IN-SITU MEASUREMENT OF RADIOACTIVE GASES USING Ge(Int) SPECTROMETORY FOR ESTIMATING THE GASES FLOW RATE

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ABSTRACT

Recently, according to the improvement of fuel performances, short-lives nuclides such as ^{19}O and ^{16}N have become mainly of the gaseous radioactivity in the turbine system at BWR plants. Therefore, the variation of the flow rate in main steam system greatly infuluences to the area radiation level, and it is very important to grasp the flow rate and the relations to the dose rate. On the other hand, the conventional flow rate measuring devices are accompanied with their inherent instabilities of indication on measuring the steam flow.

In this study, we confirmed the existence of these short-lives nuclides and their contribution to area dose rate by in-situ measurment using a portable Ge(Int) spectrometer, and developed a method for estimating flow rate by radioactive gases analysis.

IN-SITU MEASUREMENT AND STUDY

a. Measuring Device

The measuring device comprises Ge(Int) detector and pulse-height analyzer. The relative efficiency and resolution of Ge(Int) detector are 20 % and 2 keV, respectively. It has a liquid-nitrogen container of 1.2 ℓ capacity and is capable of performing one-day measurement. The pulse-height analyzer has a memory capacity of 4098 channels and high-voltage power supply unit, amplifier and a cassette tape for recording measured data are all built in. The measurement result is analyzed by a separate computor. The shielding around the detector is made of 10 cm thick lead and has a collimating function and therefore is capable to perform measurement even at the field where the dose rate is at high level.

b. Measurement around Main Steam Line

The measurement is performed around main steam line at both reactor outlet side and low-pressure turbine inlet side (See Fig. 1). The measurement corresponding to electrical output was made at low-pressure turbine inlet side, and the measurement at a time of full power only was made at reactor outlet side.

The result of gamma-ray spectrum and surface dose rate shows in Table. 1 and Fig. 2.

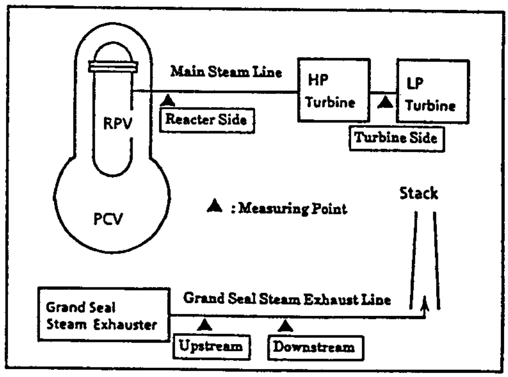


Fig.1 Measuring Point

From the measurement by Ge(Int)detector, only two nuclides of ^{16}N (half-life 7.13 sec.) and ^{15}C (half-life 2.4 sec.) were analyzed. The following differences are seen by looking from the peak count ratio of gamma-ray of 6.13 MeV and 5.3 MeV.

$$Rr = \left(\frac{^{15}C\ 5.3\ MeV}{^{16}N\ 6.13MeV} \right) \text{Reactor side} = 0.752$$

$$Rt = \left(\frac{^{15}C\ 5.3\ MeV}{^{16}N\ 6.13MeV} \right) \text{Turbine side} = 0.321$$

Since these differences are considered to have resulted from the difference of radioactive decay effect during steam flow from reactor side to turbine side, the steam travelling time (T) is obtained from the following equation:

$$Rr = \exp\ (\lambda n - \lambda c)\ T = Rt$$

$$T = \frac{\ell n \left(\frac{Rt}{Rr} \right)}{\lambda n - \lambda c} \qquad (1)$$

λn : Decay constant of ^{16}N

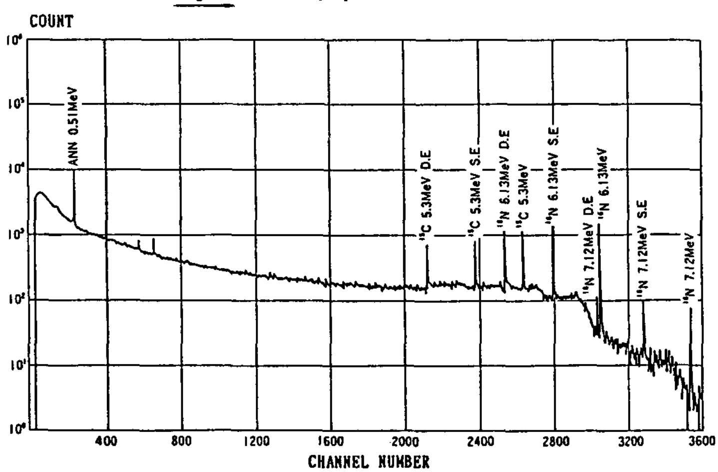
λc : Decay constant of ^{15}C

The steam travelling time from reactor side at full power to turbine side calculated by equation (1) will be approx. 4.4 seconds.

ELECTRICAL ONTPUT	TURBINE SIDE				REACTOR SIDE			
	DOSE RATE	PEAK COUNT RATE			DOSE RATE	PEAK COUNT RATE		
		^{16}N(6.13MeV)	^{15}C(5.3MeV)	$^{16}N+^{15}C$		^{16}N(6.13MeV)	^{15}C(5.3MeV)	$^{16}N+^{15}C$
MWe	mR/hr	cps	cps	cps	mR/hr	cps	cps	cps
163	23	24.0	2.1	26.1	400	--	--	--
183	31	31.3	4.0	35.3	450	--	--	--
254	59	53.2	9.4	62.6	620	--	--	--
309	105	71.2	19.6	90.8	720	--	--	--
357	140	83.6	26.8	110.4	830	44.4	33.4	77.8

Table 1 Result of gamma-ray spectroscopy and surface dose rate of main steam line measurment

Fig. 2 Gamma-ray spectrum at main steam line



The relationship between electrical output and dose rate will be almost 1 to 1 around main steam line, while rising ratio of dose rate of turbine side against electrical output is larger compared that of reactor side (See Fig. 3).

