A Review of Thermal Vacuum Chamber Capability Performance at Acceptance Test Level

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***Abstract*— The development of Satellite Assembly, Integration and Test Centre at Malaysia Space Centre is another step taken by Malaysia Space Agency (also known as ANGKASA) in developing the space sector in the country. The centre provides a facility for assembly and integration of satellite as well as the launch and environmental testing for local and others countries in South East Asia region. It comprises of various test equipment such as thermal vacuum chamber, vibration test system, electromagnetic chamber, acoustic chamber, mass properties measurement system and alignment measurement system. The thermal vacuum chamber is customized and the only chamber available in the country. It is capable to simulate space environment with high vacuum capabilities and wide range of heating and cooling capabilities. The system design review for the chamber was done in 2006 and its components have been delivered from Italy in 2007. However, due to some technical issues, the delivery to the site was delayed and the system had been stored in warehouse for almost three (3) years. Fortunately, at the end of 2009, the lab construction started and the system was able to be delivered at Malaysia Space Centre in 2010. The installation process including integration, assembly, testing and commissioning had been taking place in 2012 until 2014. Finally, in the middle of the year 2014, the system was successfully installed, commissioned and tested. In order to ensure the system complies the specification and can performs the required test, the acceptance test was conducted at the end of the commissioning phase. In this paper, the acceptance test result will be discussed in order to see the performance of the thermal vacuum chamber. This paper is organized as follows: Section II provides overview of thermal vacuum chamber; Section III describes of methodology used; Section IV discusses the result and finally, Section V provides summarization of findings.**

Keywords—thermal vacuum chamber; vacuum; temperature

I. INTRODUCTION

A satellite needs to withstand the condition such as rigors of the lift off and ascent environment occur during launch phase and extreme conditions and operational environment in orbit. Mechanical and thermal effects introduced a lot of constraints to the structure design of a spacecraft. It must be thoroughly tested to ensure survivability of the spacecraft in space. The satellite integration, assembly and testing facility is a facility that is able to simulate as closely as possible to those environments the spacecraft will encounter and it is constructed to accommodate the testing requirements for both ground-based instruments and fully qualified space flight hardware.

Thermal and vacuum test is extremely important to ensure the satellite can survive the harsh environment of space. All equipment and subsystems must be able to operate in the extreme temperature. Therefore, the thermal vacuum chamber will provide a testing environment that can be simulated to be nearly the same as the space environment encountered by the spacecraft. The testing conducted in the chamber will verify that each component and subsystem are well protected and will always be operating in their desired temperature range.

A typical thermal environment is achieved by passing liquids or fluids through thermal shrouds for cold temperatures or through the application of thermal lamps for high temperatures. This chamber is very important to provide as close as possible a space-liked thermal environment such that the spacecraft is ready to face the actual environment upon launching. In fact, any deformations or defects can be detected early and the repair and modifications can be executed immediately as soon as it is determined that the spacecraft does not comply with the criteria prepared by the thermal engineer.

A review has been done to see the thermal vacuum chamber capability performance in term of vacuum and temperature at acceptance level before the actual test can be run by the chamber. The acceptance test for thermal vacuum chamber was conducted in order to verify the design, manufacturing and assembling process in terms of functionality and performance to be conformance with the specification of the equipment. The verification by test also consist of measuring product performance and functions under representative simulated environments.

II. SYSTEM DESIGN

The thermal vacuum chamber in ANGKASA is a chamber that has been designed to perform space environment simulation test achieving temperature ranging from -180°C to +150°C with pressure up to 10^{-7} mbar. It has been designed with useful dimension of 4000mm diameter by 4000mm length and an internal net capacity of 50m^3. The chamber structure is a vacuum-tight cylinder-shaped with convex walls made in shot-penned stainless steel AISI 304 L. This chamber is placed in a metallic frame containing the machines such as thermoregulation group, cryogenic pumps, roots pump and etc. The opening system for the chamber was designed to slide horizontally using door trolley mechanism. This mechanism is includes a safety brake, which can stop the chamber's door movement with pneumatic attachment jacks. The length of the rails is 4500mm and it is also made from 304 type stainless steel.

