TESTING AND ANALYTICAL MODELING FOR PURGING PROCESS OF A CRYOGENIC LINE

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ABSTRACT
To gain confidence in developing analytical models of the purging process for the cryogenic main propulsion systems of upper stage, two test series were conducted. Test article, a 3.35 m long with the diameter of 20 cm incline line, was filled with liquid (LH_2) or gaseous hydrogen (GH_2)and then purged with gaseous helium (GHe). Total of 10 tests were conducted. Influences of GHe flow rates and initial temperatures were evaluated. Generalized Fluid System Simulation Program (GFSSP), an in-house general-purpose fluid system analyzer, was utilized to model and simulate selective tests.

INTRODUCTION
- Cryogenic main propulsion systems of upper stage purging scenarios
  - Purging of the Fill/Drain line after completion of propellant loading
  - Purging of the Feed/Drain line if the mission is scrubbed
- Flow rate of purging gas should be regulated
  - Exceeding maximum allowable pressure may lead to structural damages
- Objectives of the testing was
  - to measure how purging GHe behaved when it was injected into cryogenically chilled LH_2/GH_2 filled line
  - to support analytical purge model development applicable to any future launch vehicle that uses LH_2 as a propellant and purges Fill/Drain/Feed lines with GHe

TEST SETUP

- Insulated stainless steel incline line 3.35 m long with the diameter of 20 cm
- Fluid and wall temperatures and fluid pressures were measured at stations 1-6 and 1, 2, 4, and 6, respectively
- At station 6, two residual gas analyzers (RGA) were installed to measure the concentration of both GH_2 and GHe
- LH_2 entered and exited the test article via PV-11 and PV-12, respectively. Both valves were closed when test article reached steady state conditions
- Purging was accommodated via Purge Entry, as shown in Figure 1

