Fukushima Water Treatment Update – 14257

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ABSTRACT

The aftermath of the Great East Japan Earthquake has left the Fukushima Daiichi Nuclear Station with many challenges related to water treatment. This paper will provide information on three systems provided for the treatment of [1] accumulated water associated with the Circulated Water Cooling System, [2] sub-drain water removed from wells adjacent to the Unit 1-4 Reactor and Turbine Buildings, and [3] wash water from decontamination of vehicles and equipment. Specific information will be presented on work that was completed to overcome process, installation and logistical challenges associated with these water streams including the following:

- Selection of technology and equipment for removal of specific radionuclides
- Performance results of highly selective adsorbents used for removing radionuclides in the presence of varying concentrations of chlorides and other natural constituents
- Description of process flowsheets and equipment configuration
- Discussion of the post-accident work environment and the related work site restrictions

Results show that the customized solutions will enable the utility to clean-up the wastewater for cooling, reuse and potential discharge. The technologies used for the three water treatment systems are directly applicable to the treatment of similarly challenging water streams at commercial nuclear power plants, fuel reprocessing plants and governmental nuclear facilities worldwide. The use of these technologies will aid in the lowering of radioactivity released to the environment, worker radiation exposure and the amount of secondary waste requiring long term storage and/ or disposal.

The Challenge:

Safely process the highly radioactive effluent that has resulted from the Fukushima Daiichi accident in March of 2011.

The Priorities

The water treatment program focus has gone through numerous phases which include; Phase 1: Stabilizing the Site; Phase 2: Brine Treatment; Phase 3: Groundwater Treatment; and Phase 4: Decontamination Support. The priority on-site throughout each phase was to ensure the safety of the public and site personnel. Numerous challenges have been and continue to experienced. Significant progress has been made while many challenges continue to exist.

The Projects

<u>Phase 1: Site Stabilization</u>

Hitachi and Avantech provided critical equipment during the site stabilization phase. Specifically, Hitachi provided the reverse osmosis and evaporation equipment while Avantech provided the cesium removal system identified as SARRY. These systems have been well documented and it's not the intent of this paper to further elaborate. However, it is important to note that these systems continue to operate in their original configuration and provide the support to the site necessary for reactor maintenance. Currently these systems have processed over 625,000 cubic meters (166 million gallons) of water. The waste generation has been minimal generating approximately 94 vessels which are being stored at the site safely.

SARRY I: Cesium Removal System

In addition to the work previously performed, HGNE and Avantech are implementing the strontium removal system that will be integrated into the original SARRY system. Avantech has designed, patented, manufactured, and delivered the first two strontium removal vessels in December 2013. The system utilizes a unique cooling and shielding process that eliminates concerns with the thermal, radiological and hydrogen generation analysis. This system will be operating in March of 2014 and results can be reported if available at the time of the presentation.

Phase 2: High Performance Multinuclide Removal System

TEPCO/Hitachi and Avantech were awarded the work to provide a system in support of radionuclide removal prior to release of the water. This award was made by the Japanese government during a competitive bidding process. The work is currently on-going and will be implemented in 2014.

The basics of the process implemented include the use of filtration and adsorption as compared to precipitation which is currently being utilized. The system is comprised of the following equipment

- Feed and Booster Pumps
- Prefiltration and Postfiltration
- Adsorption Vessels with a variety of media's
- Degassification
- pH Adjustment

The equipment design challenges are similar to those encountered during the initial work at Fukushima and included radiation shielding, heat dissipation, and material handling. The basic design assumptions are detailed below;

Radiation Protection:

- Effective dose rate of less than 1 mSv/h of effective dose rate at the equipment
- Feedwater source term detailed below
  - Cs-134: 1. 0E+02 Bq/mL
  - Cs-137: 1. 0E+02 Bq/mL
  - I-129: 9. 1E-02 Bq/mL
  - Co-60: 6.6E-01 Bq/mL
  - Sb-125 : 5. 0E+02 Bq/mL
  - Mn-54 : 7. 7E-01 Bq/mL
  - Ru-106: 2.0E+02 Bq/mL
  - Sr-90: 1. 0E-06 Bq/mL

Hydrogen Removal

- Hydrogen concentration kept under 4% during normal operations
- Hydrogen be exhausted naturally during storage

Heat Dissipation

- All gamma and beta energy is turned into heat
- Heat needs to be naturally dissipated during operations and storage