A. Control System

The control system for thermal vacuum chamber used supervisory control and data acquisition (SCADA) concepts and programmable logic controller (PLC) from SIEMENS. The PLC controls the whole system with eventually distribute I/0 modules. It is connected to the computer and processes all the tasks that were programmed in it. The chamber control system is also provided with LCD panel for low level control and monitoring. It is connected to the PLC and located near to chamber. Figure 1 shows the control system architecture for TVC.

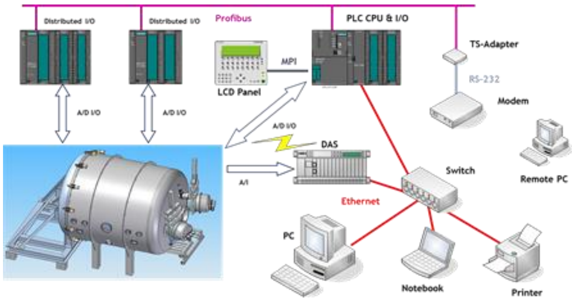

Fig. 1. Control System Architecture

B. Vacuum Pumping System

The thermal vacuum chamber compose of two (2) sets of pumping system which are pre-vacuum and high vacuum system. Pre-vacuum system consists of root pump and screw pump while the high vacuum system consists of cryogenic pump and turbo molecular pump. All pumps are oil free to prevent contamination from entering the chamber. The pumping system will working together to achieve 10^{-7}mbar.

C. Thermoregulation System

Thermoregulation system is designed with double mode condition that is cooling and heating system. The shroud is capable of being cooled down to -193°C when the shroud is flooded with Liquid Nitrogen (LN2) and capable of being heated up to 150°C when the shroud is thermoregulated by Gaseous Nitrogen (GN2). The system is designed to achieve temperature stability ±1°C.

D. Temperature Sensing

Thermocouples type "T" and Platinum Resistance Thermometer (PT-100) were used for continuous monitoring of thermal condition in the chamber and automation of thermo-regulation system.

III. METHODOLOGY AND TESTING PROCEDURES

The verification methods that had been used to verify the performance of the thermal vacuum chamber are inspection, test (including demostartion), analysis (including similarity) and review of design. These methods is described as below:

- Inspection : verification by inspection shall consist of visual determination of physical characteristics. Physical characteristics include constructional features, hardware conformance to document drawing or workmanship requirements, physical conditions, software source code conformance with coding standards.
- Test (including demonstration) : verification by test shall consist of measuring product performance and functions under representative simulated environments.
- Analysis (including similarity) : verification by analysis shall consist of perfroming theroretical or empirical evaluation using techniques agreed. Techniques comprises systematic, statistical and qualitative design analysis, modeling and computational simulation.
- Review of design: verification by review-of design (ROD) shall consist of using approved records or evidence that unambiguously shows that the requirement is met. Example of such approved record are design documents and reports, technical descriptions and engineering drawings.

The pre-requisite requirements also conducted prior the acceptance test such as calibration of the thermocouples, vacuum sensors and others.

The thermal vacuum test was conducted based on test profile as described in Table I and Table II. Test profile in Table I is used to verify the vacuum performance while test profile in Table II is used to verify the temperature performance.

