

Pump Performance Enhancement for Airborne Contamination Monitors in Nuclear Facilities

Yang Dongam*, Lee Sungho
Korea Atomic Energy Research Institute, KAERI
dayang@kaeri.re.kr

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1. Introduction

Operators of nuclear facilities, including the Korea Atomic Energy Research Institute (KAERI), bear a fundamental obligation to ensure the radiation safety of both radiation workers and the general public. Such responsibilities are clearly stipulated in national regulatory frameworks, such as the Nuclear Safety Act. To fulfill these obligations, continuous surveillance of radiation environments within nuclear facilities is essential, and Radiation Monitoring Systems (RMS) are widely employed for this purpose.

The primary function of an RMS is to provide timely and accurate alarms whenever radiation levels detected by monitoring instruments rise during radiation-related operations. By issuing such alarms, RMS play a vital role in safeguarding radiation workers and the public, while minimizing unnecessary radiation exposure.

Radiation monitoring systems are generally classified into two categories: area gamma monitors and airborne contamination monitors. Area gamma monitors directly detect gamma radiation at the location where detectors are installed, whereas airborne contamination monitors assess the level of radioactive particulates in the atmosphere. In the latter case, air is drawn into the system, and suspended particles are collected on a filter. A detector then evaluates the filter for radioactive contamination. To ensure representative sampling, airborne contamination monitors typically employ pumps that maintain an airflow rate exceeding 20 L/min, a rate greater than the average breathing volume of an adult radiation worker. Reliable air and particle sampling are therefore indispensable for the accurate performance of these monitors.

This study introduces the results of a pump performance improvement project carried out at KAERI for airborne contamination monitors. In conventional commercial systems, each monitor is equipped with an individual small-capacity pump. While this configuration enables localized sampling, it presents significant drawbacks, including reduced maintenance efficiency and a higher frequency of failures due to the limited durability of small pumps. To overcome these limitations, KAERI developed an enhanced system in which a single large-capacity pump is capable of providing airflow to as many as five airborne contamination monitors simultaneously. The adoption of a large pump not only reduces failure rates but also

improves maintainability, particularly with respect to consumable components such as carbon vanes and bearings.

2. System Description

In the airborne contamination monitors previously operated at the Korea Atomic Energy Research Institute (KAERI), the pump model employed was the VT 4.8 manufactured by Becker. In the present improvement project, the pump was upgraded to the WVS-8H model manufactured by Wonchang Vacuum. The detailed specifications of the pump are summarized in Table 1.

	VT 4.8 (Previous)	WVS-8H (Improved)
Maximum Flow Rate	1,115 L/min	152 L/min
Maximum Vacuum	≈ 150 mbar	≈ 150 mbar
Motor Power	440 W	1,500 W

Table 1. Specifications of the VT 4.8 and WVS-8H vacuum pumps.

This small-capacity previous pump(Model VT 4.8) was originally used to supply the airflow required for a single airborne contamination monitor. The upgraded pump is capable of providing sufficient airflow to operate more than five airborne contamination monitors simultaneously. The newly installed pump system was configured as illustrated in Fig. 1.

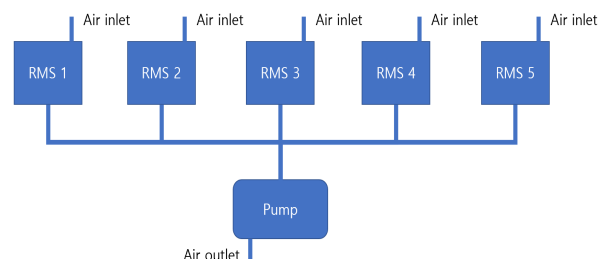


Figure 1. Schematic configuration of the newly developed pump system.

2.1 Configuration

As part of the recent performance enhancement project, the vacuum pumps were no longer connected

directly to the mains supply but were instead integrated into a control system to optimize their operating characteristics in the field. The facility's 110 VAC input power was stepped up to 220 VAC using a transformer to ensure proper voltage supply for the WVS-8H pump. In addition, an inverter was employed to modulate the supply frequency, thereby delivering an optimized electrical input to the pump. Through this configuration, each airborne contamination monitor receives the appropriate flow rate while the pump rotational speed is reduced, which in turn lowers the mechanical load during operation. Frequency setpoints are determined automatically by the Pump System Controller based on vacuum pressure feedback. For the five airborne contamination monitoring units installed at the Korea Atomic Energy Research Institute, it was confirmed that the operating condition shifted from 220 VAC at 60 Hz to 220 VAC at 45 Hz. The overall pump system configuration is illustrated in Figure 2. Figure 3 presents the configuration interface of the developed pump control system.

