RADIOACTIVE LIQUID WASTE VOLUME REDUCTION SYSTEM

Robert Williams
Garry Strand
Pacific Nuclear Systems, Inc.
NuPac Services Division, Inc.
Columbia, South Carolina

ABSTRACE

the basis of this paper is to discuss the development and operation of Pacific Nuclear System's RVR-7200 System. The RVR-7200 was developed for use at Three Mile Island (TMI) Unit II for processing of radioactive water resulting from the 1979 accident. The contaminated water was produced from direct releases of reactor coolant during the accident as well as primary coolant leakage and in leakage of river water through the reactor building air coolers. Additional water was generated during defueling and decontamination activities during the post accident years.

GENERAL DESCRIPTION AND BACKGROUND

The total volume of water that will require processing is anticipated to be about 2.3 million gallons, will require approximately 18 months to process and will generate 190 tons of solids. The method of disposal that will be used is to process the water through a closed cycle evaporator, reheat the purified distillate, and discharge it as a vapor containing essentially all of the tritium and a small fraction of the particulate contamination to the atmosphere through a controlled and monitored exhaust stack. The remaining particulate contamination will be concentrated in evaporator bottoms then dried to a solid waste form, packaged and shipped for burial at a low level radioactive waste facility.

The water to be disposed is presently in storage around the site, some of which is still used for clean-up activities. About 40 percent of the 2.3 million gallons will require some sort of preprocessing before final processing by the RVR-7200 System. Some of this water has already received processing through ion exchange, filtration or distillation.

The 2.3 million gallons of accident water, herein referred to as processed water, contains approximately 1,020 curies of tritium. Since no conventional waste treatment processes will effect the tritium content of the water, all the tritium will be released to the environment through evaporation/ vaporization. The total estimated quantity of tritium released during the 2 year evaporation process is 0.105 grams. This equates to 0.7 milliliter of tritium in the entire 2.3 million gallons of processed water. The processed water contains a chemical composition of Ortho-boric Acid (H_3BO_3) and Sodium Hydroxide (N_2OH). The average concentration of these chemicals throughout the 2.3 million gallons is 3500 parts per million (ppm) Boric Acid, and 700 ppm Sodium Hydroxide. As the water is evaporated, the boric and sodium concentrates will combine to form Sodium Tetra Borate and Sodium Meta-Borate ($N_2O\ 2B_2O_3$ and $N_2O\ B_2O_3$ respectively). Upon completion of the evaporation/drying process the 2.3 million gallons will yield 190 tons of Boric Acid Sodium Borate solids. Contained within these solids are the radionuclides listed in Table I. The total weight of radioactive material present within the 190 tons will be less than one pound.

EQUIPMENT DESCRIPTION

The processed water disposal system consists of: (1) a vapor recompression distillation unit (main evaporator) that will distill the processed water feed in a closed cycle process and collect the purified distillate for subsequent release by vaporization; (2) an auxiliary evaporator that will further concentrate the bottoms from the main evaporator; (3) a flash vaporizer unit that will heat and vaporize the purified distillate from the main evaporator and release the vapor to the atmosphere in a controlled and monitored manner; (4) a waste dryer that will further evaporate water from the concentrated waste and produce a dry solid; and (5) a packaging system that will prepare the dry solid waste in containers acceptable for shipment and for burial to a commercial low level radioactive waste disposal site (see Fig. 1.).

MAIN EVAPORATOR

The main evaporator, or VC-300 is a vapor recompression evaporator. The unit consists of a horizontal shell consisting of tube (bayonet) type heat exchangers, a steam vapor compressor, separator/vapor dome, a concentrate tank and distillate tank.

