Management of Radioactive Substance at Shika Nuclear Power Plant

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Various radioactive substances are generated in the nuclear reactor, and cause the management of radioactive substances as an important job in the nuclear power plant. The radioactive substance of the fission product is remained inside the fuel rods, because the fuel failure seldom occurs. The other radioactive substance generated by the neutron absorption reactions in the coolant water such as Co-60, which is called the radioactive corrosion products, is the main subject of the chemical management in the nuclear power plant, because it causes high radiation exposure during the periodical inspection. In the Shika Nuclear Power Plant, the several techniques for the radiation exposure reduction are adopted. In addition, the radioactive waste management is performed strictly to decrease the waste generation amounts and to minimize the discharge of radioactive quantities. The effect of the radioactive substances discharged from the Shika Nuclear Power Plant for pubic has been negligible.

1. Introduction

The Hokuriku Electric Power Co. has been promoting diversification of power resources by appropriate combination of hydraulic, thermal (coal and oil) and nuclear power in order to assure a stable supply of electricity for the future. The Shika Nuclear Power Plant, which has been operated since July 30th., 1993 when its commercial operation started, is an important part of this diversification program.

As shown in Figure 1, the Shika Nuclear Power Plant is located in Shika-machi of Ishikawa-prefecture, which is at the west coast of the famous scenic Noto peninsula facing the Sea of Japan. It takes about 2 hours to drive from Toyama-city to Shika-machi.

Figure 2 shows the layout of the Shika Nuclear Power Plant. The site area is approximately 1.6km^2. The main buildings are the Reactor Building, the Turbine Building and the Radioactive Waste Treatment Building.

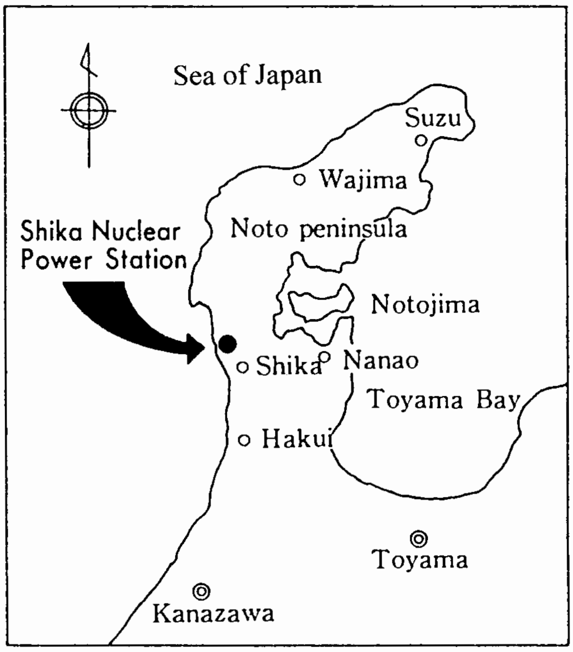

Figure 1 Location of Shika Nuclear Power Plant.

The type of the nuclear reactor of the Shika Nuclear Power Plant is Boiling Water Reactor (BWR). The thermal and electric power output is 1593MW and 540MW respectively. The fuel used in the reactor is low

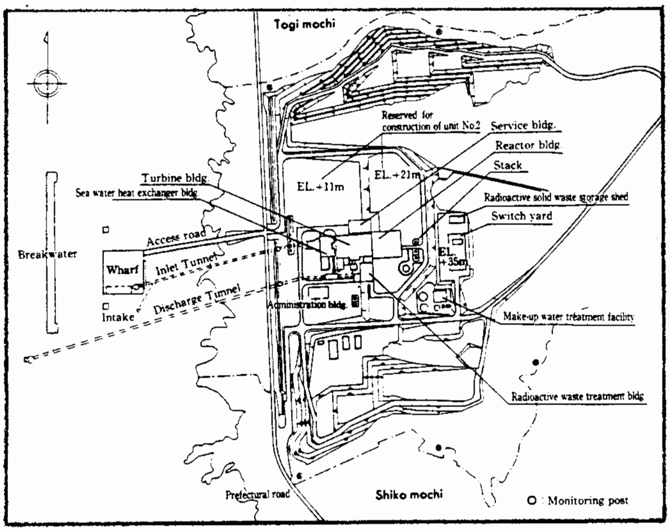

Figure 2 Layout of Shika Nuclear Power Plant.

enrichment uranium dioxide.

