CHARACTERISTICS OF HVAC SYSTEM IN RADIOISOTOPE PRODUCTION FACILITY

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ABSTRACT

The Radioisotope Production Facility (hereinafter called "RIPF"), a subsidiary of the HANARO Research Reactor, has been in operation since 1995. They have 4 banks; at Bank#1, consisting of 4 concrete cells, I-192 and Co-60 are produced; at Bank#2, consisting of 11 lead cells, an R&D project is conducted; at Bank#3 consisting of 6 lead cells, I-131 is produced; and at Bank#4, consisting of 4 lead cells, Tc-99m generator is produced. In order to prevent the gaseous radioactive substances from being discharged into the atmosphere, there are three filtration steps at the exhaust side of Bank#3. Also, pre-filters and HEPA filters are mounted in each of the respective hot cell banks. The charcoal cartridge and HEPA filters are, without exception, replaced every 18 month, for maintenance. After replacement, an in-place leakage test, using the R-11 and D.O.P tester according to the ASME N510-2007, is conducted.

This paper describes the characteristics of the HVAC system in the RIPF and the maintenances of their components, such as the AHU, HRU, blower, fan, damper, and filter. The management of HEPA filters and charcoal adsorbents are very important for protecting the environment and workers. Thus, this paper deals with the maintenance and repair of these filters and hands-on leak test results. In addition, this paper illustrates an evaluation of radio-iodine discharged into the atmosphere through the vent stack in HANARO.

1. Introduction

The active area, where radioactive materials in RIPF are being handled, consists of facilities such as hot cell banks, cold kits, a neutron activated analysis, and laboratories relevant to it. There are 4 hot cell banks, which are representative facilities in the RIPF. Bank#1 has 4 concrete cells, Bank#2 has 11 lead cells, Bank#3 has 6 lead cells, and Bank#4 has 4 lead cells. Bank#1 is mainly used for producing I-192 radioisotope for industry. Nowadays, it is done through knowledge transfer to industry. Bank#2 is used for various types of research, for example an analyzing target investigated in HANARO, or producing isotopes for industry. Bank#3 is used for producing I-131 to diagnose and cure thyroid cancer, which covers up to 60 % of domestic consumption. Bank#4 is used for producing Tc-99m generator, which covers around 65 % of domestic consumption. It has also been done by knowledge transfer to industry. In addition, cold kits to manufacture radio-pharmaceuticals, a neutron activation analysis facility by means of the pneumatic transfer system and an animal laboratory are installed in the active area.

This thesis describes how a ventilation system in the active area is managed and maintained so that types of particles, aerosols, and gaseous radioactive materials are produced, while users of the RIPF carry out various activities for research and development.

2. Configuration of the HVAC system

Some radioisotopes found thus far are helpful for more prosperous human life in various fields such as science, medicine, industry, and agriculture, while radioactive waste, which is an inevitable consequence, is being produced. The HVAC system is the final means for preventing radioactive materials from being discharged into the atmosphere. The Air Handling Unit, AHU, is a device used for cooling and heating as part of the HVAC system. There are 4 AHU's, z001 ~ z004, in which z001 and z004 are for regional offices and an electrical distribution room in the inactive area, and z002 and z003 are for laboratories and hot cell banks in the active area. The Heat Recovery Units, HRU's, are installed to minimize the temperature change in the office areas, laboratory areas, and hot cell bank areas so that chilled air cannot penetrate the building during the winter.
Fresh air flown into the active area should not be re-circulated and the active area should maintain negative pressure to protect the diffusion of contaminated air into the environment. Tab. 1 illustrates the specification of air flow and the capacity of cooling and heating in each AHU [1]. The RIPF is classified using zones 6,000 through 9,000 according to the concentration of the radiation levels. The 6,000 zones are non-radiation zones, which are ordinary office areas and maintain a negative pressure of 3 mmAq in comparison to the outside of the building, that is, for preventing leakage from the building by a backward flow of contaminated air when the exhaust fan is stopped in the active areas. Of course, that phenomenon shall be blocked before diffusion of the contaminated air into the atmosphere by the back draft damper installed on damper and various filtering devices in the ventilation system. The 7,000 zones are the operation areas of all hot cells. The 8,000 zones are laboratories and the service areas of all hot cells, and the 9,000 zones are inside the hot cells and glove boxes. Tab. 2 illustrates the deference pressure and radiation levels for each zone [2]. Hot cell bank#1 to bank#3 which have two exhaust fans each, providing 100% capacity, are running in turn every other month.