TABLE I. TEST PROFILE FOR VACUUM PERFORMANCE TEST

No	Vacuum Performance Test		
	Type of test	***Test Profile***	
1	Ultimate Vacuum Test	Vacuum level	10^{-7} mbar
		Duration	10^{-6} mbar within 5 hours

TABLE II. TEST PROFILE FOR TEMPERATURE PERFORMANCE TEST

No	Temperature Performance Test		
	Type of test	***Test Profile***	
1	Test Temp. Range GN2	Temp	-173°C to +150°C
2	Test Temp. Range LN2 + IR	Temp	-180°C to +150°C
3	Test Temp. Fluctuation and Uniformity	Max. Average Temp. Fluctuation	±1°C
		Max. Temp. Difference	±10°C

A. Test Setups

The test setup for the thermal vacuum test consists of 20 of thermocouples type T that were attached at the shroud of the chamber as in Figure 2. This configuration is needed in order to monitor the uniformity of temperature inside the chamber.

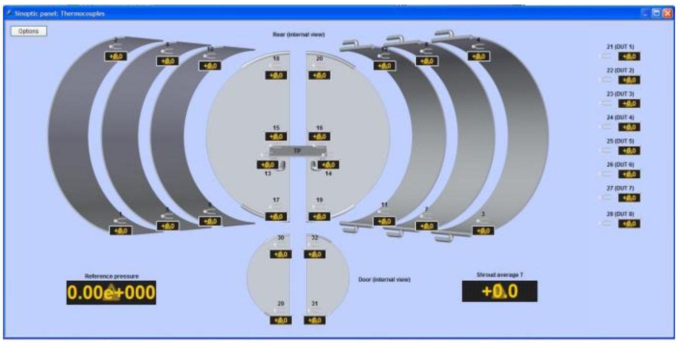

Fig. 2. Location of 20Nr. Thermocouple at the shroud inside the Chamber

IV. RESULTS

A. Vacuum Performance Test

The result prove that there is no anomaly occurred during the test profile and it achieved the desire specification. Below figures show the result for ultimate vacuum test, quick venting test and slow venting test.

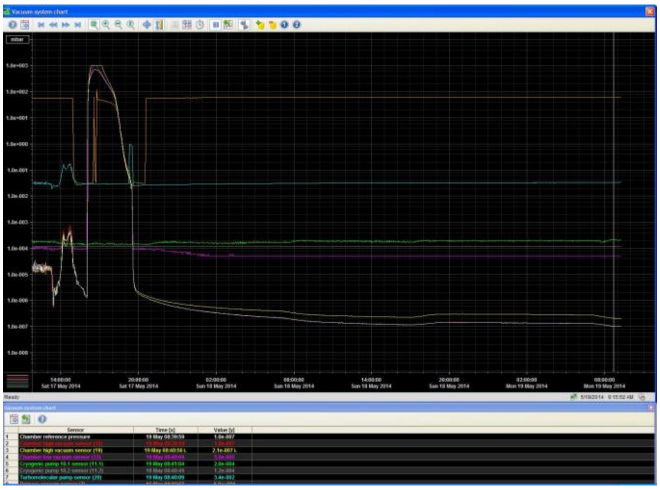

Fig. 3. Ultimate Vacuum Test 10^{-7}mbar

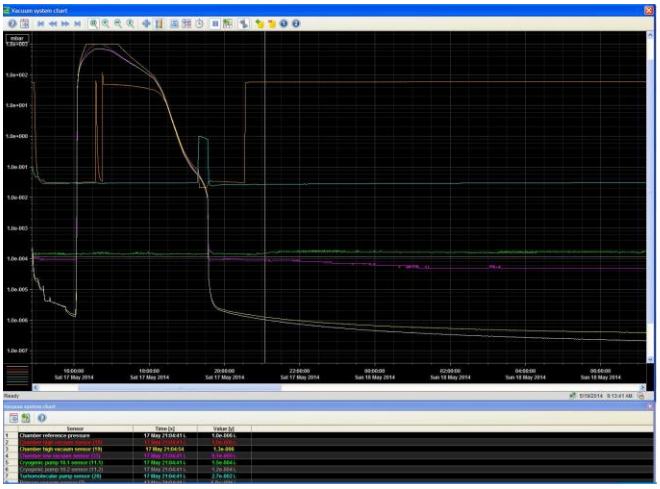

Fig. 4. Ultimate Vacuum Test 10^{-6}mbar within 5 hours.