BWR is so called because steam is generated by directly boiling water in the reactor. The pressure vessel contains the uranium fuel and the coolant water. Heat generated by the nuclear fission of the uranium fuel is transmitted to the coolant water passing between fuel rods. This water is converted into high-temperature and high-pressure steam which passes through the main steam pipes to the turbine causing its rotation and the electricity generation. After rotating the turbine, the steam enters the condenser where it is cooled down and condensed into water by sea-water. It is then fed back into the reactor pressure vessel by the feed water pump.

Various radioactive substances are generated in the nuclear reactor, and cause the control of radiation and radioactive substances as an important job in the nuclear power plant.

2. Generation of Radioactive Substances

The generation of radioactive substances are mainly divided to 2 categories, the nuclear fission and the neutron absorption reaction. The former reaction is conducted in the fuel pellet. In these days, the fuel failure seldom occurs because of high quality assurance, so the fission products are remained inside the fuel rods. On the other hand, the latter reaction is conducted outside the fuel rods as well as inside the fuel rods, because neutron flux exist outside the fuel rods as well. Various materials and substances included in the coolant water outside the fuel rods have possibility to be changed to radioactive substances by the neutron absorption reaction. In these days, the radioactive substance in the coolant water generated by the neutron absorption reaction is the main object for the radiological control in the nuclear power plant.

3. Basic Conception of Radiation Protection

The basic conception of the radiation protection must be described, because it is the unavoidable subject in the nuclear power industry.

The standard of the radiation protection in Japan is specified in the law according to the recommendation of International Committee of Radiation Protection (ICRP). The purpose of the radiation protection based on ICRP is to "eliminate a nonstochastic and deleterious effect and to restrict a stochastic effect to the allowable level". To prevent the nonstochastic effect, the dose equivalent limit is set to a sufficiently low value so that it dose not exceed the threshold value. To prevent the stochastic effect such as cancer, the effect and risk of the radiation due to the use of nuclear power energy must be restricted to the low level in which the resultant benefit can be more sufficiently admitted than in another industry.

Such a conception is called the "mind of ALARA (as low as reasonably achieved)". For the nuclear power plant, the radiation exposure by various works is usually a low dose equivalent of less than the reference value. Therefore, the radiation exposure dose not directly influence the body. To avoid the unnecessary radiation exposure, however, various facilities are considered and works in the radiation control area are strictly controlled for the radiation protection based on the mind of ALARA.

As the actual standard, the radiological control in the nuclear power plant must be performed based on the "Law for the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactor". The radiation protection measures are taken so that the employees in the nuclear power plant and the general public around the power plant are enough safely protected from the radiation due to the nuclear power plant. The radiation exposure dose for the general public around the nuclear power plant is set as low as possible according to the "Guideline on the Target Dose Value of Areas Adjacent to Electric Power Generating Light Water Reactor Facilities".

4. Chemical Management

The purposes of the chemical management in the nuclear power plant are as follows,

- Maintaining and monitoring the soundness of the nuclear fuel rods
- Maintaining and monitoring the soundness of equipments, components and pipes
- Decreasing the concentration of the radioactive substances in the coolant water.

The radioactive substances in the coolant water and so on are measured regularly and the radiation level at the main steam pipes is monitored continuously. If the fuel failure might occur, the concentration of the fission products in the coolant water and the radiation level at the main steam pipes would increase. Continuous monitoring and regular measurement help us to find out the abnormal condition such as the fuel failure as soon as possible.

