Importance of Compression Frequency and Fluid Fill-Up Procedure in Pressure Cycling Test for Composite Vessel

2018. 6. 27

Sungmin Cho, Ph. D
Hydrogen Energy Research Division
Korea Gas Safety Corporation

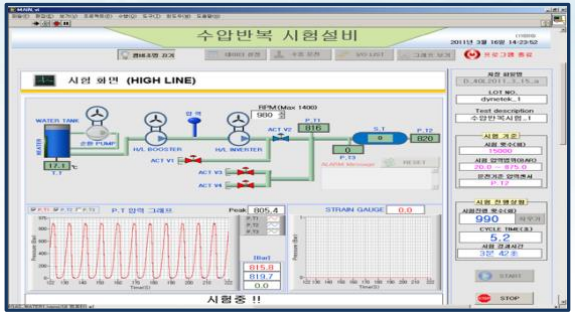
한국가스안전공사

1. Cycling Test Instruments in KGS

Ambient/Extreme Temperature Hydraulic Cycling Testers

Underground Pit

Remote Controllers



Key Features

- **CCTV surveillance**
- **Fully remote controlled by LabView**
- **Capacity : fluid supply up to 84 L/min at max. 110 & 55 MPa**

2. Issues Raised…

HDPE Liner Damaged after Extreme Temperature Cycling Test(EC79)

Swollen Surface

Puncture to Leak

Presence of Air | **High Temp.** | **Fast Cycle**

Suspected Causes

3. Cycling Test Procedure by GTR No. 13

6.2.2.2. Pressure cycling test (hydraulic)

The test is performed in accordance with the f wing procedure:

(a) The container is filled with a non-corrosive fluid;

(b) The container and fluid are stabilized at the specified temperature and relative humidity at the start of testing; the environment, fuelling fluid and container skin are maintained at the specified temperature for the duration of the testing. The container temperature may vary from the environmental temperature during testing;

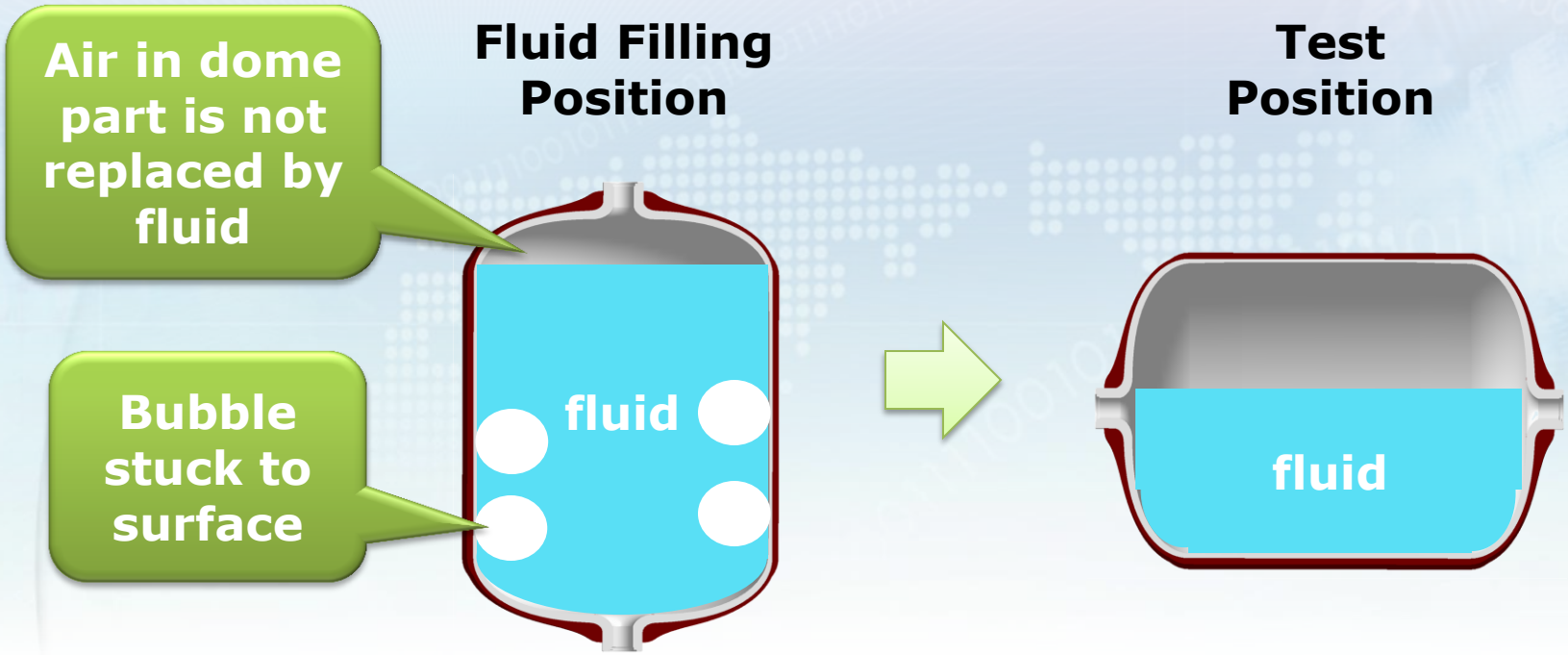
(c) The container is pressure cycled between 2 (±1) MPa and the target pressure at a rate not exceeding 10 cycles per minute for the specified number of cycles;