B. Temperature Performance Test

The result of temperature performance test is shown as Figure 5, Figure 6, Figure 7 and Figure 8.

Fig. 5. Test Temp. Range GN2 for -173°C to 150 °C

Fig. 6. Test Temp. Range GN2 for -173°C to 150 °C

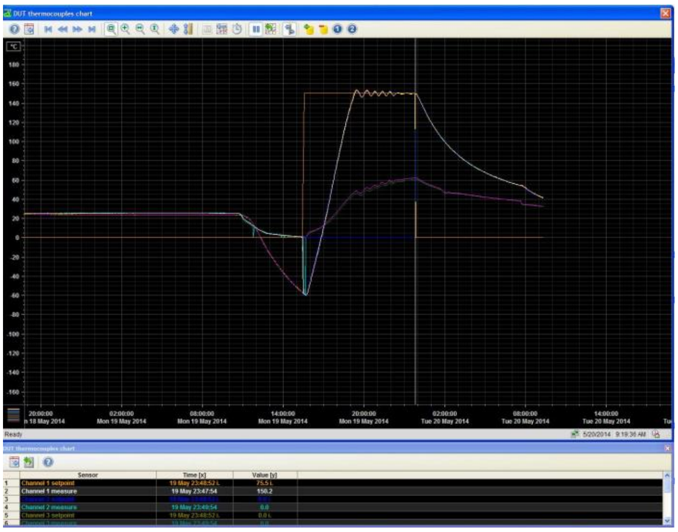

Fig. 7. Test 2 LN2 +IR +150 End Result

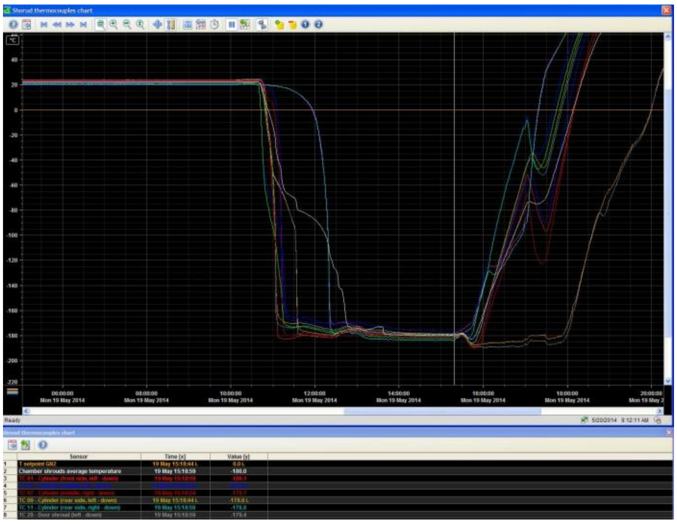

Fig. 8. Test 2 LN2 +IR -180 End Result

V. CONCLUSIONS

From the acceptance test that had been conducted proved the system is able to achive the vacuum condition up to 10^{-7}mbar and temperature range from -180°C to +150°C. This condition allow the system to run thermal vacuum test for satellite before it can be launched to the orbit. It is also in accordance with the available international standard such as ECSS. Throughout the testing and verification process, there main problem which could jeopardized the thermal vaccum process was the chamber leakage problem. As a counter measure, there are several precaution steps that need to be consider to avoid the chamber leakage problem such as cleaning of the LN2 intefacing pipe, proper tork wrenge value during thightening the bolts and the . It is crucial because, the leakage problem can only detected after the low vacuum level at 10^{-3}mbar couldn't be reached withih 3 hours. Apart from that, there are some other features that could be consider for system upgrading for the future work such as:

a) Cleanliness control and monitoring;

b) LN2 piping mechanism; and

c) Loading and unloading methods.

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