In the Shika Nuclear Power Plant, the abnormal condition such as the fuel failure has not been experienced, so, the concentration of the fission products in the coolant water and the radiation level at the main steam pipes have kept low level since the start of plant operation.

$$^{50}Cr\ (n,\ \gamma)\ ^{51}Cr$$
$$^{54}Fe\ (n,\ p)\ ^{54}Mn$$
$$^{58}Ni\ (n,\ p)\ ^{58}Co$$
$$^{59}Co\ (n,\ \gamma)\ ^{60}Co$$

Figure 3 Main Neutron Absorption Reactions.

Meanwhile, the radioactive substance generated outside the fuel rods by the neutron absorption reaction is the focus for the chemical management of the nuclear power plant in these days. Figure 3 shows the main radioactive substances generation by the neutron absorption reaction. The most concerned radioactive substance is Co-60 because its half life is effectively long of 5.27y and it emits high energy γ -rays of 1.17MeV and 1.33MeV. Co-60 is generated through the reaction of neutron and cobalt which is dissolved from the material to the water and led to the nuclear reactor. Co-60 is piled up at the surface of various pipes, especially the primary reactor loop recirculation System (PLR) pipes, to cause high radiation exposure during the periodical inspection. The radioactive substance in the coolant water generated by the neutron absorption reaction such as Co-60 is called the radioactive corrosion product.

The various technique of radiation exposure reduction is adopted in the Shika Nuclear Power Plant. The first technique is the introduction of the low-cobalt-content materials. The low-cobalt-content materials are used in the pin controllers for the control rods and the tubes for the high pressure feed water heater. The second is the reduction technique of Co-60 concentration in the coolant water. In the

Shika Nuclear Power Plant, the iron injection into the feed water is adopted, because iron can decrease Co-60 concentration by the reaction with cobalt at the surface of the fuel rods to be the insoluble compound of ferrite. The third is the reduction technique of Co-60 piling at the pipe surface. The mechanical polishing technique, which makes the fine roughness at the surface be enough small to prevent the radioactive corrosion products from being adsorbed, is adopted for the PLR pipes.

Co-60 and the other radioactive corrosion products in the coolant water are measured regularly to check the radioactivity concentration. The radiation level of PLR pipes is deeply concerned with the concentration of the radioactive substances in the coolant water.

Tritium is the other main radioactive substance in the coolant water. It is due to the neutron absorption reaction of natural deuteron in the coolant water and the cladding penetration of tritium generated by the nuclear fission reaction in the fuel rods. Tritium in the coolant water is measured periodically.

5. Radioactive Waste Management

The radioactive waste management is also an important job in the nuclear power plant. The basic purposes of the radioactive waste management are to decrease the generation amounts of gaseous waste, liquid waste and solid waste, and to minimize the discharge quantity of radioactivity by the proper management.

Figure 4 shows the disposal methods of the radioactive waste at the Shika Nuclear Power Plant.

The gaseous radioactive wastes are the exhaust gas from the main condenser and the exhaust gas of the ventilation system and so on which might have the radioactive rare gases and iodine. They are discharged through the stack which is 100m-high, after they are processed through the activated charcoal type rare gas holdup device and the filter to de-

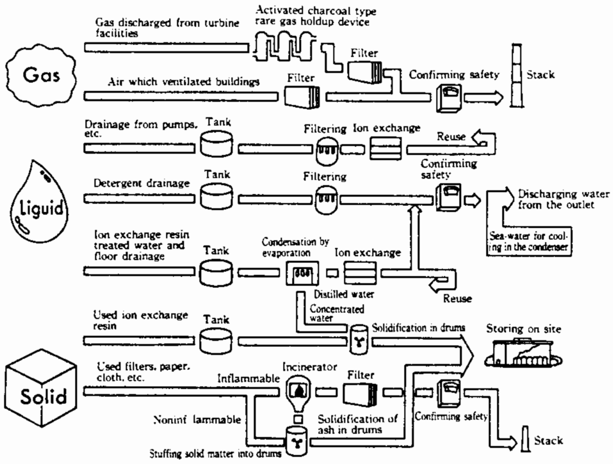

Figure 4 Disposal Methods of Radioactive Waste in Shika Nuclear Power Plant.

crease their radioactivity level to enough low level. The radioactivity level of the gaseous waste is monitored continuously.