*AHU No.	Supply Region	Air Flow (CMH)	Cooling Capacity (kcal/hr)	Heating Capacity (kcal/hr)
Z001	Office regions	60,850	507,900	249,700
Z002	Laboratory regions	44,350	570,440	208,020
Z003	Hot cell regions	37,900	512,410	260,840
Z004	Electric Distri. RM	16,650	59,890	-

*Air Handling Units

Tab. 1. Specification of the Air Handling Units

Classification	Description	Negative Pressure (mmAq)	Radiation Level (mSv/hr)
Zone 9,000	Hot cell or Glove box	25	≥ 0.5
Zone 8,000	Service area, Laboratory	10.0	< 0.5
Zone 7,000	Operation area	1.5	$\leq 1.25*10^{-2}$
Zone 6,000	Official area	3.0	$\leq 6.25*10^{-3}$

Tab. 2. Negative pressure and radiation levels for each zone

The hot cell bank#4 has three exhaust fans each providing 50% capacity. All hot cell banks have MOD filters and HEPA filters. A carbon adsorbent is installed in bank#3, particularly to deal with organic iodine. The filter housing bank#3 consists of pre filters, HEPA filters, and activated carbon absorbents. To discharge contaminated materials from bank#3, the three filtration steps should be passed. Charcoal adsorbent is installed at the first filtration step right after bank#3, and pre filters, HEPA filters, and cartridges of charcoal adsorbent are installed at the second and third filtration steps. These units have a standby train in parallel to make it possible to switch to another filter train when the set point of the differential pressure or the radiation level is exceeded. Also, the air flown into the operation area and the service area of bank#3 is discharged into the atmosphere through the main stack and the auxiliary stack. The air flown into the operation areas are discharged through the main stack after passing through inside the hot cells. The air flown into the service areas are discharged through the auxiliary stack after passing through glove boxes and fume hoods.

The technical criteria for the performance tests of the air cleaning unit, ACU, which is a unit for the filtration of the gaseous materials in RIPF, are Reg Guide 1.52 "Design, Inspection, and Testing Criteria for Air Filtration and Adsorption Units [3], ASME AG-1 Sec. FF Article 5000 [4], and ASTM D3803-1989 "Standard Test Methods for Radioiodine Testing of Nuclear Grade Gas-Phase Adsorbents" etc. A charcoal adsorbent that satisfies the criteria of the qualification tests in accordance with ASTM D3803-1989 is purchased. The charcoal adsorbent is QA class 'S'. In order to purchase, we need to provide a purchase specification and quality assurance requirements to the manufacturer. A total hands-on inspection of charcoal adsorbents in the process of production is carried out by the person in charge of QA and the manager in charge of the RI operation in KAERI. In addition, we inspect all the purchases of not only HEPA filters but also charcoal adsorbents.

3. Maintenance of the HVAC system

The maintenance of the HVAC system is very significant since it protects workers and facilities from radioactive materials. It is conducted according to periodical procedures described in the Safety Analysis Report, SAR. These are daily checkups, which include checking the statuses of the ventilation fans, blower motors, the v-belt and pulley, dampers, DP of the filters and adsorbent, and the temperature and humidity in each area of the banks. The acceptable DP of the filter and charcoal adsorbent in the filter banks should be maintained at less than 50 mmAq in the HEPA Filter, and under 60 mmAq in the charcoal adsorbent. The temperature should be kept between 15 to 28℃ and the relative humidity between 10 to 70% in the hot cell banks [5]. Every 3 months, a self-checkup is carried out to confirm the integrity of the blowers, motors, fans etc., and some of them are overlapped with the daily checkup. The facilities are inspected without exception, every 18 months in accordance with the ASME N510-2007. After a replacing of the filters and adsorbents, the statuses of the frame, housing, dampers, and lighting as well as the DP of the filters and the air volume of the duct are checked, and a D.O.P (Dioctyl Phthalate) test in the HEPA filter, and an R-11 test in the charcoal adsorbent are performed. As a part of the In-place Leakage Test, further tests and inspections, after replacing HEPA and gas adsorbent, are conducted, as shown below.

