Design Study for KSLV Integrated Power Plant Test Facility

Sun-Il Kang, Jung-Ho Lee, Young-Han Kim and Seung-Hyup Oh
Korea Aerospace Research Institute (KARI)
45 Eoeun-Dong, Yuseong-Gu, Daejeon, 305-333, Korea
aerodol@kari.re.kr

Keywords: Rocket, KSLV, IPP, Firing Test

Abstract

KARI is achieving the KSLV program according to National Space Technology Development Program. In this paper, the authors are intended to introduce the Integrated Power Plant (abb. IPP) test facility which will be constructed for the variety of tests on KSLV program.
IPP test facility refers to comprehensive testing equipment for liquid rocket launch vehicle. Using this facility, KARI can verify the adaptiveness of parts and subsystems for launch vehicle and finally can qualify the system characteristics of launch vehicle doing kinds of test including hot firing test. Using this facility, KARI can simulate the vehicle launching circumstances and it make to predict the performance of launch vehicle when its flight test.

Design Concept and Basic Requirements

This is a step which define the characteristics of facility and physical, functional, environment requirements. The authors make a definition about it as follows.

Design Concept

- IPP Test Facility is an equipment for execute integrated propulsion system test of various launch vehicles (including KSLV) developing by KARI or other institutes of Korea.
- The main purpose of this facility is to confirm the performance comprehensively and to certify parts and assemblies of launch vehicle and its propulsion systems.
- Location of facility : Naro Space Center (Goheung-Gun, ChollaNam-Do)
- Safety First : Test Facility must be equipped safety systems can be quick and safe deal with accident appearances
- Easy modification or expansion of facility if required.
- Environmental friendly design

Basic Requirements

- Capability of test facility
  - Maximum thrust : 200ton(1st stage)
  - Maximum burning time : 200sec(3 minutes) per 1 full time firing test
  - 2 times of full time firing test in 1 propellant filling should be possible
  - Two test stands(1st stage and 2nd stage of launch vehicle test stand apart) in one facility site area
  - Measurement channels : low freq. 500 ch, high freq. 100 ch or moreover
  - Sampling rate condition : low freq. 1kS/s, high freq. 100 kS/s or moreover
  - UPS battery backup time : Min. 20 minutes(in full load case)
- Functional requirements
  - Pressurization type of rocket engine : turbopump pressurization
  - 1st stage test stand may be consider testing the clustering type rocket engine
  - 1st stage test stand may be consider testing the gimballing type rocket engine(max. gimbal angle ± 8°)
  - Shall be able to operate in all season
  - United control and measurement of vehicle propulsion system and ground supply system should be possible
  - Emergency system available when abnormal operating conditions
  - Real time control, storage, display

Design Study for Test Facility

Based on design concept and basic requirements, the authors execute the design study for IPP test facility as follows.

Test Facility General Configuration

As like as the other liquid rocket test facility, IPP test facility has the configuration which consist 4 major systems and its substructures (Fig. 1).

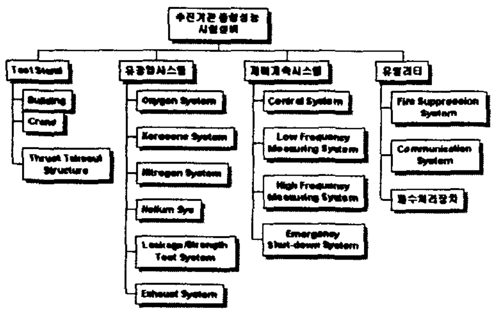

Fig. 1 Configuration of IPP Test Facility

Consider the location and its geographical features and configurations, the authors produce the test facility site layout and its graphical sketch like Fig. 2 and Fig. 3.

