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ESTABLISHMENT OF THE ENGINEERING RELIABILITY EVALUATION SYSTEM FOR THE DEVELOPMENT OF UHV PUMPS

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Abstract: Engineering reliability evaluation system has been under establishment for the development of ultrahigh (UHV) vacuum pumps such as 3,600 L/s cryo and 2,500 L/s turbo-molecular pumps (TMP). This paper briefly addresses the utilization of the characteristics evaluation system already developed in KRISS to design, characterize, and establish the reliability evaluation system through two project years ahead. The purpose ensured of the main national project is the completion of the commercialization of UHV pumps in recognition of international engineering reliability.

Keywords: Engineering reliability, Cryo pump, TMP, high vacuum, characteristics evaluation.

1. INTRODUCTION

The Korean national project for the development of UHV pumps has been issued from December of 2008 to September of 2013 for five project years with four sub projects logically composed as follows;
Sub project 0: Development of UHV pumps, General,
Sub project 1: Development of the low vibration cryo pumps,
Sub project 2: Development of ultra high speed compound turbo-molecular pump, and
Sub project 3: Development and establishment of integrated characteristics evaluation system for UHV pumps.

The establishment of engineering reliability evaluation system in Sub project 3 has been initialized from October of 2011 to September of 21013 as a part of the whole project years for the completion of UHV pump development. In order to recognize the international engineering reliability, the system needs to be developed along the measurement traceability with metrological assurance worldwide.

As seen in Fig. 1 the critical measurement parameters to ensure the characterization of the UHV pump are pressure (p), mass flow (Q), and orifice conductance (C). In the case of the orifice application the molecular flow region in the orifice chamber is prevailed in the characteristics evaluation system of Fig. 2, which introduces the constant volume flow meter system (CVFM) developed for measuring pumping speed of dry vacuum pumps[1]. The CVFM was shown to demonstrate the expanded relative uncertainties of 0.5% or less (coverage factor k = 2, 95% confidence level) for measurement of throughputs in the range of 0.5 ~ 1000 mbar.l/s.

However, the viscous and molecular mass flow range of less than 0.01 mbar.L/s is not well clearly characterized in the vacuum application field. In this reason we leave this issue in this paper for one of future work items, i.e., the completion of the traceability chain of mass flow with metrological approach.

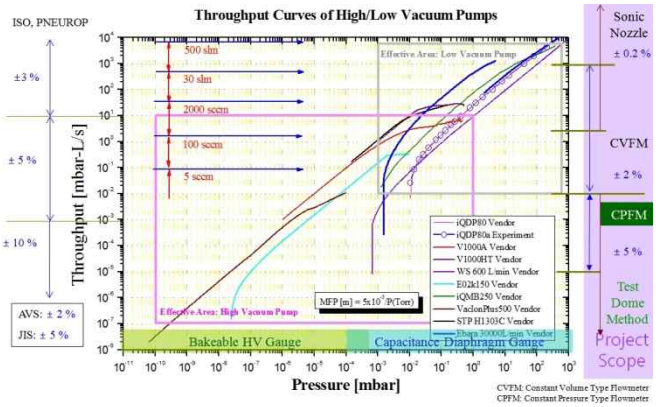

Fig. 1. Throughput curves of vacuum pumps in the domain of pressure vs. mass flow rate map

Fig. 2. Characteristics evaluation system of UHV pumps

2. CHARACTERISTICS EVALUATION SYSTEM

The measurement of capability of the CVFM was exploited to calibrate 0.03, 0.2, and 1.6 mm throat diameter sonic nozzles. Calibration results illustrate that the combined relative uncertainties of the calibrated sonic nozzles approached the measurement capabilities of the

CVFM[2]. The calibrated sonic nozzles were demonstrated to enable precise measurement of pumping speeds of a dry vacuum pump under test as much as the measurement capability of the CVFM. More specifically, the difference was found to be within 0.2% even in the five-decade range of 0.01 ~ 1000 mbar.L/s.

Upon the results previously discussed about the mass flow system and international measurement procedures[3-9], the characteristics evaluation system for UHV pumps was schematically drawn as in Fig. 3 and Fig. 4. As in Fig. 5 the measurement parameters for UHV pumps includes pumping speed, ultimate pressure, power consumption, noise, mass flow rate, vibration, and others dependent on the pump type.