The liquid radioactive wastes are the drains from several equipments, sampling drains, chemical drains and decontamination work drains and so on which might have the radioactive substances of the fission products and the corrosion products. They are processed by the filter, the evaporation concentrator and the ion exchange demineralizer, depending on their chemical characteristics. The processed liquid waste water is reused for the plant water basically. In the case when the total volume of the plant water is increased, some processed liquid waste water is discharged with the condenser cooling sea-water through the outlet tunnel, after its radioactivity is confirmed to be enough low by sampling and analysis.

The discharge radioactive quantities of gaseous and liquid wastes discharged from the nuclear power plant is controlled with the discharge control target value to be charged a year. This discharge control target value is evaluated as the discharge rate of radioactive wastes in the design stage of a nuclear power plant, and is deeply concerned with the target dose value of 50 μ Sv/year based on the "Guideline on the Target Dose Value of Areas Adjacent to Electric Power Generating Light

Discharge Quantity Of Radioactive Gaseous Waste (Unit:Bq)

Item \ Fiscal Year	1992	1993	1994	1995
Rare Gas	ND	ND	ND	ND
Iodine-131	ND	ND	ND	ND

Note) • ND is Non Detectable.
• Detectable Limit Concentration of Rare Gas is Less than 2×10^{-2} Bq/cm³.
• Detectable Limit Concentration of Iodine-131 is Less than 7×10^{-9} Bq/cm³.

<Reference>

Discharge Control Target Value of Rare Gas	1.1×10^{15} Bq/year
Discharge Control Target Value of Iodine-131	3.0×10^{10} Bq/year

Discharge Quantity of Radioactive Liquid Waste (Unit:Bq)

Item \ Fiscal Year	1992	1993	1994	1995
Liquid Waste (Excluding Tritium)	ND	ND	ND	ND
Tritium	3.0×10^{9}	1.6×10^{10}	5.7×10^{10}	1.4×10^{11}

Note) • ND is Non Detectable.
• Detectable Limit Concentration of Liquid Waste(Excluding Tritium) is Less than 2×10^{-2} Bq/cm³ (Which is the representative Value for ^{60}Co).
• Detectable Limit Concentrarion of Tritium is Less than 2×10^{-1} Bq/cm³.

<Reference>

Dischange Control Target Value of Liquid Waste(Excluding Tritium)	3.7×10^{10} Bq/year
Dischange Control Standard Value of Tritium	3.7×10^{12} Bq/year

Table 1 Discharge State of Radioactive Waste from Shika Nuclear Power Plant.

Water Reactor Facilities" mentioned above. Whenever the discharge radioactive quantities of gaseous and liquid waste are less than the discharge control target values, the dose equivalent of the general public around the power plant is less than the target dose value.

Table 1 shows the discharge radioactive quantities of gaseous and liquid waste in the Shika Nuclear Power Plant. From fiscal year 1992, when the pre-operation of the Shika Nuclear Power Plant was performed, until 1995, the discharge radioactive quantities of rare gas, gaseous iodine-131 and liquid waste (excluding tritium) are non detectable level. The level of the discharge radioactive quantity of tritium in liquid waste is 10^{9} through 10^{11} Bq/year.

The solid radioactive wastes are the used ion exchange resin, the used filters and miscellaneous solid wastes and so on. Noninflammable wastes are compressed and packed into drums, while inflammable wastes are incinerated and cement-vitrified in drums. High radioactive wastes such as the used ion exchange resin are stored in the storage tank for a sufficient period to reduce the radioactivity level. These wastes will be dried or incinerated and then cement-vitrified in drums. All drums are safely stored in the Solid Waste Storehouse.