The processed water enters the concentrate tank where it is fed to the main evaporator at approximately 4 gallons per minute (GPM). The processed water feed enters the main evaporator shell on the bottom where it is heated to boiling by steam condensing in the tubes. The water level in the heat exchanger covers about one-third of the tubes. As the liquid boils, a vigorous foaming action occurs, wetting the upper tubes providing an instantaneous vaporization. If there is inadequate foaming action to wet the tubes the system can be operated in a spraying film mode. In this mode, a portion of the feed enters the top of the heat exchanger wetting the upper tubes. Both ends of the heat exchanger have clear plexiglass windows allowing the operator to observe the liquid level and foaming action, enabling

TABLE I

Identification of Radionuclides in Processed Water

	Column 1	Column 2	Column 3	Column 4	Column 5
Nuclides	Curies Present in 2.3 MGAL	Concentration in Ci/ml in 2.3 MGAL	Specific Activity in Ci/gram	A-2 Value	Total Grams Present in 2.3 MGAL
Cesium-137	3.2E-1	3.7E-5	9.8E+1	10	3.7E-3
Cesium-134	7.66E-3	8.8E-7	1.2E+3	10	6.38E-6
Strontium-90	9.6E-1	1.1E-4	1.5E+2	0.4	6.4E-3
Antimony-125/	2.0E-2	2.3E-6	1.4E+3	25	1.43E-5
Tellurium-125m			1.8E+4	100	
Carbon-14	8.7E-1	1.0E-4	4.6	60	1.89E-2
Technetium-99	8.7E-3	1.0E-6	1.7E-2	25	5.12E-1
Iron-55	4.2E-3	4.8E-7	2.2E+3	1000	1.91E-6
Cobalt-60	4.2E-3	4.8E-7	1.1E+3	7	3.82E-6
Iodine-129	<5.2E-3	<6.0E-7	1.6E-4	2	<3.25E+1
Cerium-144	<1.4E-2	<1.8E-6	3.2E+3	7	<4.38E-6
Manganese-54	<3.5E-4	<4.0E-8	8.3E+3	20	<4.2E-8
Cobalt-58	<3.5E-4	<4.0E-8	3.1E+4	20	<1.13E-8
Nickel-63	<5.2E-3	<6.0E-7	4.6E+1	100	<1.1E-4
Zinc-65	<8.5E-4	<9.8E-8	8.0E+3	30	<1.06E-7
Ruthenium-106/ Rhodium-106	<2.9E-3	<3.3E-7	3.4E+3	7	<8.53E-7
Silver-110m	<4.9E-4	<5.6E-8	4.7E+3	7	<1.04E-7
Promethium-147	<4.2E-2	<4.8E-6	9.4E+2	25	<4.47E-5
Europium-152	<3.3E-6	<3.8E-10	1.9E+2	10	<1.74E-8
Europium-154	<3.8E-4	<4.4E-8	1.5E+2	5	<2.53E-6
Europium-155	<9.6E-4	<1.1E-7	1.4E+3	60	<6.86E-7
Uranium-234	<8.7E-5	<1.0E-8	6.2E-3	0.1	<1.40E-2
Uranium-235	<1.0E-4	<1.2E-8	2.1E-6	0.2	<4.76E+1
Uranium-238	<1.0E-4	<1.2E-8	3.3E-7	Unlimited	<3.03E+2
Plutonium-238	<1.0E-4	<1.2E-8	1.7E+1	.003	<5.88E-6
Plutonium-239	<1.2E-4	<1.4E-8	6.2E-2	.002	<1.94E-3
Plutonium-240	<1.2E-4	<1.4E-8	2.3E-1	.002	<5.22E-4
Plutonium-241	<5.7E-3	<6.5E-7	1.1E+2	0.1	<5.18E-5
Americium-241	<1.0E-4	<1.2E-8	3.2	.008	<3.13E-5
Curium-242	<8.7E-4	<1.0E-7	3.3E+3	0.2	<2.64E-7
TOTAL	<2.27 Ci	<2.6E-4 Ci/ml			<384.66 gram

*Total activity and concentration shown are for projected "Base Case" water.