Material Handling

- Utilize shield bells for filter removal

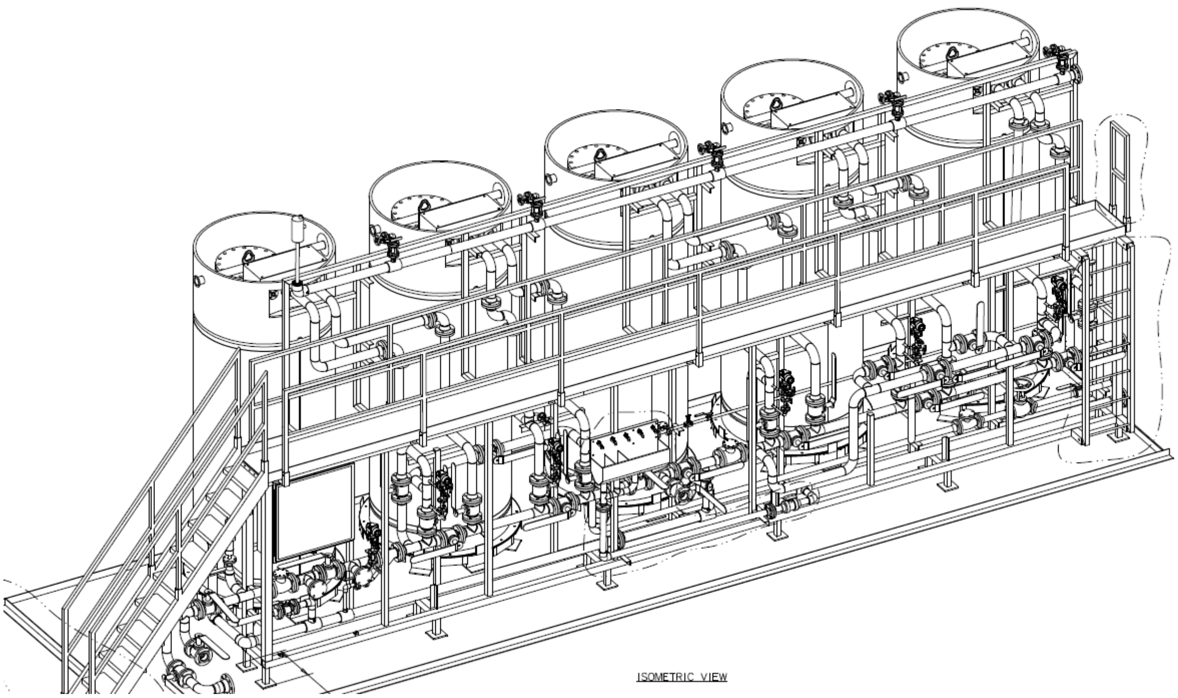
This equipment is currently in design and updated drawings and manufacturing pictures will be provided during the presentation.

Phase 3: Groundwater Remediation

Hitachi and Avantech are delivering and installing the groundwater treatment system. The system is supported by sixteen wells that are being pumped to a common feed tank. The objective of the system is to process the groundwater around each of the reactors to ensure groundwater intrusion to the reactor facilities is managed. Furthermore, by lowering the groundwater levels the water level in the basement will also be able to be reduced thus minimizing the volume of additional groundwater intrusion. By minimizing the groundwater intrusion the volume of brine generated is further minimized. As a result the life cycle savings of this system is significant and will provide long term benefits both environmentally as well as financially.

The treatment process is designed to remove both undissolved and dissolved impurities from the water which will ultimately remove the radionuclides in the groundwater. The process is broken down into two stages of filtration and then ion exchange. The filtration process is a performed with a series of four filters in a graded approach from five micron to less than one micron. The final filters are a proprietary product that is designed to maximize the dirt holding capacity. The system is designed to process a flow rate of 50 m3/hr/train (10 gallons per minute/train). The system has two trains of operation to support the site.

Dissolved impurities are removed through a series of custom made adsorption vessels with proprietary media inside the vessels. The process has three primary and two secondary adsorption vessels with the exact same design. The Adsorption Vessel is a down-flow adsorption and/or ion exchange unit. It can be loaded with most all types of filtration, adsorption and ion exchange media. The vessel is designed with a screen top distributor that equally distributes incoming water over the media bed. Water then flows down through the media to a bottom collector that is designed to eliminate flow channeling through the bed and to use all the media in the bottom head. The only thing that distinguishes a primary and secondary SIXM from one another is the type of media that it holds and its position within the process train. The primary and secondary adsorption vessels are integrated together utilizing a valve rack design that allows all of the vessels to operate in either a lead or lag configuration. This flexibility ensures the generation of radioactive waste is minimized by utilizing the maximum ion exchange capacity throughout the system. Detailed below is a sketch of the valve racks utilized



HI-G Adsorption Vessel Valve Rack

The system is designed to handle the influent water characteristic identified in the table below. The anticipated effluent is also detailed in the table below.