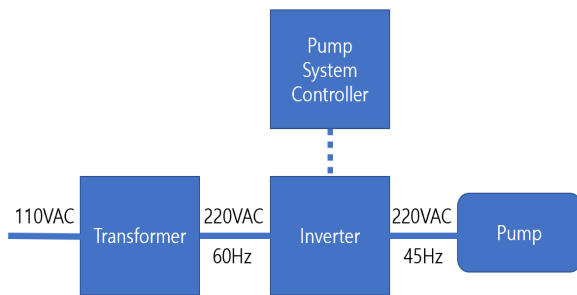


Figure 2. Electrical configuration of the pump control system.

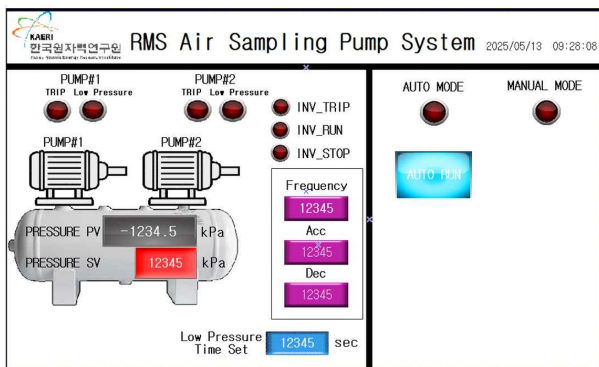


Figure 3. User interface of the developed pump control system.

2.2 Performance Evaluation

2.2.1 Power Consumption

In the initial configuration, five small pumps were required to provide the necessary flow for five airborne contamination monitors, resulting in a total power consumption of 2,200 W. By employing a single pump to supply all five monitors, the maximum power requirement was reduced to 1,500 W. Furthermore, by

controlling the operating frequency from 60 Hz down to 45 Hz, the power consumption decreased further to approximately 1,125 W. This corresponds to a reduction of about 49% compared with the original 2,200 W demand.

2.2.2 Pump Load

By controlling the pump to operate at 45 Hz instead of 60 Hz, significant advantages were achieved not only in terms of power consumption but also with respect to pump load. As the rotational speed decreased from approximately 1,160 rpm to 870 rpm, the mechanical load imposed on the pump was reduced accordingly. This reduction in load contributes to an extended service life of the pump, while the wear of consumable components such as bearings and carbon vanes is decreased by approximately 25%.

2.2.3 Maintenance Convenience

Airborne contamination monitors in nuclear facilities typically employ rotary vacuum pumps, which require essential maintenance of key consumable components such as bearings and carbon vanes. The previously used VT 4.8 pump, due to its compact structure with major components tightly integrated within a small volume, posed considerable challenges for maintenance personnel when disassembly and servicing were required. In contrast, the newly installed WVS-8H pump features a more spacious internal layout, allowing for easier access to critical parts and thus facilitating maintenance operations. Moreover, while the previous pump was a foreign product with significant difficulties in securing consumables and spare parts, the WVS-8H is domestically manufactured, making the procurement of essential materials more straightforward.

3. Conclusion

The implementation of the WVS-8H pump with inverter-based frequency control at KAERI demonstrated significant improvements in the performance of airborne contamination monitoring systems. Replacing multiple small-capacity pumps with a single large-capacity unit reduced total power consumption by approximately 49% and decreased mechanical stress through lower rotational speeds, thereby extending service life and reducing wear of consumable components. In addition, enhanced maintainability and the availability of domestically produced spare parts further improved operational reliability. Overall, the proposed system provides a more efficient, sustainable, and reliable infrastructure for continuous airborne radioactivity monitoring in nuclear facilities.

REFERENCES

- [1] VT 4.8 Catalog
- [2] WVS-8H Catalog