(d) The temperature of the hydr luid within the container is maintained and m d temperature.

Air should be completely removed

Suggest no faster than 2.5 cycles per minute

4. Mechanism of Air Pocket Build-up



Key Features

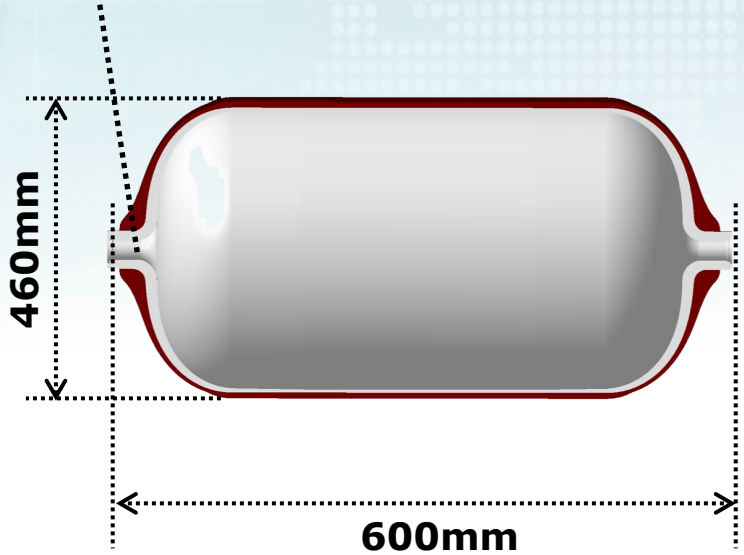
- Air can be injected by careless operators
- Air in upper dome part is not likely replaced by fluid
- Considerable amount of bubbles remain stuck to surface of vessel

5. Experimental Approach

Vessel dimensions

- High pressure vessel for CNG (Type3, Al-6061T6 liner)
- Working pressure 20.7 MPa, Capacity 106 L

1.125-12UNF-2A



Dimensions of Liner	
Material	Al6061T6
Thickness	4 mm
Length	600 mm
O.D.	434 mm

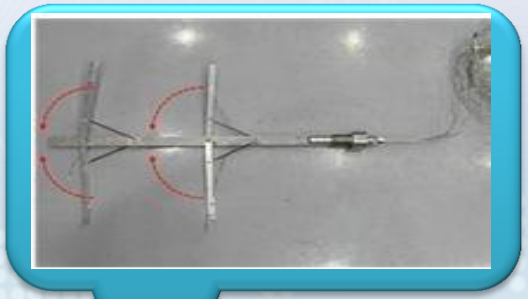
Dimensions of Composite Layer	
Material	Carbon fiber/Epoxy resin
Thickness	12 mm
O.D.	460 mm