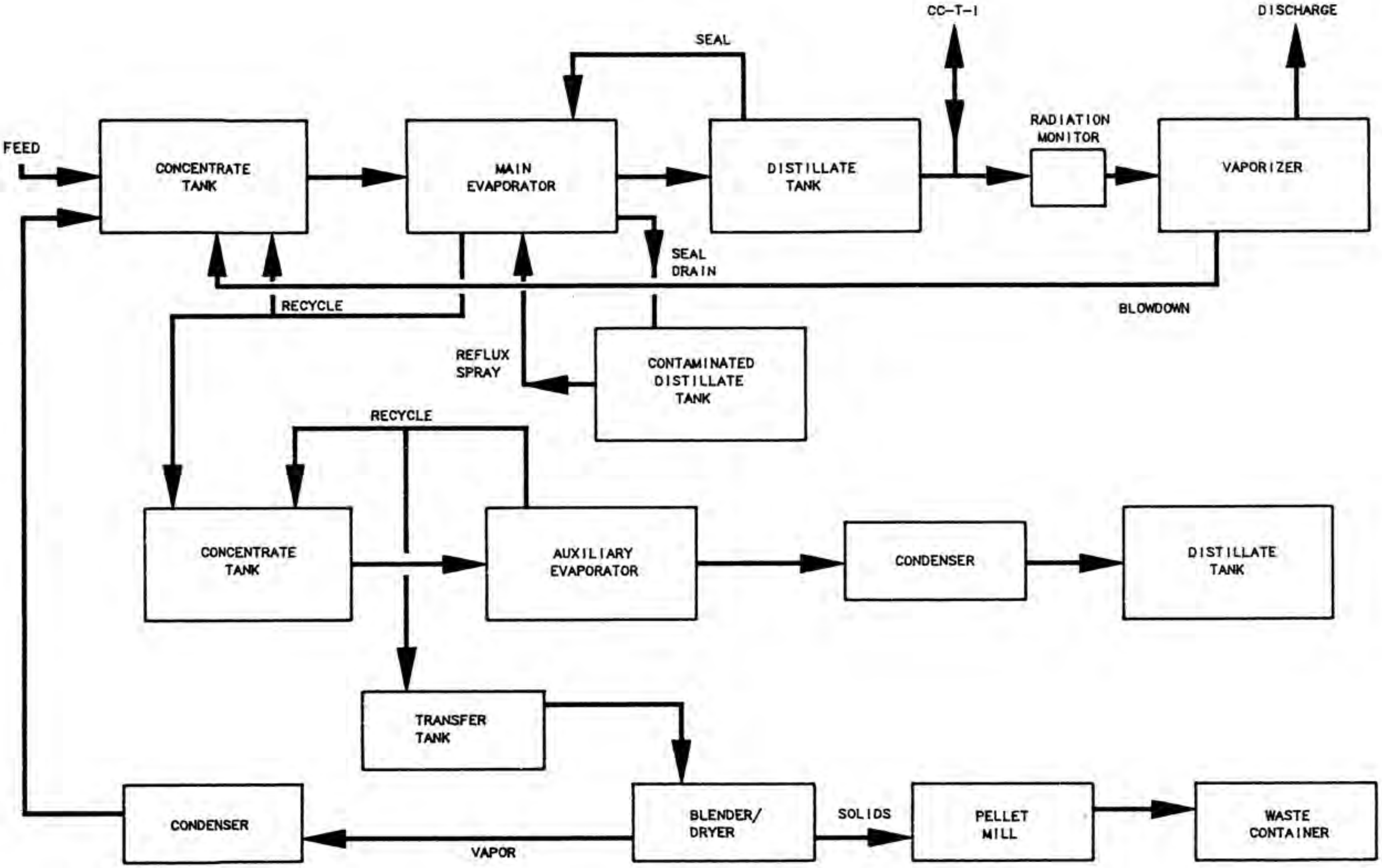

Fig. 1. TMI-2 Processed Water Disposal System.

the operator to make adjustments for proper feed to the system.

The resulting steam exits the heat exchanger shell through two risers where it enters the separator/vapor dome. Water entrained in the steam falls out to the bottom of the vapor dome where it is drawn off by a pump and returned to the main concentrate tank. Any remaining liquid entrained in the vapor is removed as it passes through a woven wire double demister. The dried vapor then enter the suction side of the vapor compressor via a 14 inch steam line where there is a significant increase in temperature and pressure. The resulting steam is discharged in to the tube side of the heat exchanger in the evaporator heating section providing heat to the boiling liquid in the shell. Because the system operates under a vacuum, the processed (feed) water will boil at about 160 degrees Fahrenheit. The vapor compressor will raise the temperature further to approximately 180 degrees Fahrenheit. The vapor compressor supplies all the heat needed by reclamation and reuse of the latent heat from vaporization of the steam produced from evaporation. Much like a refrigeration cycle utilized in conventional heat pumps. The resulting purified distillate which will contain almost all of the tritiated water is collected in the main evaporator distillate tank. From this tank the distillate can be pumped to on-site storage tanks for further monitoring or directly to the flash vaporizer. If routed directly to the flash vaporizer, the distillate is routed through a radiation monitor and sampler before being released to the atmosphere.