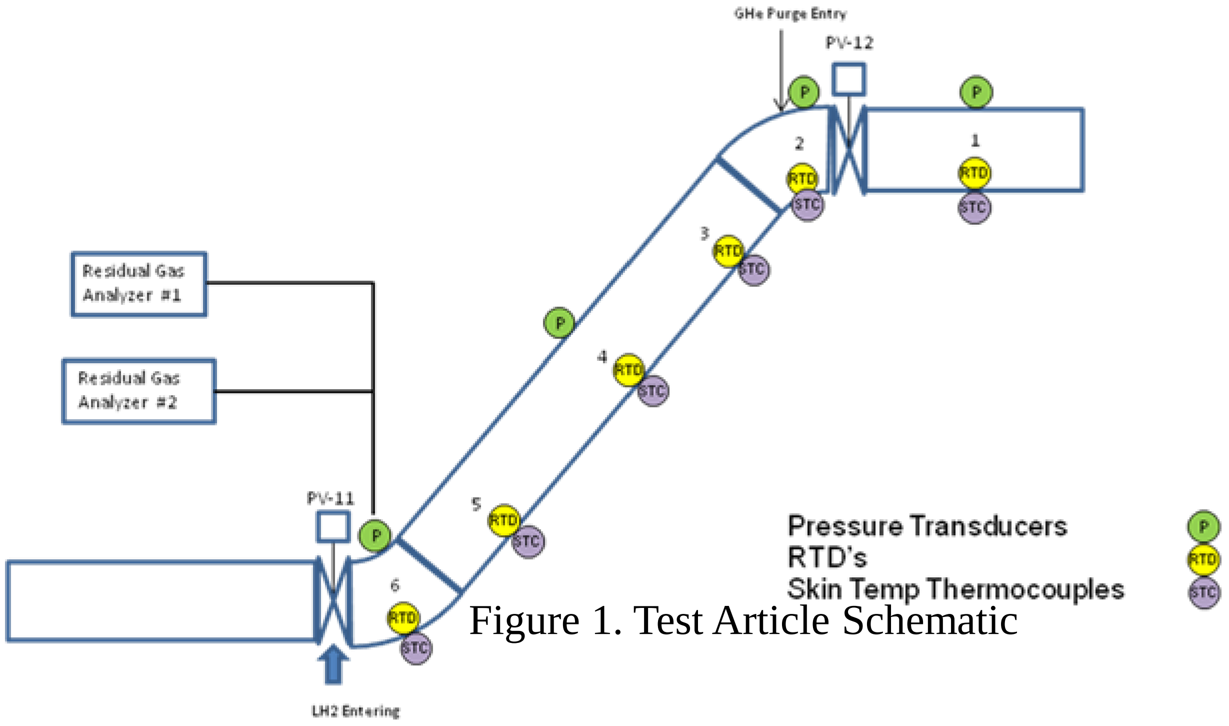

Figure 1. Test Article Schematic

TEST PROCEDURES

Two test series ,as shown in Table 1, were conducted at the Hydrogen Cold Flow Facility of West Test Area of Marshall Space Flight Center (MSFC)

- Test article was filled with
  - LH_2 in first series, tests 1-6
  - GH_2 in second test series, tests 7-10

Test #	Fluid	GHe Initial Temperature (K)	Purge Flow rate g/s
1	LH_2	291.5	3.18
2	LH_2	291.5	3.18
3	LH_2	291.5	5.9
4	LH_2	291.5	5.9
5	LH_2	330	5.9
6	LH_2	330	5.9
7	GH_2	291.5	5.9
8	GH_2	291.5	5.9
9	GH_2	330	5.9
10	GH_2	330	5.9

Table 1. Description of Each Test

RESULTS AND DISCUSSIONS

- Higher purge flow rate would lead shorter purge duration, as shown in Figure 2
- Purge process would not influence significantly by initial GHe temperature, as shown in Figures 3 and 4
- Utilizing GFSSP [1], tests 1, 3, and 7, were selected, simulated, and compared with test data
- Figures 5 –7 depict reasonable agreements between predicted and measured GH2 concentration at exit

ACKNOWLEDGEMENTS

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REFRENCES

1. "Generalized Fluid System Simulation Program (GFSSP) Version 6.0," A.K. Majumdar, A.C. LeClair, R. Moore, P.A. Schallhorn,
   NASA/TM-2013-217492, October 2013

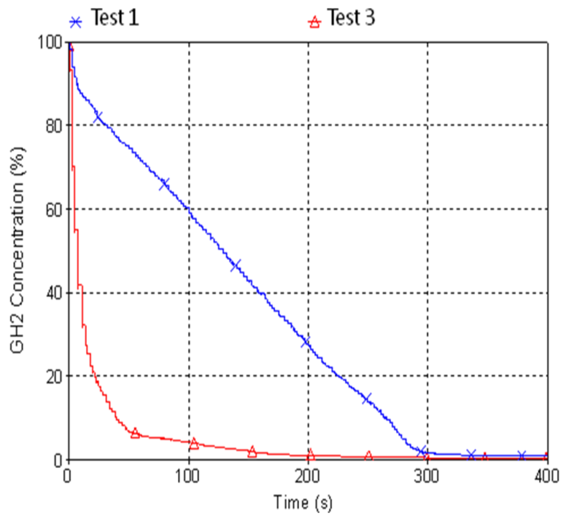

Figure 2. Purge Durations for Test 1and Test 3.