6. Experimental Approach

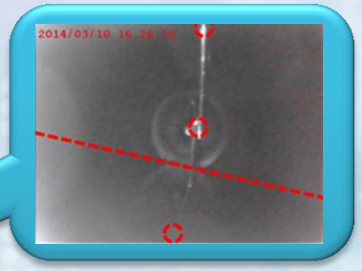
Thermocouples

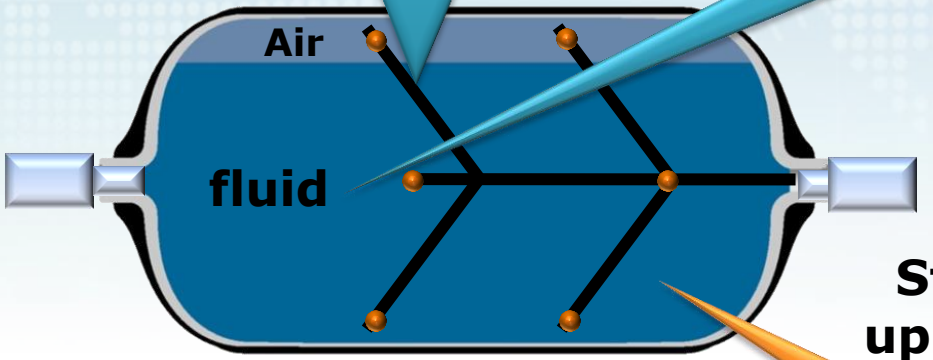
- 6 K-type TCs fixed at the tips of arms
- 2 measure temperature of air pocket
- 4 measure temperature of fluid (water)

Step 2. Insert TCs



Step 3. Check water level



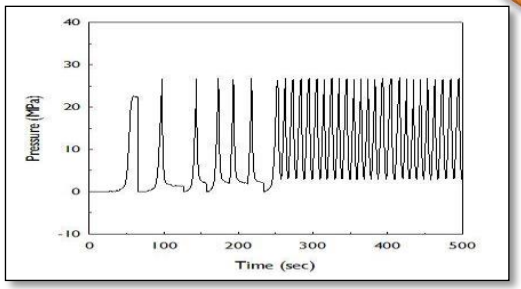


Step 4. Fluid Cycling

Step 1. Fill water up to 70 kg/106 kg

Fluid Supplier

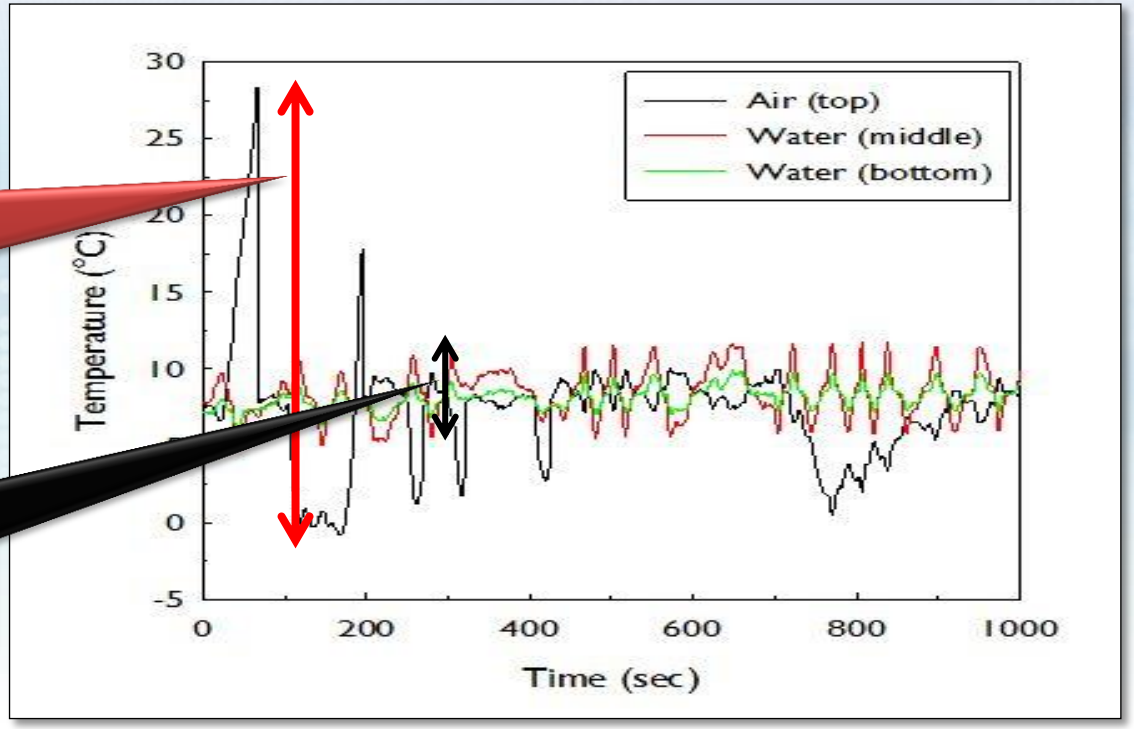
- Pressure Range 2 to 25.9 MPa
- Tap water is pumped
- 4cycles per minute