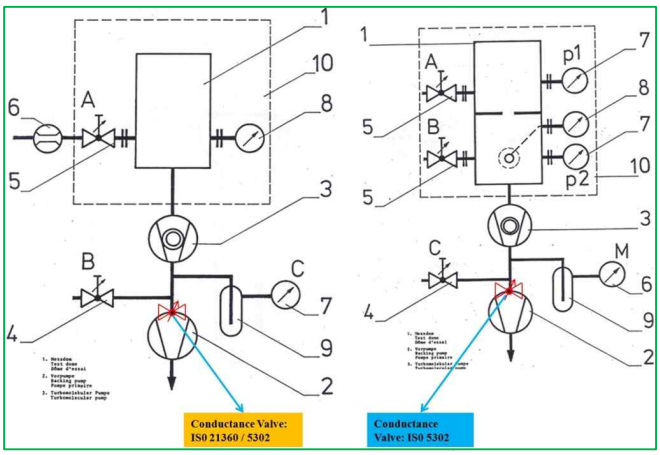

Fig. 3. Schematics of the characteristics evaluation system

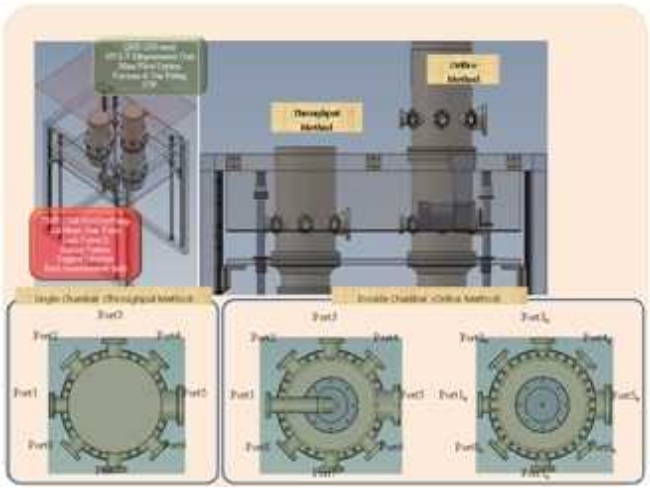
Fig. 4. System design of throughput and orifice method

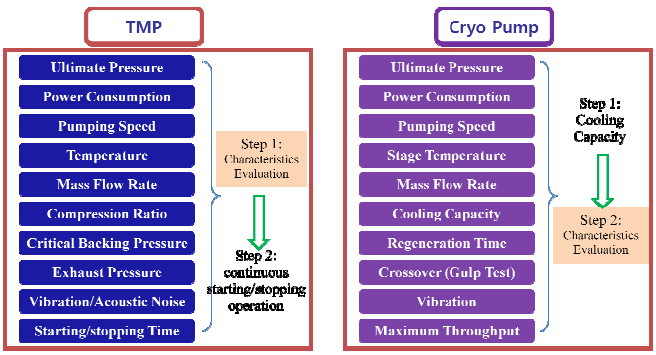

Fig. 5. Measurement parameters in laboratory

3. TEST PROCEDURE AND RESULTS

The pumping speed or volume flow rate, the most significant measurement parameter of UHV pumps, cannot be measured directly, thus has to be clearly defined to evaluate the pump characteristics. In timely manner the parameter can be experimentally obtained through the procedure mentioned in Fig. 6.

Other parameters such as vibration, noise, power in Fig. 5 may also be measured simultaneously with pumping speed measurement or different ways with independent evaluation systems for continuous starting/stopping operation for TMP, and cooling capacity measurement for cryo pump.

Pumping speed measurement

1. S [L/s] is physically "volume flow rate", which can not be measured directly.
2. Measure q & p, in a time.
3. $S=q/p$
4. $q=q_{\text{(flow meter)}}$ or $q=C_o(P_1 - P_2)$
5. Minimum 3 pressures in a decade
6. Plot relations S-p or S-q.

Fig. 6. Procedure of pumping speed measurement

The expanded uncertainty of the pumping speed measured with the throughput method is less than 10 % (coverage factor = 2, 95% confident level)[4].

