria for humans>



<Overpressure-impulse thresholds for damage for buildings>

* Kashkarov S, Li Z, Molkov V. Blast wave from a hydrogen tank rupture in a fire in the open: hazard distance nomograms. Int J Hydrogen Energy 2020;45:2429e46.

* Debroey J. Probit function analysis of blast effects on human beings - the flemish 40 mbar overpressure criterion. Royal Military Academy; 2016. https://doi.org/10.13140/RG.2.1.1206.2321.

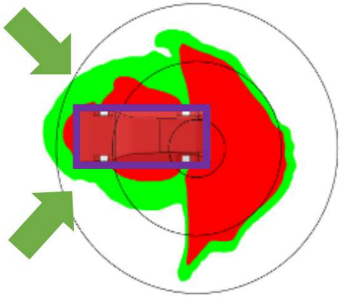
4. Conclusion

▪ Test Results

- ✓ **An explosion accident may occur if the FCEV's TPRD does not work.**
- ✓ **In the event of an explosion of the FCEV's hydrogen tank, people within a radius of 5 m may be killed by overpressure.**
- ✓ **In the hydrogen tank test, the maximum overpressure was 130 kPa for the high-pressure (700 bar) tank and 70 kPa for the middle pressure (350 bar) tank. The low-pressure (10 bar) tank did not explode.**
- ✓ **The internal pressure increased to 760 bar for the 700-bar tank, to 446 bar for the 350-bar tank, and to 20 bar for the 10-bar tank.**

▪ Safety distance suggestions for hydrogen facilities

- ✓ **Include these distances in the hydrogen fire explosion accident response manual for firefighters and managers**
- ✓ **Consider these distances in the designs of hydrogen-based facilities**



References

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- ✓ Jet Flame Risk Analysis for Safe Response to Hydrogen Vehicle Accidents, Sustainablity(MDPI), Byoungjik Park and Yangkyun Kim (2023)
- ✓ A Numerical Study on Jet Release from Off-site and Mobile Hydrogen Refueling Station for Separation Distance, Fire Science and Engineering, Byoungjik Park and Yangkyun Kim (2021)
- ✓ Numerical and experimental analysis of jet release and jet flame length for qualitative risk analysis at hydrogen refueling station, Process Safety and Environmental Protection 155 (2021) 145–154, Byoungjik Park and Yangkyun Kim (2021)
- ✓ Risk Assessment Method Combining Independent Protection Layers (IPL) of Layer of Protection Analysis (LOPA) and RISKCURVES Software, ENERGIES(MDPI), Byoungjik Park and Yangkyun Kim (2021)
- ✓ IFA, Extract from the rescue data sheets for the Hyundai NEXO, https://www.ifa-swiss.ch/en/magazine/detail/what-to-dowhen-hydrogen-vehicles-burn (December 22, 2020).
- ✓ Carbon Fiber Composite Material Cost Challenges for Compressed Hydrogen Storage Onboard Fuel Cell Electric Vehicles (energy.gov)
- ✓ Review of Decompression Damage of the Polymer Liner of the Type IV Hydrogen Storage Tank, Zeping Jin et. all, Polymets(MDPI), 15(10), 2258, (March, 2023)
- ✓ Kashkarov S, Li Z, Molkov V. Blast wave from a hydrogen tank rupture in a fire in the open: hazard distance nomograms. Int J Hydrogen Energy 2020;45:2429e46.
- ✓ Debroey J. Probit function analysis of blast effects on human beings - the flemish 40 mbar overpressure criterion. Royal Military Academy; 2016. https://doi.org/10.13140/RG.2.1.1206.2321

Thank you !!

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Research Specialist

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