New Facilities to Reduce Releases from Swedish BWRs – 14009

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ABSTRACT

The ability to control releases from nuclear power plants is of vital importance, not the least from an environmental point of view. As a result, the Swedish utilities are continuously investing in new methods and facilities to reduce their releases to the recipients. This has been further enhanced by the requirement to fulfill the latest Oslo-Paris (OSPAR) convention. Two major investment projects are currently being performed at two of the Swedish BWR sites.

The Forsmark nuclear power plant, a 3-unit BWR site, had to perform controlled releases of large quantities of slightly contaminated water during outages, due to limited cleanup capacity in the radwaste plant, when large pools and tanks were emptied in the power plant. The unit no. 1 and 2 have a common radwaste plant, and the utility decided to increase the buffer storage capacity instead of the treatment capacity, to be able to store the contaminated water and treat it over a longer period of time.

Westinghouse was engaged to increase the buffer capacity in the current liquid waste treatment system by installing two additional buffer tanks with a volume of 1,500 m3 each. The complex treatment system was redesigned with a new house, new pumps, pipes and other necessary process components to incorporate the extra buffer volume. This was done during the period of 2010-2011. Now, with an extra capacity of 3,000 m3 in the liquid waste treatment system, the releases of low active waste water during outages are at an acceptable level from a regulatory point of view.

The Oskarshamn nuclear power plant in Sweden, also a 3-unit BWR site, is going to reduce the release of radioactive off-gases in one of its units, unit no. 2, by installing carbon columns. These columns contain activated carbon that will selectively retain and thus delay the radioactive noble gas isotopes in the off-gases. Since most of the radioactive noble gases are short-lived, they will then have decayed before being released through the main stack of the plant.

Westinghouse, having delivered similar off-gas treatment delay systems to other Swedish plants, was awarded this contract in 2013 and the installation will be done during 2015.

INTRODUCTION

Traditionally the Swedish requirements for restriction of radioactive releases to the recipients from nuclear power plants have been based on the dose that a fictive so called critical group receives. The critical group consists of typical inhabitants living in the vicinity of the power plant and to a large extent is living on locally produced food. As the areas around the Swedish nuclear power plants are scarcely populated and located on the sea shores, where the liquid releases are highly diluted when pumped out in the sea, these requirements have been met with a comfortable margin.

With the Oslo-Paris (OSPAR) convention for the protection of the marine environment of the

North-East Atlantic, a new set of requirements has been introduced. These requirements also concern the releases of radioactivity to the sea. The way to calculate the releases is now based on purely the activity release without conversion to the dose to the critical group. For the Swedish nuclear power plants it has resulted in more demanding requirements.

As a result, the Swedish utilities are investing in new methods and facilities to reduce their releases to the recipients. Two major investment projects are currently being implemented at two of the Swedish BWR sites, Forsmark and Oskarshamn, both with Westinghouse as the main contractor.

FORSMARK

The Forsmark nuclear power plant consists of three BWR units, all with fairly state-of-the-art off-gas treatment facilities, compared to other nuclear sites in Sweden. Thus, the Forsmark utility, FKA, is focusing on the liquid releases. The two oldest units, unit 1 and 2, have a common radwaste treatment plant equipped with different systems for cleanup of contaminated water coming from the power plant. The systems utilize filtration, ion exchange and evaporation to separate the radioactivity from the remaining water that could be released to the cooling water channel after monitoring of its radioactivity content.

During the annual outages, the waste treatment plant receives increased amounts of water, when systems and pools at the nuclear plant are emptied. The buffer tank capacity for receiving the flushed water has been limited to 3,000 cubic meters as a maximum. The cleanup capacity, particularly for evaporation, sets limits on how fast these tanks could be emptied. The evaporator plant can treat 4 to 5.5 cubic meters per hour so it will take more than a month to empty these tanks. As the planned outages for the two BWR units follows each other, the amount of water pumped to the waste treatment plant sometimes exceeds the treatment capacity. The choice would then be to release water without treatment or to reschedule the outage activities with negative impact on the electrical power production. None of these options are favorable, so a solution was requested.