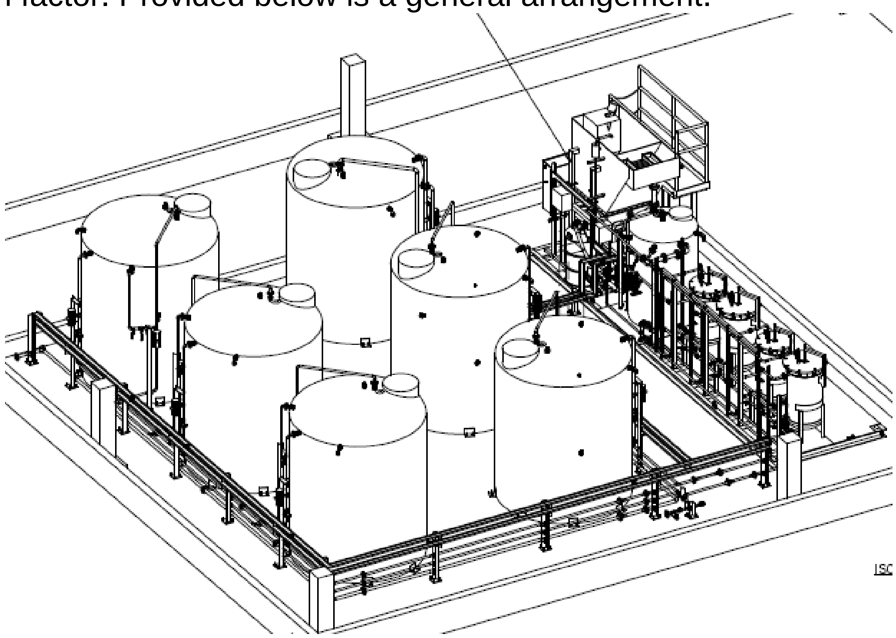
	Characteristic	Influent	Effluent
Chemical Quality	Cl	800 ppm	
	Ca	23 ppm	
	Mg	61 ppm	
	COD	7 mg/l	<30 mg/l
	n-hexane	<1 mg/l	< 5 ppm
	pH	7.1-7.5	5.8 – 9.0
	Suspended Solids	30 mg/l	<50 mg/l
	Temperature	0 – 40 ^{o}C	
Activity Conc.	Cs-134	5.12E+00 Bq/mL	ND
	Cs-137	9.46E+00 Bq/mL	ND
	I-131	< 6.65E-02 Bq/mL	ND
	Co-60	< 1.64E-02 Bq/mL	ND
	Sb-125	2.70E-02 Bq/mL	ND
	Ag-110m	2.99E-01 Bq/mL	ND

	Sr-89	1.44E-03 Bq/mL	ND
	Sr-90	3.56E-02 Bq/mL	ND

The anticipated effluent is also detailed in the table above.

<u>Phase 4: Decontamination Support</u>

Decontamination Support Water Treatment System (Atrex C/W) is the facility to treat waste water arising from decontamination processes used at the site. It collects the waste liquid and removes activity, solids, and organic materials prior to reuse of the liquid. The treatment process utilizes filtration, adsorption, and ion exchange to treat the influent wastewater. The process allows the operator to be able to utilize or by-pass any of the process equipment as well as recycle wastewater as necessary to improve the decontamination factor. Provided below is a general arrangement.



Atrex^{TM} General Arrangement

The treated water is reused for the decontamination of cars. The anticipated influent characteristics of the wastewater are identified in the table below

Item	Unit	Inlet (Waste Water)	Outlet (Treated Water)	Remarks
SS	ppm	200	<50	Assume sand, silt and clay
Cl-	ppm	10		
COD	ppm	50	30	Reference Value Only, not limit
Oil	ppm	10	5	

pH		8.0 – 9.0	5.6 – 8.6	
Cs-134	Bq/l	1000	<25	
Cs-137	Bq/l	1000	<25	

The system is designed to operate at a flow rate of 2.5 m3/hr and will produce an effluent with non-detectable radioactivity. The adsorption media's are focused on Cesium and Strontium removal and are provided in a unique format. Avantech has designed a basket that is easily replaceable and eliminates the need to remove the entire vessel or sluice the media. These change-outs are performed utilizing a shield bell that minimizes radiation exposure.

Conclusion

The challenges at Fukushima are significant and wide ranging. One of the more complicated issues is wastewater treatment because of the effluent discharge requirements coupled with the difficulty in developing the wastewater treatment infrastructure. Avantech has had very good success in implementing the complex solution called SARRY. We are now deploying the lessons learned from SARRY to support the site water treatment in the areas of site decontamination. Groundwater remediation, Cesium and Strontium removal, as well as brine treatment. Not all of these systems are operational at the time of the writing but the latest data will be provided dur