

Fire Safety of Hydrogen-Fueled Vehicles:

System-Level Bonfire Test

by

R. Rhoads Stephenson

Motor Vehicle Fire Research Institute

www.mvfri.org

rodys@earthlink.net

High Pressure Cylinder Tests

(part of FMVSS 304)

- Bonfire test is routinely done for CNG
- A similar test has been drafted for H2
- Bare tank and PRD are exposed to bonfire for 20 minutes. Must either:
 - Remain intact, or
 - Vent safely
- Problems
 - Fire not well specified – just temperatures under tank
 - PRD must be shielded from direct flame

304 Test on CNG Tank



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FMVSS 304 - Conclusions

- Tank Burst is very energetic
 - Mechanical energy is released in milliseconds
 - Unacceptable to have tank burst
 - PRD *must* work
- 304 is mainly a PRD test – not a tank test
 - No modern composite tank will last for 20 minutes

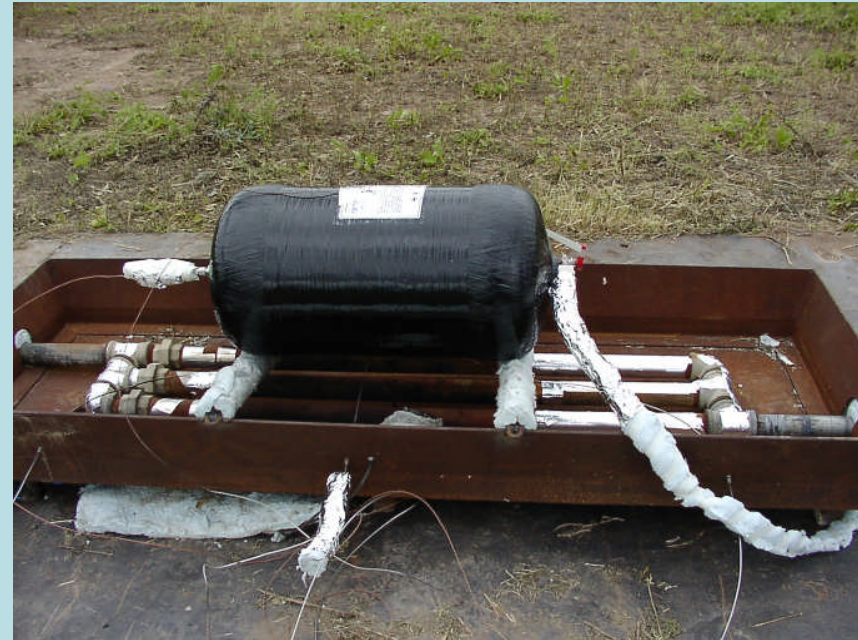
Hydrogen Burst Test

- Goals:
 - (1) Study the fire resistance of the tank, and the temperature and pressure its contents prior to burst
 - (2) Determine the characteristics of the energy release from a fire induced burst
- Performed 304-like test w/o PRD

Hydrogen Fuel Tank Test Setup

Instrumentation

- Tank internal temperature and pressure
- Exterior temperatures
- Blast pressures at 4 locations
- Visual and IR video



Tank positioned in bonfire test rig

Burst Test



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Tank Failure Times

- The composite material on the surface of the tank ignited 45 seconds into the test
- The tank ruptured 6 minutes and 27 seconds into the test

Burst Test Conclusions

- Temperature and pressure inside tank increased a negligible amount
 - Temperature up 20 C
 - Pressure up 200 psi (13 bar)
- Largest fragment (14 Kg) landed 80 meters (270 feet) away
- 43 psi overpressure at 2 m (6.3 feet)
- 6 psi overpressure at 6.5 m (21 feet)

Burst Test Conclusions

It is unacceptable for a H2 tank to burst!!

The PRD valve must work!

Conclusions (continued)

- **Successful operation of PRD is a system-level issue**
 - Number and location of tanks
 - Plumbing
 - Number and location of PRDs
 - Redundant PRDs?
 - Sizing of vent lines
 - Shielding and insulation of tanks
 - Flow of flames around fuel system
- A bare tank with a single PRD does not simulate a real vehicle

System-Level Bonfire Test

- Europeans require bonfire test on plastic fuel tanks – ECE R-34 Annex 5
- Test is not required in the US, but most tanks sold in US are qualified with this test

ECE R-34 Test

- Whole vehicle or buck used
- Tank is filled 50% with gasoline
- Exposed to gasoline pool fire
 - One minute at full heat flux
 - One minute with ceramic screen which cuts heat flux
- The tank “passes” if it survives for 2 minutes of exposure

ECE R-34 Test on Vehicle



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Observations

- Tank “passed” the test at 2 minutes
- Tank failed 7 seconds later
- Two minutes may be long enough for an uninjured person to escape
 - It is clearly too short if the occupant needs to be extricated

Proposed System Level Test for H2

- Composite hydrogen tanks are plastic
- Why not apply something similar to European ECE R-34 test?
- It tests the whole system
- It is independent of the hydrogen storage technology
 - Compressed gas
 - Liquid Hydrogen
 - Hydrides

Modifications

- Replace gasoline pool fire with a propane planer flame – diffused through sand
 - Easier to control
 - Less air pollution concern
- Exposure duration ?
 - Suggest 20 minutes like FMVSS 304
 - Must either vent safely or stay intact

Future Work

- Vehicle level test will be performed
 - Issue to study: Passenger compartment may become untenable well before 20 minutes
 - Debug the test procedure
- Recommend to NHTSA

Questions?

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