FKA decided to increase the buffer storage capacity as a first step, and an agreement with the regulator was made to have the higher capacity installed by end of 2011. The chosen solution was to install an additional 3,000 cubic meters of storage capacity in a new building. The design activities started in November 2010, so the time schedule was tight. In order to perform the work in the shortest time possible a single joint project organization was formed between the utility and Westinghouse, where the utility undertook the civil design work and erection of the new building while Westinghouse performed the process design, purchase of equipment, installation, tests and commissioning of the new facility. All activities were led by a single project manager, from Westinghouse, reporting to the FKA projects department.

The new system consists of two tanks, with a volume of 1,500 cubic meters each, equipped with pumps and connected to the existing waste treatment plant with new pipes. Based on the prior experience from operation of this system, the tanks were specially designed to handle the worst type of residual water coming from the plants, with a high content of suspended solids. An example is that the bottoms of the tanks were made conical to facilitate flushing out all contents of the tanks. The design of the tanks and system also makes it possible to separate the particles and sludge from the water. These tanks are now used for the worst type of water while the previous tanks normally receive cleaner water.

After the early design phases the main components were ordered and the erection work of the building started. In August 2011 the walls were raised and the tanks were lifted in from above. The roof was then put into place and the remaining installation work started inside the building. In November the system was ready for commissioning and before the end of the year 2011 the system was taken into service.

The new system has worked well during the outage seasons of 2012 and 2013 and the expected buffer capacity has proven to be useful. The critical event will be when the wet-well has to be emptied which means that the waste treatment facility will have to receive 3,000 cubic meter at one single occasion. This will now be possible without having to increase the activity release.

Figure 1: Installation of one of the new 1,500 m3 buffer tanks at the Forsmark site.

OSKARSHAMN

The Oskarshamn nuclear power plant also consists of three BWR units, but with two of the units from the earliest generation of Swedish BWRs. The utility, OKG, prioritized that efforts are made on the gaseous releases as these two units have a simpler design of the off-gas treatment system than the newer plants.

The Swedish plants use different steps to treat the incondensable gases coming from the turbine condenser. The first step is to reduce the volume flow by removal of hydrogen gas produced by radiolysis of the reactor water by means of a recombiner. The gas is led through a noble metal catalyst bed where the hydrogen is allowed to react with oxygen gas and the resulting water vapor is removed by condensation.

The second step is a passive delay system, where the gas from the recombiner is led through a large tank filled with sand. The purpose of this step is to delay the gas flow to allow the short-lived noble gases, mainly krypton and xenon, to decay and thus reduce the activity content of the gas flow. The residence time in the sand tank is up to 20 hours. The purpose of the sand is mainly to make sure that the flow is well defined and uniform.

The newer BWR units also have a complementary system based on active delay of the noble gases. Activated carbon (charcoal) has a higher affinity to noble gases than other molecules in the air gas. The residence time for krypton is 25 times higher than for air while the same factor is 400 for xenon. These systems consist of four columns filled with activated carbon, each with a volume of 4 cubic meters. The columns work in pairs and are designed for retaining of xenon. Before the front of xenon breaks through the column bed the flow direction in the column is reversed by suction back to the condenser. The xenon gas is thus trapped in an eternal loop.

The last step of the off-gas treatment system is filters for removal of iodine and then the gas flow is directed to the main stack of the plant.

The Oskarshamn units 1 and 2 were not equipped with the activated carbon systems and OKG made the choice to install a similar system at unit 2. Westinghouse was given the task to install such a system. OKG will erect a new building along the wall of the turbine building where the sand tank is located. Westinghouse will provide the new equipment and be responsible for design, installation, testing and commissioning. The contract was signed in April 2013 and the system will be in ready for usage by end of 2015.

OKG has specified a simpler solution with a straight-forward flow through the columns, i.e. no recirculation will be used this time. The system will thus be more robust but the volume of the columns needs to be larger.

The activity contents of the different xenon and krypton nuclides are shown in Table 1, based on the last 10 years of operation.