The main evaporator system will produce a concentrated solution of about 10 percent total solids. This solution is discharged through a pump to the auxiliary evaporator concentrate tank. From this point the solution is sent to the auxiliary evaporator for further concentration or 20 percent total solids.

AUXILIARY EVAPORATOR

The auxiliary evaporator is constructed similarly to the main evaporator, except that it needs a condenser to reject heat and operates at a higher vacuum. The heat source to the auxiliary evaporator is waste heat from the hot distillate in the main evaporator distillate tank supplemented by two 30 KW electric heaters. The hot distillate is pumped through the electric heaters where it reaches a temperature of about 170 degrees Fahrenheit. The hot distillate flows into the tube heat exchanger which is similar to those used in the main evaporator. The distillate then returns from the tubes back to the main distillate tank.

The separator/vapor dome functions the same as described for the main evaporator except the dry vapor is routed to the main evaporator for start-up heat. The concentrate solution reaches a concentration of 20 to 25 percent in the auxiliary evaporator and is discharged at a rate of 0.3 to 0.5 GPM to the blender/dryer transfer tank.

BLENDER/DRYER

When the concentrate solution reaches a predetermined level in the transfer tank it is pumped to the blender/dryer for final processing. The blender/dryer consists of an agitator scraper which is encased in an insulated stainless steel shell. The cylindrical shell has three sections of electric strip heaters, each capable of producing 400 degree Fahrenheit temperatures. The inside surface of the dryer is continuously scraped by the agitator scraper that removes and mixes material that dries on the inside surface of the shell. Through this process the remaining water is removed leaving a dry product containing the remaining radionuclides from the processed water.

PACKAGING

The dry powder will be transferred via a flexible tube conveyor to a pellet mill for conversion to pellets approximately 3/8 inch x 1/2 inch long. These pellets are discharged into a 55 gallon drum contained in a negative pressure enclosure. The drums are then sealed, surveyed and shipped for burial.

SUMMARY

The RVR-7200 has recently completed successful pre-operative and acceptance testing at Three Mile Island. Pending acceptance of the test data by Pennsylvania's Department of Environmental Resources, it is anticipated that radioactive processing will begin in February, 1990.

Since implementing the RVR-7200 at Three Mile Island, NuPac Services has developed two smaller RVR systems. These units operate at 200 and 800 gallons per day and utilize the blender/dryer capabilities used in the RVR-7200. Through extensive testing it has been found that these units are capable of drying to a solid form, liquid waste such as PWR evaporator bottoms, ion exchange resins, activated charcoal and sludges that cannot be dewatered with conventional dewatering systems. By monitoring various parameters on the RVR systems, tested waste streams can be dried to meet regulatory concerns for burial criteria at all low level waste burial sites.

SYSTEM PERFORMANCE AND VOLUME REDUCTION

The system performance is measured by several factors. These factors are decon factors (carry-over from the entire process versus the feed stock) and total volume reduction. The decon factor was designed to meet .3 percent carry-over for the entire waste liquid system. Waste water enters the system at 3500 ppm boron and is measured at the distillate discharge to the vaporizer at the vaporizer discharge to the atmosphere. The system has met the .3 percent decon factor and has averaged .1 percent. When measured at the vaporizer discharge the decon factor has been an average of .05 percent. With the feed stock of 3500 ppm boron the distillate has 3.5 ppm boron and the vaporizer has 1.75 ppm boron.

The volume reduction is based on the total amount of waste processed versus the total burial volume. This system will handle 306,667 cubic feet of liquid waste. The burial volume will be approximately 5,429 cubic feet of waste or 743/55 gallon drums. The volume reduction for this system is 56:1 because of the total evaporation and vaporization of the liquid. Other systems where the liquid is not vaporized will yield a volume reduction from 5:1 for non-stabilized waste to 12:1 for stabilized waste. The true volume reduction for each plant will vary according to the solids content and radionuclides in the waste stream. The actual waste for burial will be the solids content of the waste water only.

REFERENCES

1. GPU Nuclear, "Technical Evaluation Report for the Processed Water Disposal System," (1988)