The results of the characteristics evaluation for UHV pumps developed with Sub project 1 and 2 in the 1st fiscal project year from December, 2008 to September, 2011 were shown in Fig. 7, Fig. 8, and Fig. 9. In the case of 3,600 L/s cryo pump the pumping speed was above 4, 250 L/s with both HC 70 and CP2800. This means the target value of the 1st fiscal year, 3,600 L/s, has been successfully achieved.

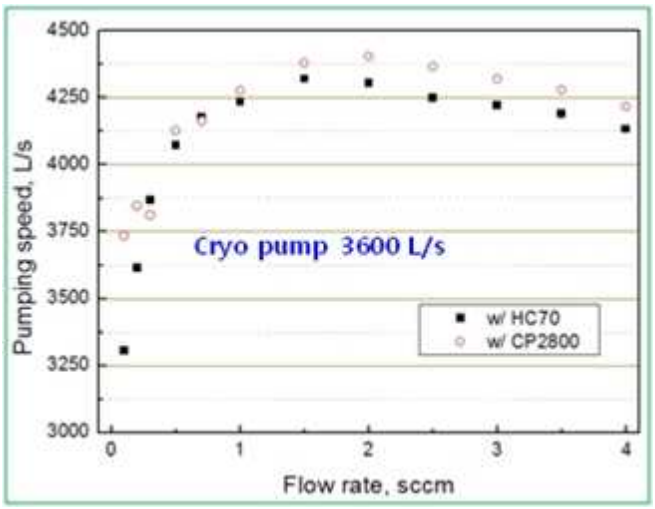

Fig. 7. Pumping speed measurement of the cryo pump developed in the 1st fiscal project year

In the case of 2,500 L/s TMP the pumping speed was above 2,450 L/s, and the ultimate pressure at 22,000 rpm 6.4 × 10^{-8} mbar. This means the target values of the 1st fiscal year, 2,500 L/s and 10^{-8} mbar, have been also successfully achieved.

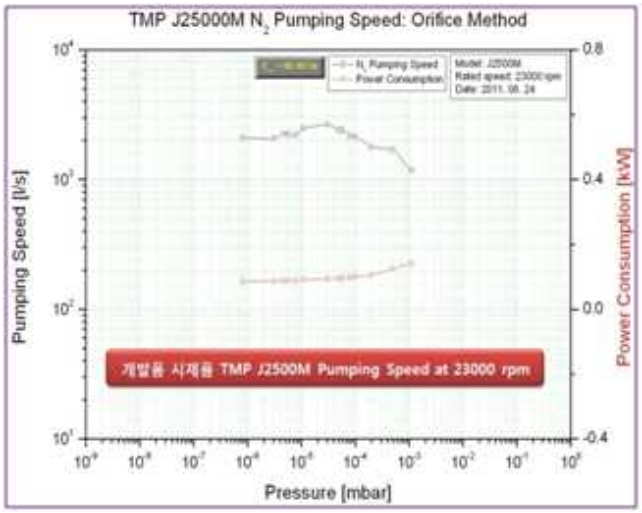

Fig. 8. Pumping speed measurement of the TMP developed in the 1st fiscal project year

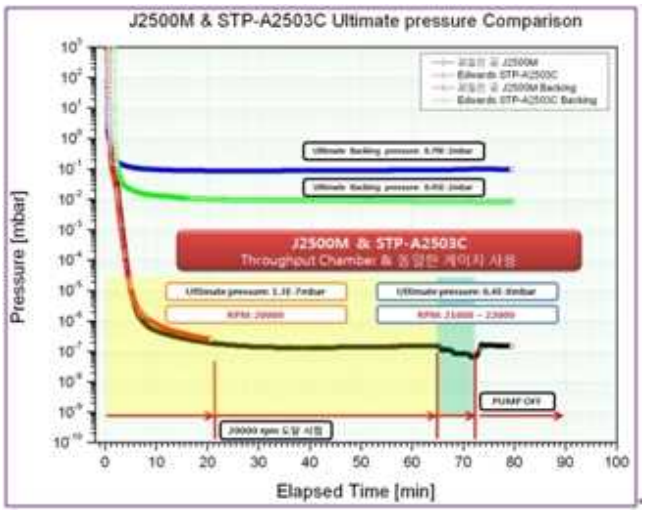

Fig. 9. Ultimate pressure measurement of the turbo-molecular pump developed in the 1st fiscal project year

4. ENGINEERING RELIABILITY SYSTEM

Fig. 11 illustrates the developmental stage of UHV pumps in both 1st and 2nd fiscal years. In 1st fiscal project years both type of UHV pumps had been on the right track of development initially designed with government funds. However, the final purpose of the 2nd stage development is the completion of commercialization of the pumps. That means, achievement of international engineering reliability is very important, and must be completed in two years. For this reason

One of the mostly focused evaluation process will be engineered in the actual process line such as semi-conductor manufacturing factory with parameters projected in Fig. 11.