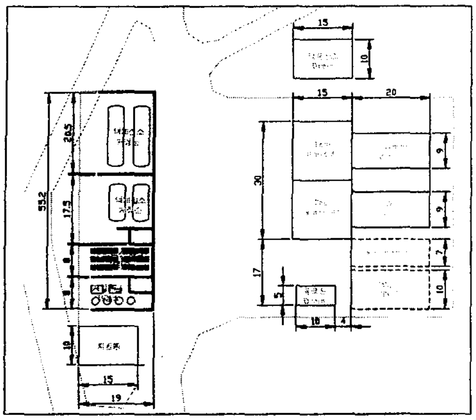

Fig. 2 Site Layout (2-D)

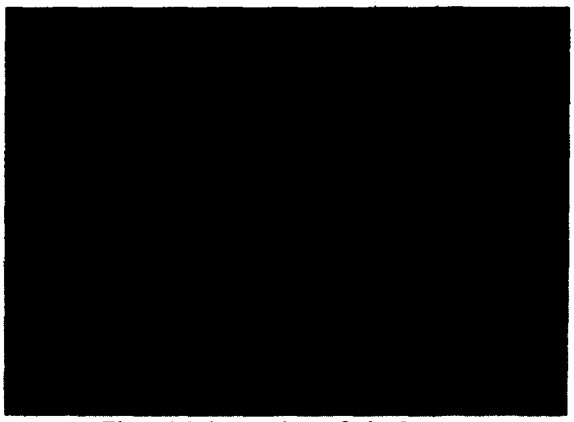

Fig. 3 Bird-eye-view of Site Layout

Test Facility Operating Capacity Analysis
Based on design concept and basic requirements, the authors execute the operating capacity analysis for IPP test facility as follows.

1. Reference Data (referred by 1st Stage)
   - Propulsion System Requirements
     - Thrust : > 100 ton (at sea level)
     - Specific Impulse : > 230 sec (at sea level)
   - Engine System Requirements
     - Turbo Pump feed type pressurization
     - Propellant : Kerosene(Fuel) + LOX(Oxidizer)
     - Regenerative combustor cooling
   - Propellant Feeding System Requirements
     - Oxidizer tank located forward fuel tank

	Fuel	Oxidizer
Inner Dia., m	2.4	2.4
Required mass, kg	14041	30643
Required volume, m^3	18.15	28.25
Ullage pressure, Mpa	0.327 ± 0.034	0.433 ± 0.034
Pressurant Flow rate, kg/sec	0.04	0.1

Table 1 Propellant Feeding System Spec. Analysis

- Pressurant tanks located inside the oxidizer tank
- Propellant flow rate : 116.8 kg/sec (fuel), 255.9 kg/sec (oxidizer)
- Total burning time : 116.7 sec

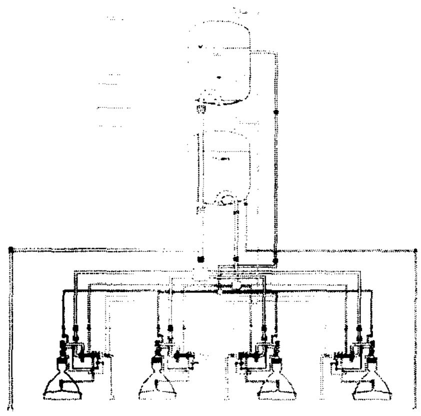

Fig. 4 Propulsion System P&ID

- Pressurant and storage pressure : Helium, 34 MPa
- Propellant tank specification : see Table. 1

2. Analysis Results
   - LOX Feeding System
     - For Oxidizer of vehicle propulsion system
     - Flow rate : Max. 20 m/sec
     - Storage volume : 200 Nm^3 (100 Nm^3 x 2 EA)
     - Operating pressure : Max. 0.5 MPa
     -