7. Results

Temperature amplitude in air pocket

Temperature amplitude in water layer



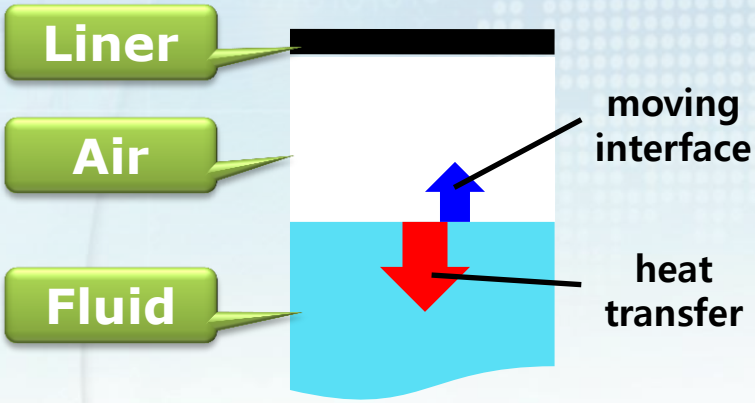
Observations

- T_{water} gradually increases with cycles
- T_{air} repeats up and down as pressure cycles (-2 to 28°C)

8. Thermal Analysis I

$$\frac{\rho d\left(C_p/h\right)}{\Gamma} = 0.25$$

$$\left[\frac{\text{Rate of heat transfer}}{\text{Rate of interface movement}}\right]$$



Symbol	Definition	Value	Unit
ρ	Fluid density	1.6	Kg/m^3
Cp	Heat capacity	1,000	J/kgK
H	Convective heat transfer coefficient	100	W/m^2K
d	Half thickness of air pocket at rest	0.16	m
r	Period of cycle	4	s

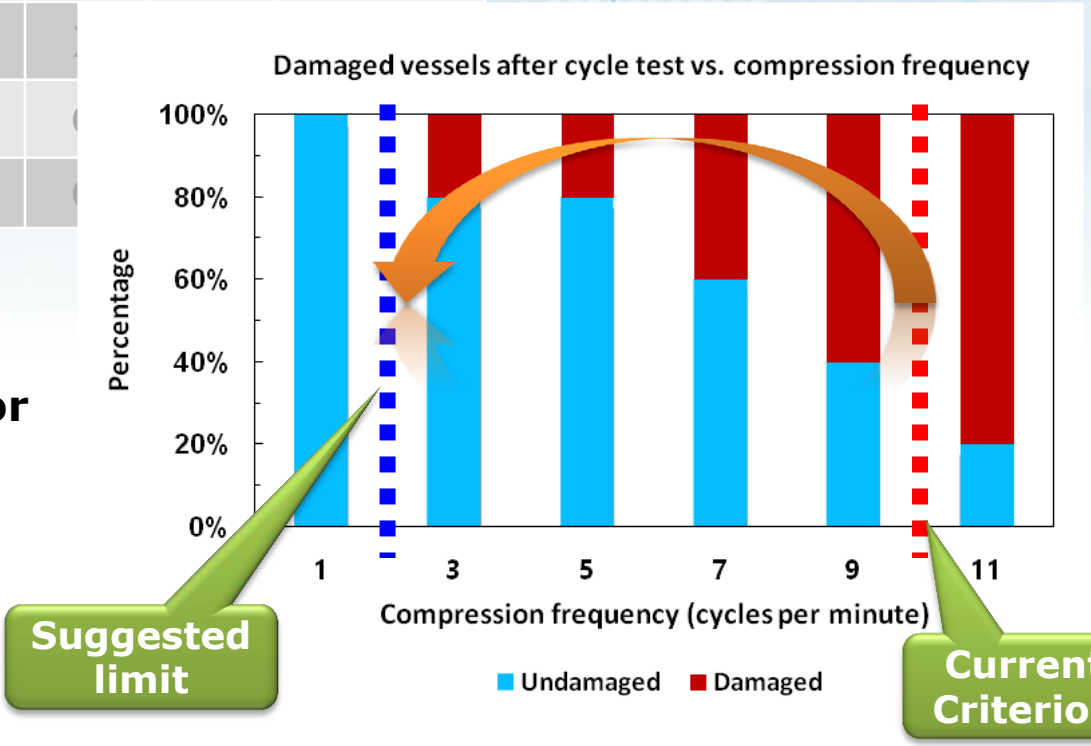
Discussions

- Rate of heat transfer < Rate of compression-expansion cycle
- Plastic liner is exposed to thermal shock(~40°C) during test
- Temperature amplitude can further increase in full-length test (i.e., 12,000 cycles according to EC79)