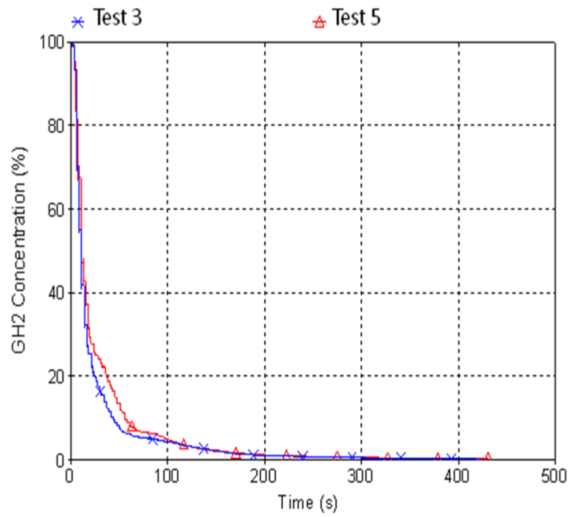

Figure 3. Purge Durations for Test 3 and Test 5

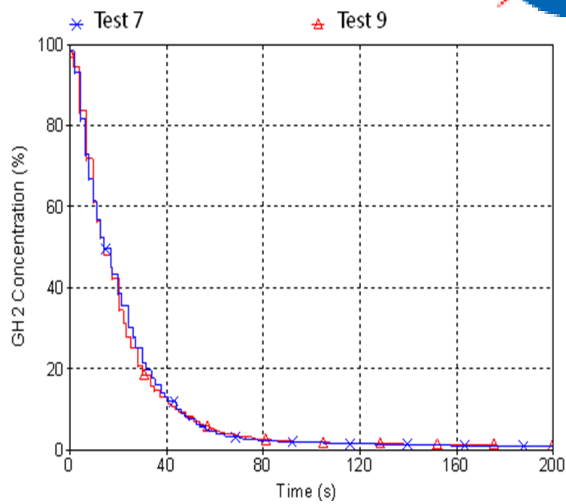

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Figure 4. Purge Durations for Test 7 and Test 9.

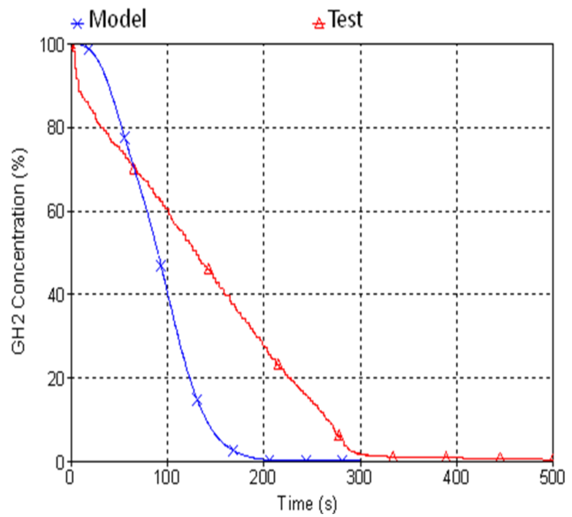

Figure 5. Concentration Histories for Test 1

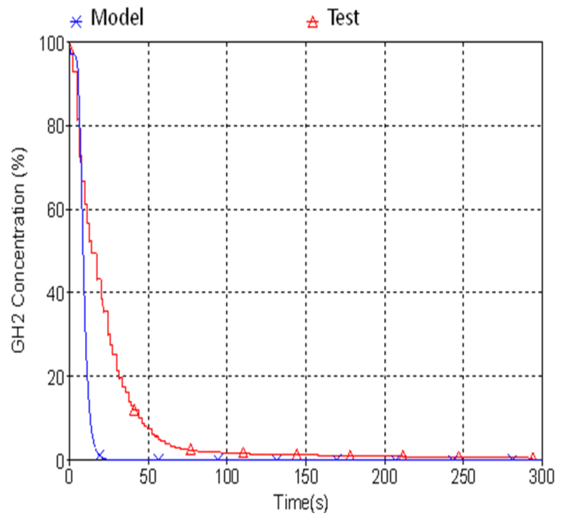

Figure 6. Concentration Histories for Test 3

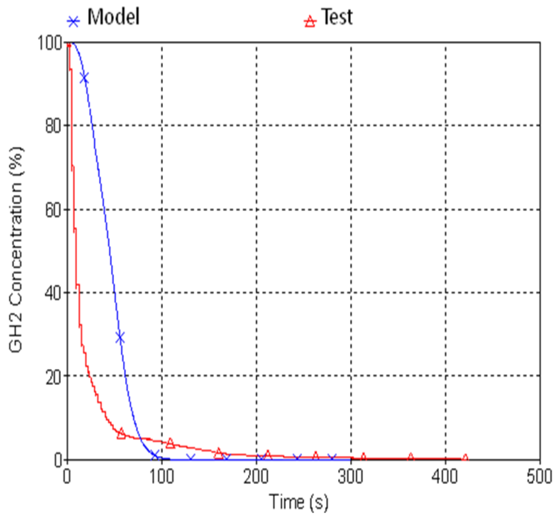

Figure 7. Concentration Histories for Test 7