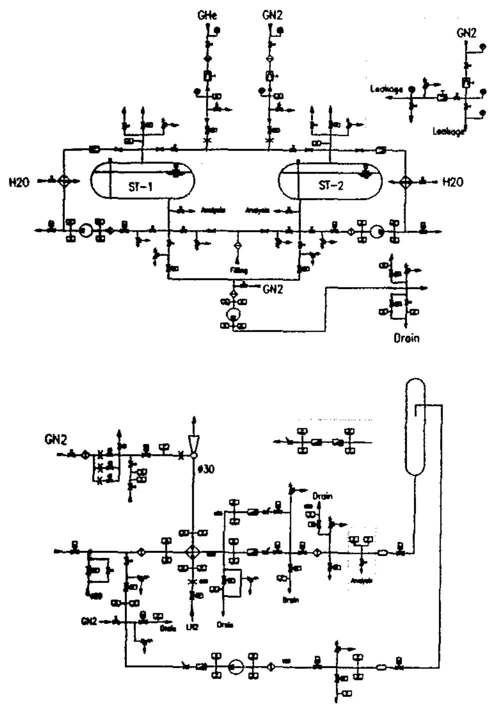

Fig. 5 LOX Feeding System P&ID

- Kerosene Feeding System
  - For Fuel of vehicle propulsion system
  - Flow rate : 1 ~ 1.5 Nm^3/min
  - Storage Volume : 130 Nm^3 (65 Nm^3 x 2 EA)
- Helium Feeding System
  - For Pressurant of vehicle propulsion system
  - Flow rate : 210 kg/h
  - Storage Volume : 40 Nm^3 (1 Nm^3 x 40EA)
  - Operating Pressure : Max. 40 MPa
- Nitrogen Feeding System
  - For purge and emergency pressurization of vehicle propulsion system and utility gas for ground feeding system

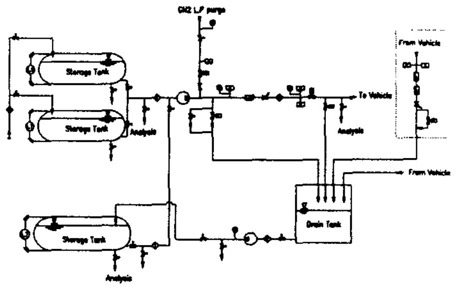

Fig. 6 Kerosene Feeding System P&ID

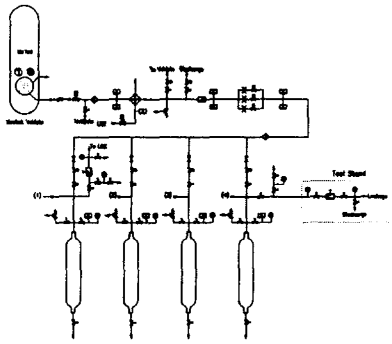

Fig. 7 Helium Feeding System P&ID

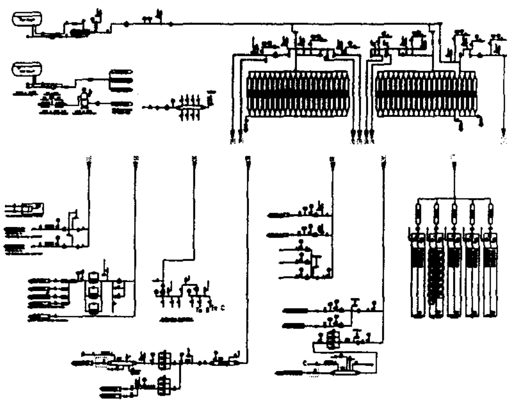

Fig. 8 Nitrogen Feeding System

- Liquid nitrogen storage volume : 100 Nm^3 (50 Nm^3 x 2EA)
- Nitrogen gas storage volume : 40 Nm^3 (1 Nm^3 x 40EA)
  - Operating Pressure : Max. 40 MPa
- Flame Deflecting System
  - For safe guide and discharge of engine exhaust gas and surplus propellants
  - Consist of water spray and its supplying systems, flame deflector and wasted water purifier system
  - Spray water flow rate : Max. 3 ton/sec

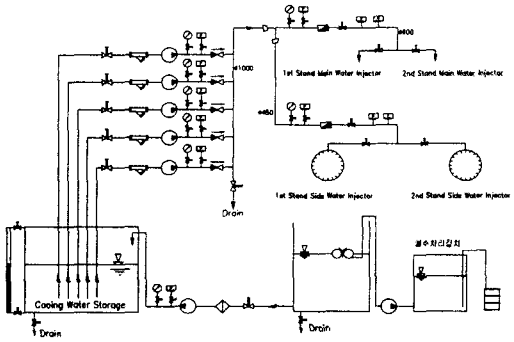

Fig. 9 Flame Deflecting System

- Control System
  - Adopt FPGA modules based on PXI bus
  - Adopt an Emergency blocking system
  - Realtime control logic
  - Dual control circumstance : adopt automatic and manual operating mode
- Measurement System
  - Adopt gateway for signal processing and A/D converting
  - Adopt an Ethernet LAN data communication based on fiber optic network
  - Consist low freq. DAQ(reliability first, measuring temperature, pressure, flow rate, etc.) system and high freq. DAQ(performance first, measuring pressure, vibration, acceleration, etc.) system