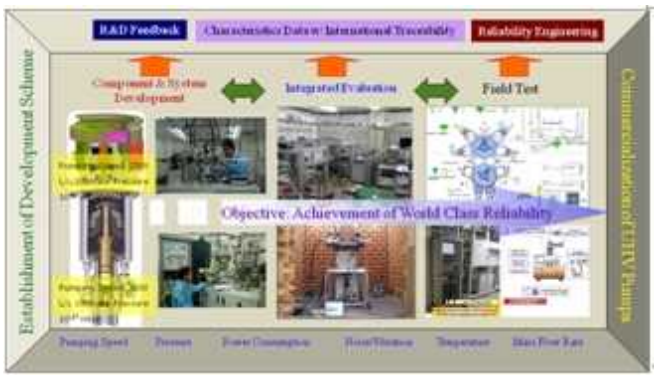

Fig. 10. Commercialization Flow Chart

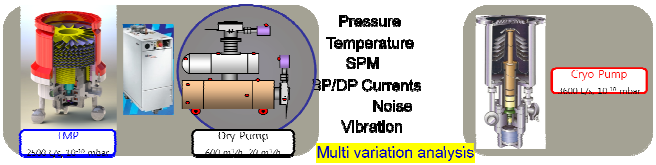

Fig. 11. Measurement parameters in the process sites

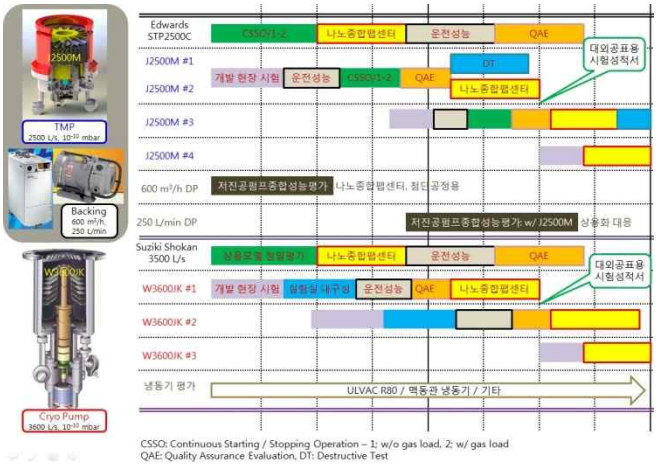

Fig. 12. Time table of the establishment of the engineering reliability evaluation system for UHV pumps

5. REMARKS

The whole schematic design and establishment processes of the engineering reliability system will be discussed with Fig. 12 and Fig. 13 in the poster session.

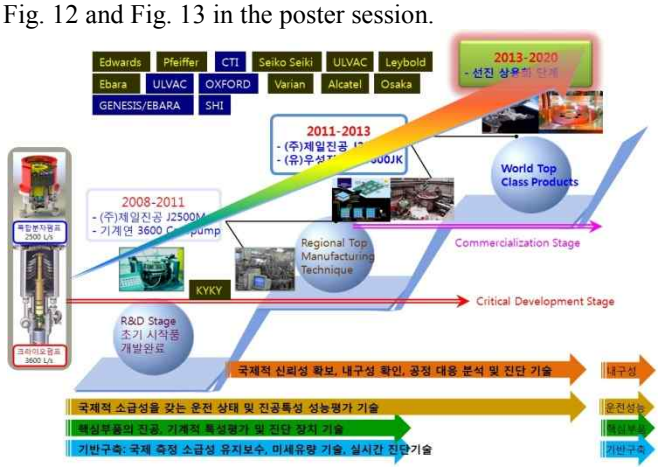

Fig. 13. Realization of the development of UHV pumps

6. ACKNOWLEDGMENTS

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