9. Analysis II(to be conducted…)

Classification		Sample #					Damage Ratio
		1	2	3	4	5	
Frequ-ency (Cycles per minute)	1	O	O	O	O	O	0
	3	O	X	O	O	O	0.2
	5	X	O	O	O	O	0.2
	7	X	O	O			
	9	X	X	O			
	11	X	X	X			

An example of result from test series



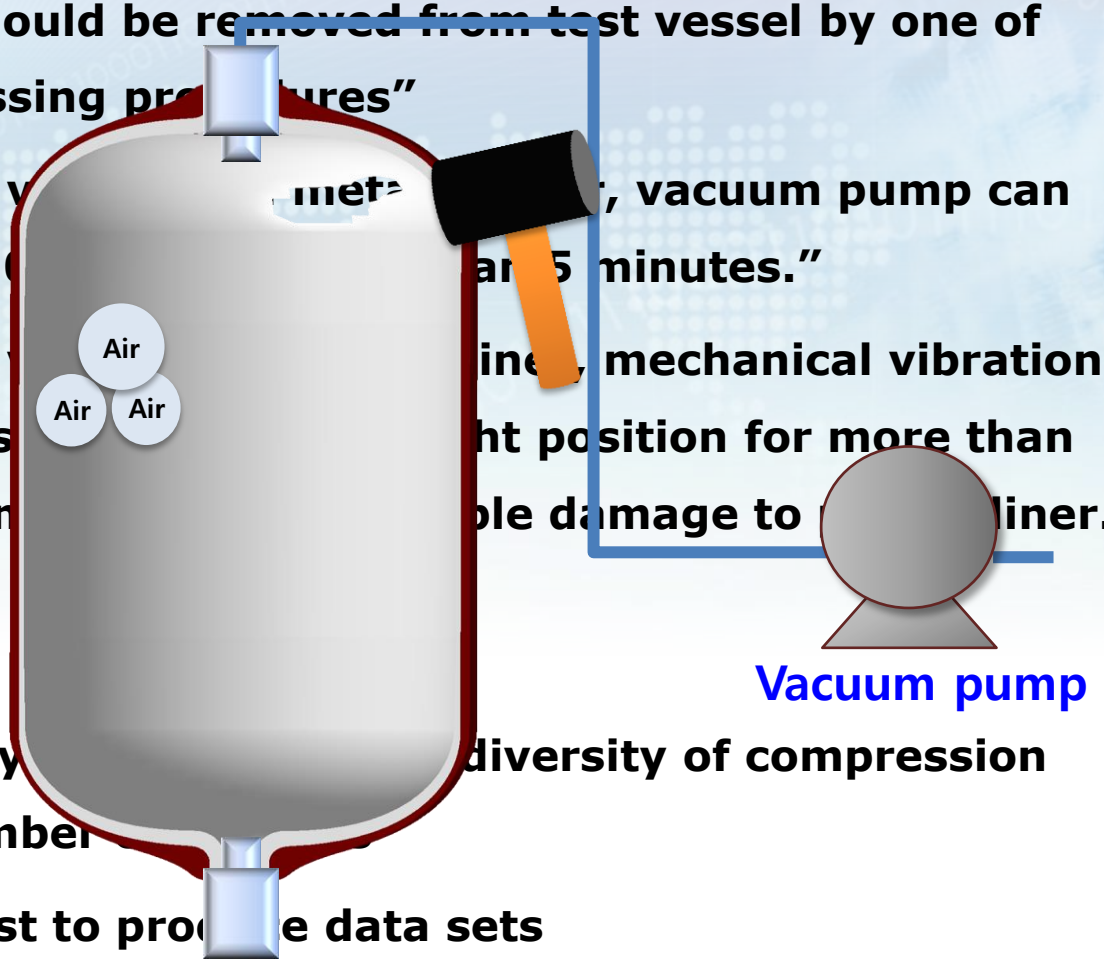
Test series

- **To determine new limit for compression frequency (currently, no more than 10 cycles) per minute**

10. Suggestions

Amendment of GTR No. 13

- 6.2.2.2 (a-1) "Air should be removed from test vessel by one of the following de-gassing pr ures"
- 6.2.2.2 (a-1-1) "For v met , vacuum pump can be applied at least 1 ar 5 minutes."
- 6.2.2.2 (a-1-1) "For in mechanical vibration can be applied to tes ht position for more than 5 minutes. Vacuum n ble damage to liner."



Round-robin tests

- To build up reliability diversity of compression frequencies and numbe
- To save time and cost to pro e data sets

Thank you for your attentions

Inquiry, Question, Collaboration

E-mail: cho225@kgs.or.kr