TABLE 1: Xenon and krypton activities

Nuclide	Half life	Unit	Average activity rate (Bq/s)
Xe-133m	2.19	d	1.8E+05
Xe-133	5.25	d	9.3E+04
Xe-135m	15.3	min	3.8E+06
Xe-135	9.14	h	1.1E+06
Xe-137	3.82	min	1.8E+07
Xe-138	14.1	min	1.6E+07
Xe-139	41	s	1.8E+05
Xe-140	13.7	s	
Kr-85m	4.48	h	1.9E+05
Kr-85	10.76	y	3.8E+04
Kr-87	76	min	9.7E+05
Kr-88	2.8	h	5.8E+05
Kr-89	3.2	min	6.2E+06
Kr-90	33	s	

As seen in the table most of the nuclides are fairly short-lived, except Xe-133 with a half life of

5.25 days and especially Kr-85 with a half life of 10.76 years. The focus has thus been to reduce the xenon activity and the design criterion is to achieve a delay of xenon of 200 h, corresponding to about 8 days which would be more than one half life for Xe-133.

With a design flow rate of 60 Nm^3/h the required volume of activated carbon is about 35 cubic meters which has been divided between two columns in parallel. The system will consist of two such lines in parallel so the number of columns will be four. The system is designed for gas flows from 10 to 100 Nm^3/h in each line. To improve the conditions for adsorption of the noble gas molecules the humidity of the incoming gas flow is reduced by cooling of the gas to 6 degrees Celcius and condensation of the humidity. The gas is then heated to about 25 degrees which lowers the relative humidity to about 30%.

With the new system in place it is expected that the total releases from the Oskarshamn site will be well within acceptable levels. The main objective is to keep the release rates of noble gases below 3,000 GBq/year for the entire site, corresponding to 1,000 GBq/year for Unit #2.

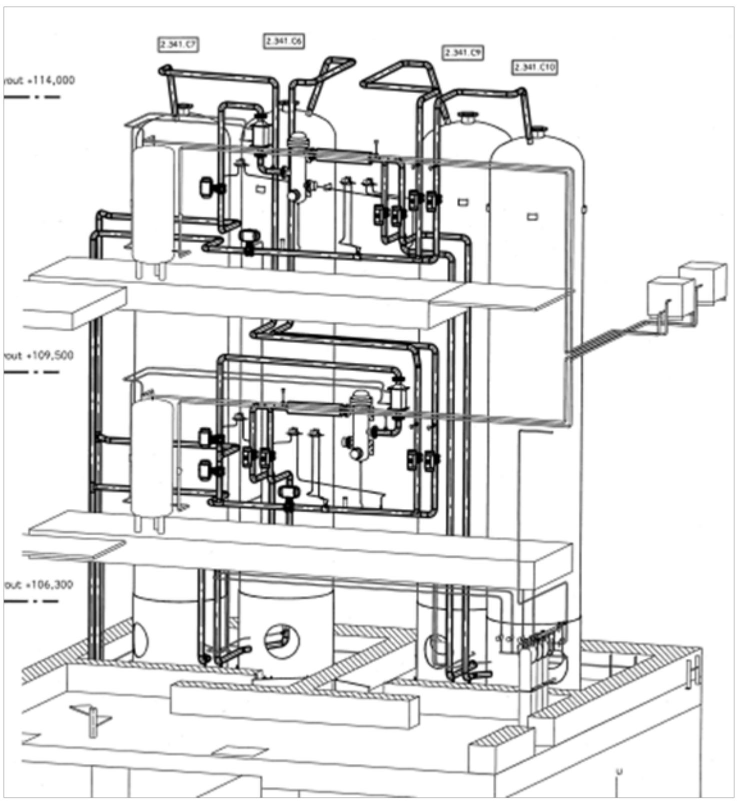

Figure 2: Layout of the new carbon column system at Oskarshamn unit 2.

CONCLUSIONS

The Swedish nuclear power plants have all been facing higher demands on minimizing the releases of radioactivity to the recipients. These requirements have been met by different measure where FKA has chosen to reduce their liquid releases for the Forsmark site while OKG has focused on their gaseous releases from the Oskarshamn site. The different approaches all depends on the specific circumstances at each of the sites, so the chosen solution differs between the sites.

The two utilities have both during recent years made large investments in safety modernizations and power uprates. With these new investments in their plants they have also expressed a clear willingness to meet higher environmental requirements.

The Forsmark project has been a success with a technical solution that has worked well during the outage seasons of 2012 and 2013, and the extra 3000 m3 of buffer capacity has proven to be useful.

The Oskarshamn project is still in its initial phase so the performance of the new system is yet to be seen.