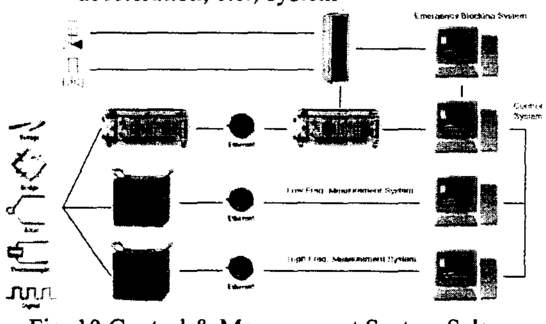

Fig. 10 Control & Measurement System Scheme

- Test Stand System
  - For protection external circumstances like wind, rain, etc. and taking out thrust produced by rocket engine and giving working area
  - Consist of Cabin, base structure, crane and elevator
  - Steel beam and concrete structure
  - Size : 30m × 25m × 35m(W×L×H)
  - Adopt coil spring type anti-vibration system
- Utilities

- For assisting test procedure progression and aid to manage emergency state
- Consist of fire suppression system and communication system (refer to Fig. 12)

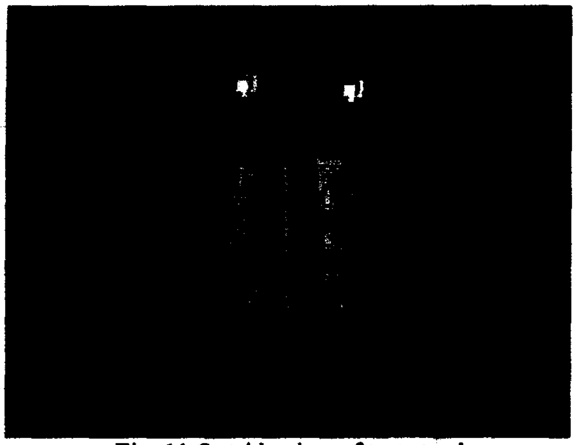

Fig. 11 Outside view of test stand

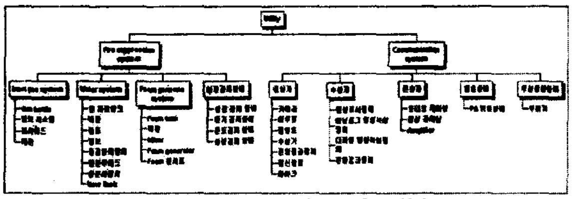

Fig. 12 Constitution of utilities

- Fire suppression system : use 3 kind of suppression solvents inert gas, chemical foam, water (refer to Fig. 13)

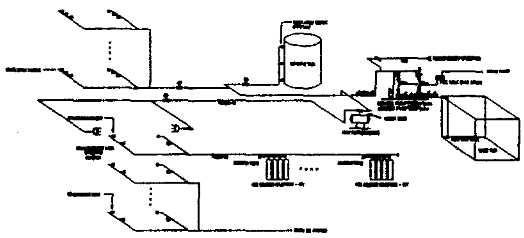

Fig. 13 Fire suppression System Scheme

Conclusion

Through this paper, the authors achieved basic design studies about test facility for launch vehicle propulsion system.
Based on it, the authors set up some proposals about design study for IPP test facility as belows ;

- Established the design concepts
- Produced basic design requirements
- Prepared the basic constitutions
- Established the specifications about test facility and its components.

Afterwards, deepening design study and detailing the specification, selecting the components will be needed and finally, all of the results of design study will be integrated and drawn a plan.
Besides, the authors have a plan to inquire data and set up rules about test facility operating paralleled.

Postscript

This paper is written as part of "Research and Development KSLV – I" supporting Ministry of Science and Technology and thanks for support.

References

1) Kang, S. I., Lee, J. H., Kim, Y. H., Oh, S. H., Cho, K. R. : Conceptual Design Study for KSLV IPP, The 4th Symposium on Space Launch Technology, 2003, pp.92-94.
2) Kang, S. I. : Construction and Verification of Test Facility for KSR-III Rocket Feeding System, KARI-PSI-TN-2001-005, 2001
3) Kang, S. I. : Test of KSR-III Rocket Propellant Feeding System Using PTA-II Test Facility, The Second National Congress on Fluid Engineering, 2002
4) Kang, S. I. : Conceptual Design Analysis of Integrated Power Plant Test Facility for KSLV, KARI-PSG-TM-2003-012, 2003
5) Hong, Y. S. : Space Propulsion Engineering, Chungmunkak, 1993