This can be explained by the fact that the nuclides contributing to dose rate are of only two kinds of ^{16}N and ^{15}C and that flow rate is proportional to electrical output. That is: the dose rate at reactor side which corresponds to the output at a ratio of 1 to 1 becomes larger at turbine side because of decay effect that if flow rate becomes larger the flow travelling time becomes faster and decay effect becomes smaller.

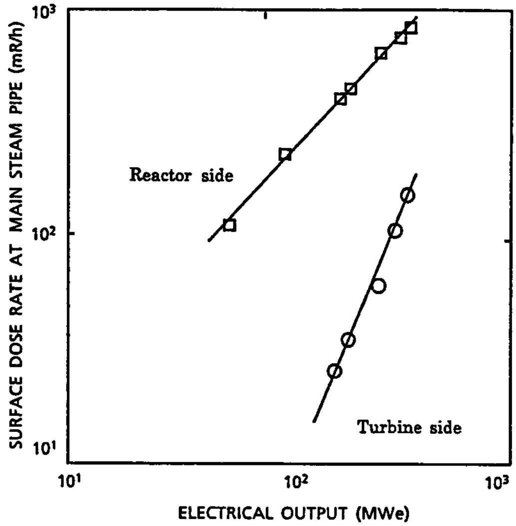


Fig. 3 Relationship between dose rate and electrical output

This is verified by the fact that the result of reverse operation of the peak count of ^{16}N and ^{15}C at each power level at turbine side to the peak count at reactor side from decay effect and steam flow rate, calculated by the following equation, often agrees with inclination curve of the dose rate at reactor side (See Fig. 4).

$$Nr = Nt * \exp(\lambda n) * R * T$$

T : Steam travelling time at full power (4.44 sec.)
R : Full power/applicable power ratio
Nt: Peak count at turbine side (actual measurement)
Nr: Peak count at reactor side

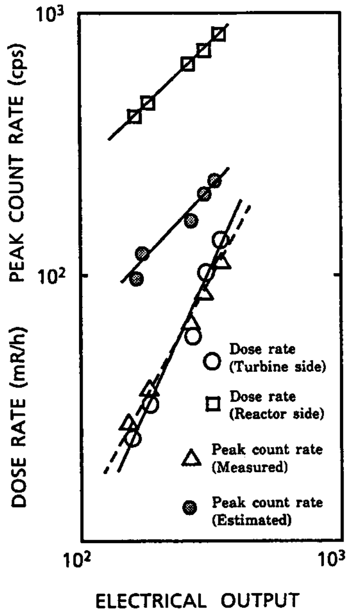
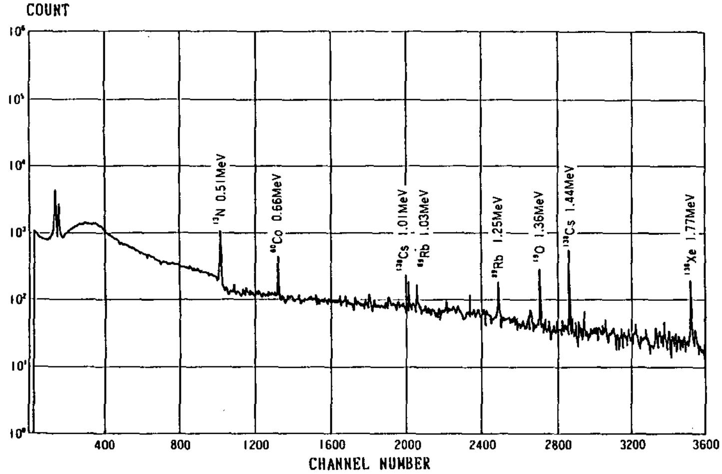


Fig.4 Dose rate and peak count rate at each electrical output

c. Measurement around Turbine Gland Seal Steam Exhaust Line

For measurement on turbine gland seal steam exhaust line, the measurement was performed on both upstream and downstream side like the case of main steam line, using Ge(Int) detector (See Fig. 1). Examples of measured spectrum are shown in Fig. 5. From the concerned exhaust line, gamma-ray of ^{19}O (1357 keV, half-life 9.96 min.), ^{13}N (511keV, half-life 26.9 sec.),etc. were analyzed.

Fig. 5 Gamma-ray spectrum at turbine grand seal steam exhaust line



Like the case of main steam line, the steam travelling time obtained from the difference in the peak count of ^{19}O and ^{13}N was 41.8 sec. Further, the gas flow rate obtained from the distance between measured points (21.8 m) and pipe cross sectional area (0.235 m^2) was 442 m^3/hr, and this value agrees quite well with the indication of conventional process flowmeter.

CONCLUSION

By in-situ measurement using Ge(Int) detector, identification of short-lives nuclides, which is difficult to analyze with the normal sampling measurement, becomes possible and, in addition, the nuclides contributing to the dose rate is clarified and also gaseous travelling time or flow rate are obtainable.

In the past, at nuclear power plant it was considered that contribution of fission products to the dose rate such as noble gas contained in the gas was large and that indication of gas monitor was affected by this contribution.

However, at present where fuel performance has been improved, indication of the monitor is affected by ^{13}N, ^{16}N, ^{15}C, ^{19}O, etc.

Accordingly, it is necessary to pay attention to the fact that flow rate gives influence to variation of gas monitor indication since these nuclides are of short-lives nuclides.