3.1 Airflow measurement

For the airflow measurement of the ventilation system, holes are made in the duct surface and measured by the Equal Area Method. The DP is measured using a standard pitot tube. The measured DP is converted into stream velocity and the air flow rate is calculated by multiplying the cross section of the duct. The measured air flow rate is controlled to stay within the range of ±10% of the design criteria. The air flow rate is controlled by the damper controller if it is out of range.

Filtration Units (exhaust of bank #3)		Air Flow Rate(CMH)		Differential Pressure			DOP TEST < 0.05%	Halide Test < 0.05%
		Design	Meas.	Design		Meas.		
1st step	G315	510	-	60		0	-	0.00
	G316	510	-	60		7	-	0.00
2nd step	G589	850	907.3	*H	50	0	0.00	0.01
				*C	60	0		
	G590	850	907.3	H	50	6	0.02	0.00
				C	60	7		
3rd step	G589-1	850	907.3	H	50	-	-	0.01
				C	60	6		
	G590-1	850	907.3	H	50	-	-	0.01
				C	60	7		

* H: HEPA, C: Charcoal

Tab. 3. Periodical checkup results of the bank#3 [6]

Tab. 3 illustrates the air flow rate, the DP, the efficiency of HEPA and gas adsorbent at the bank #3 in 2012. As shown in Tab. 3, it should be passed through three filtration steps in order to eliminate gaseous radioactive materials. At the first filtration step, a charcoal absorbent with standby train is mounted on the exhaust side right after bank#3. The air flow rate at the first filtration step was not measured because the radiation level was high to access for the test. The measured air flow rate shows that they are in the range of 10% of the design criteria. In addition, both D.O.P and Halide test results are within the parameters of the technical criteria.

3.2 In-place filter testing for HEPA and activated carbon adsorbent

In-place Leakage Testing for HEPA and charcoal adsorbent are conducted after replacing the filters. The standard size of the HEPA and charcoal adsorbent are the same at 610*610*292 mm. After replacing the filters, a hands-on test of HEPA should be conducted under the conditions of a 50 CMM air flow rate, and 24.0-25.3 mmAq of pressure drop, and the efficiencies of the HEPA need to be up to 99.95%. A type IV cartridge of activated carbon adsorbent should satisfy over 97.5%, the lowest adsorption rate, when it is tested by the removal efficiency of methyl iodine and at a temperature of 30℃ and a relative humidity of 95% in accordance with the ASTM D3803-1989 [7]. The leak rate of activated carbon filter needs to be under 0.05% in accordance to a hand-on leakage test, using halide gas. In Tab. 3, there are no results for the 1st D.O.P test because the filter bank at the first filtration step is only composed of charcoal adsorbent. The results of the 2nd and 3rd of D.O.P and halide tests seem sound.

The Derived Release Limits, DRL of radioiodine discharged into the atmosphere from the RIPF is 2.22E12 Bq/yr. Figure 2 illustrates the discharged amount through the stack for the last 5 years. The average discharged radioiodine for 5 years since 2008 is 4.35E8 Bq/yr, which is only 0.019% of the DRL. The trend line of the main stack was increased continuously in accordance to the production of I-131. In particular, the figure of radioiodine discharged from the main stack in 2012 was 2.85 times higher than in the previous 4 years. Because the production of radioiodine in that year was 1,522 Ci and it was 47.5 % higher than 1,032 Ci, the average from the year 2008 to 2011.

