Attachment 1

November 7, 2011
Nuclear and Industrial Safety Agency

Regarding Detection of Xe-135 from the Primary Containment Vessel of Unit 2 at Fukushima Dai-ichi NPS, Tokyo Electric Power Co., Inc.

1. Background

- On November 1, 2011, Tokyo Electric Power Co., Inc. (TEPCO) conducted a measurement of gases in the Primary Containment Vessel (PCV) of Unit 2 using the newly installed PCV gas control system. As a result, Xe-133 and Xe-135, noble gas nuclides produced through nuclear fission, were detected.
- Due to the short half-lives of the nuclides, about five days for Xe-133 and about nine hours for Xe-135, TEPCO figured that these nuclides were produced through nuclear fission occurred very recently, not produced before March 11.
- TEPCO submitted a report to NISA on November 4 stating that the nuclides were produced from spontaneous fission[*1], not from criticality where a series of fissions occurs continuously.

[*1]: Inside a reactor in an advanced state of burnup, nuclides that bring about spontaneous nuclear fission without neutrons are produced. These nuclides cause a certain amount of nuclear fission even in sub-criticality. Typical nuclides of this kind are Cm242 and Cm244.

2. Summary of Evaluation by TEPCO

Due to the detection of fissile nuclides of Xe-133 andXe-135, there were once concerns that “criticality” where a series of fissions occurs continuously was reached at Unit 2. However, it has been concluded that criticality was not reached for the following reasons:

(1) Low radioactive concentration in the detected Xe-135[*2]

1) Concentration of Xe produced by spontaneous fission

- Fissile nuclides such as Xe-135 are also produced by spontaneous fission. The calculated value of the concentration of Xe-135 produced from the amount of spontaneous fissile nuclides in the reactor at present and the actual measurement value obtained by sampling were compared.
- As a result, since the actual measurement value and the calculated value of Xe-135 concentration have the same number of digits as shown below, Xe-135 detected this time is considered to have been

produced by spontaneous fission.

[Calculated value] 9.9×10^{-3}[Bq/cm^3]

[Actual measurement value] 2.7×10^{-2}[Bq/cm^3]

*2: Although Xe-133 was also detected, Xe-135 having a shorter half-life is typically evaluated here as it is clear that Xe-135 was produced by nuclear fission occurred very recently.

2) Concentration of Xe produced from fission by criticality

The output level at the time when criticality is reached at startup of a real BWR is several kW. Presuming that this figure being 1kW for convenience, concentration of Xe-135 produced in criticality was estimated and compared with the actual measurement value obtained this time.

As a result, since the concentration of Xe produced through criticality has a value of four digits larger than the actual measurement value, Xe-135 detected this time is considered not to have been produced through fission caused by criticality.

[Calculated value of critical fission] 6.3×10^{2}[Bq/cm^3]

[Actual measurement value] 2.7×10^{-2}[Bq/cm^3]

(2) Xe-135 was detected even after injection of boric acid, a neutron absorber

- In criticality, if boric acid water, a strong neutron absorber, is injected into the reactor, sub-criticality is reached inside the reactor and chain reaction of nuclear fission will not occur anymore. Accordingly, Xe-135 will not be detected after injection of boric acid water.
- However, while the concentration of Xe-135 measured on November 1 before boric acid water injection was 1.2×10^{-5}[Bq/cm^3], Xe-135 of the same order, 1.7×10^{-5}[Bq/cm^3], was detected on November 2 after the injection.
- It has been consequently concluded that the detected Xe-135 was produced by spontaneous fission unaffected by neutron absorbers, not by fission caused by criticality.

(3) No significant change has been found in reactor parameters

- In order to keep track of the reactor and PCV status, temperature and pressure at various sites are currently being measured continuously. Accordingly, if the reactor reaches criticality, increased

temperature and pressure caused by the generated energy will be observed.

- However, no significant increase has been identified in the parameters other than the lowered temperature at the bottom of the PCV due to increased water injection rate into the reactor and the decreased pressure due to nitrogen injection at the gas control system. The same goes for the indicated values of the monitoring posts.
- Since no significant increase has been identified in the plant parameters and the monitoring posts, it has been concluded that criticality is not reached in the reactor.

3. Evaluation by NISA

(1) Evaluation of Xe-135 concentration by NISA

NISA conducted its own evaluation of Xe-135 concentration assuming the case of spontaneous fission, and the result was 1.2 to 1.7 x 10^{-1}[Bq/cm^3]. The actual measurement value obtained by TEPCO was 2.7 x 10^{-2}[Bq/cm^3], and the both values are largely at the same level considering the simple evaluation. It is therefore almost considered that the detected Xe was produced by spontaneous fission.

Incidentally, the calculated value obtained by TEPCO was 9.9 x 10^{-3}[Bq/cm^3], which differs from the value evaluated by NISA given above. This is due to the differences in the calculation method described below.

1) Curium inventory

In NISA evaluation, the inventory immediately after the reactor shutdown was assumed as 9.32 x 10^{16}[Bq] for Cm242 and 3.87 x 10^{15}[Bq] for Cm242, and exponential decay in the period of 260 days was taken into account. (TEPCO applied interpolation using linear function.)

2) Xe-135 yield

The yield of Xe-135 produced by spontaneous fission of curium was obtained by adding Xe-135 directly produced from curium and Xe-135 produced by the decay of I-135 directly produced from curium, and 7.5% was applied. (TEPCO did not take the Xe-135 produced by the decay of I-135 into account.)

3) Gas-phase capacity of the PCV

Since the water capacity in the PCV is not clear, gas-phase capacity of 3,000m^3 assuming that the PCV is partly submerged and 4,240m^3 assuming that the PCV is filled with gas-phase, two values spread in a wide range, are applied in the estimate.

4) Gas leakage rate from the PCV

The leakage rate of 0.6m^3 due to water vapor leakage from sites other than the gas control system was also taken into account. (TEPCO did not take the rate into account.)

Table: Evaluation of Radioactive Concentration inside the PCV of Xe-135 Produced by Spontaneous Fission (Estimated by NISA)

Gas-phase capacity of PCV	Nuclide	Radioactive concentration (Bq/cc)
3,000m^3	Cm242	4.6×10^{-2}
	Cm244	1.2×10^{-1}
	Total	1.7×10^{-1}
4,240 m^3	Cm242	3.3×10^{-2}
	Cm244	8.6×10^{-2}
	Total	1.2×10^{-1}

(2) Impact assessment of boric acid water injection

In criticality, neutrons are absorbed and fission reaction is suppressed by the injection of boric acid water, and criticality is terminated and the Xe-135 concentration may decrease as a result. However, since no change in the Xe-135 concentration before and after the boric acid water injection has been identified, it can be considered that criticality was not reached.

(3) Conclusion

Based on the above description, it is considered that Xe detected this time was produced by spontaneous fission, not by fission caused by criticality. Accordingly, NISA considers the contents of the report by TEPCO as basically reasonable.

4. Actions to be taken

NISA directed TEPCO to attain the state that the concentration of

radioactive materials in the PCV can be appropriately monitored in order to secure the medium-term safety (on October 3), and TEPCO is currently formulating the plan for measurement method and monitoring. NISA will verify the validity of the plan and instruct TEPCO to conduct periodic measurements and to swiftly report to NISA in case of incident.