(Unit:drums)

Item \ Fiscal Year	1992	1993	1994	1995
Number of Drum Generation	0	248	220	224
Accumulative Number of Drum Generation	0	248	468	692
Number of Other Waste Generation	0	16	0	0
Accumulative Number of Other Waste Generation	0	16	16	16

The Capacity of storage Quantity in the Solid Waste Storehouse is approximate 5000 of 200-liter Drum

Table 2 Storage State of Radioactive Solid Waste in Shika Nuclear Power Plant.

Table 2 shows the number of drum generation in the Shika Nuclear Power Plant from 1992 to 1995. The capacity of storage quantity in the Solid Waste Storehouse is approximate 5000 drums.

6. Monitoring Environment Radiation

In order to confirm that the amount of the radioactive substances discharged from the Shika Nuclear Power Plant is so small that the effect on the environment is inconsequential, the environment radiation monitoring has been conducted since 2 years prior to the pre-operation of the Shika Nuclear Power Plant.

7 monitoring posts set near the site boundary continuously measure and record the radiation level in the atmosphere. Figure 5 shows a monitoring post. The concentration levels of the radioactive substances in the air are also measured continuously. In addition, the concentration levels of the radioactive

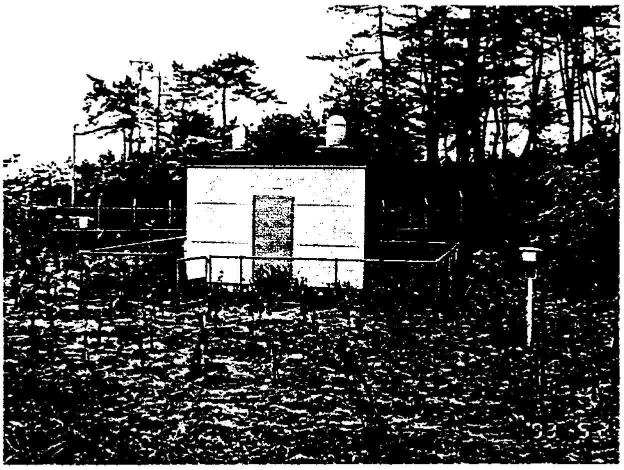

Figure 5 Monitoring Post in Shika Nuclear Power Plant.

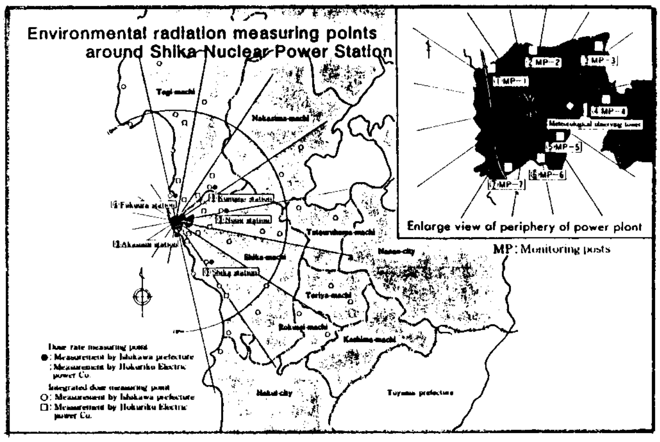

Figure 6 Environmental Radiation Measuring Points around Shika Nuclear Power Plant. (○ measured by Ishikawa Prefucture. □ measured by Hokuriku Electric Power Co.)

substances contained in such samples as soil, farm products, drinking water, sea water and fish and so on, which are collected inside and outside the power station site, are measured periodically.

These measurements are being conducted not only by the Shika Nuclear Power Plant of the Hokuriku Electric Power Co. but also independently conducted by the local government of Ishikawa Prefecture. Figure 6 shows the environmental radiation measuring points around the Shika Nuclear Power Plant.

The results of these monitoring are open to the public after first being technically evaluated by the "Ishikawa Prefecture Technical Committee for Environmental Radiation Measurement", and then checked by the "Ishikawa Prefecture Nuclear Environmental Safety Control Council".

The effect due to discharged radioactive substances from the Shika Nuclear Power Plant for public has been announced to be negligible since the start of plant operation by the "Ishikawa Prefecture Nuclear Environmental Safety Control Council".