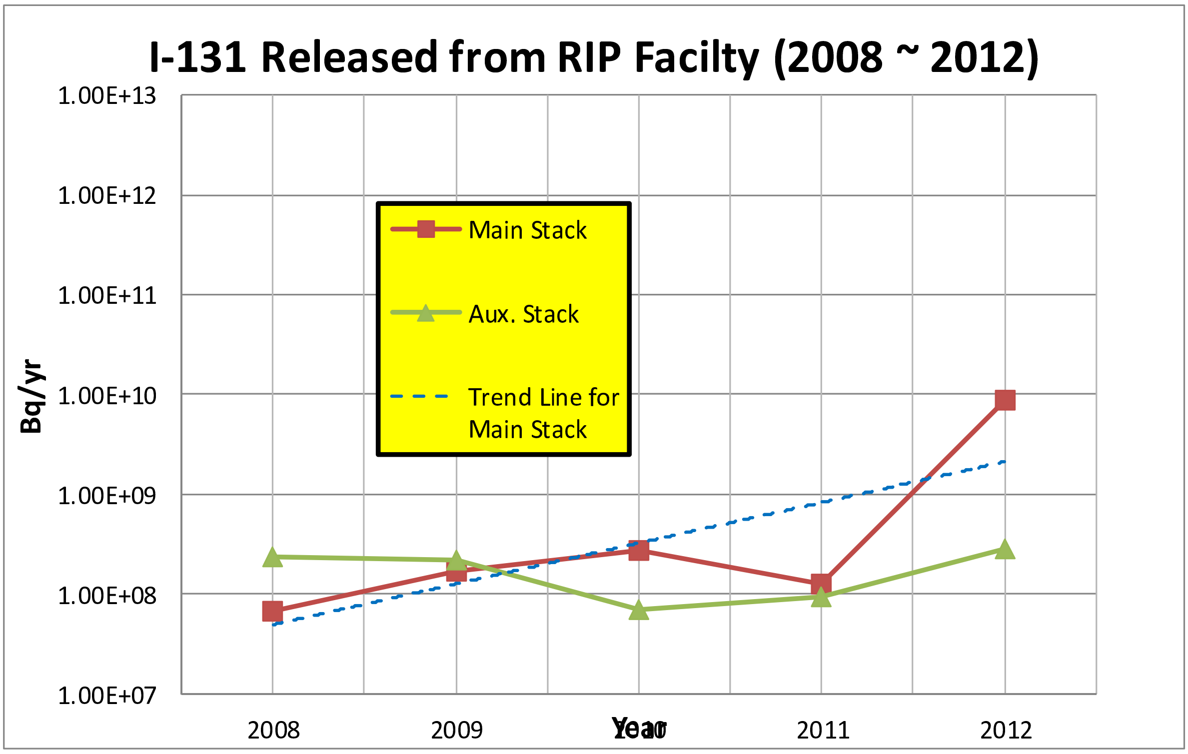

Fig. 1. I-131 released from RIPF for the last 5 years

4. Remarks

The components of the Air Handling Unit in RIPF are wearing out after almost 20 years of operation since it started operating in 1995 with HANARO. As for the AHU, their housings were corroded and the heat coils in the AHU were torn out several times. In addition, the motors, blowers, pulleys etc., were also damaged and replaced. One of the main functions of RIPF is for producing the radioisotopes. When it comes to the importance of the production of medical isotopes, it should be remembered that a patient's life is at stake. Thus, scheduling for long-term maintenance should be considered as the production of isotopes is stopped while the facilities are maintained. Therefore, we need to coordinate closely with the department of radioisotopes production to plan long-term maintenance needs.

5. References

[1] SAR 11.3.4.1 Heating, Ventilating and Air Conditioning, HVAC, KAERI, 2011
[2] Facilities for R&D of Medical Radioisotopes, KAERI/RR-2383/2002, MOST, 2002
[3] Reg Guide 1.52 "Design, Inspection, and Testing Criteria for Air Filtration and Adsorption Units, Rev. 3, USNRC, 2001
[4] ASME AG-1 Sec. FF Article 5000 "Inspection and Testing", 1988
[5] ANSI N-509 "Nuclear Power Plant Air-Cleaning Units and Components", 1998
[6] B.J. Yoon and et al., In-place leak test of Air Cleaning System in RIPF, KNS, 2009
[7] ASTM D3803-1989 "Standard Test Methods for Radioiodine Testing of Nuclear Grade Gas-Phase Adsorbents", 1989