Designing a New Radioactive Liquid Waste Treatment Facility for Los Alamos National Laboratory to Update Treatment Technologies and Meet Current Regulatory Requirements – 8205

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ABSTRACT

This paper discusses the new Radioactive Liquid Waste Treatment Facility (RLWTF) being designed for Los Alamos National Laboratory (LANL) and also provides information regarding the updates to the facility resulting from improvements in technologies and changes in regulations and codes that have occurred since the existing facility was built. It explains how the new facility will be a suitable replacement for the existing facility and how the new facility will allow LANL to continue its current mission as well as have the capability to treat any new waste stream resulting from a future expansion of the laboratory.

Specific topics relating to the improvements in technology that are discussed include replacing existing settling technologies with improved chemical precipitation technologies using hydrochloric acid, sodium hydroxide, magnesium chloride, and ferric chloride. Also discussed are improved filtration technologies and dewatering technologies.

Topics discussed regarding regulatory and code requirements include the current state and federal regulatory criteria and the new seismic criteria requirements that the design conforms to.

INTRODUCTION

The existing RLWTF, located at LANL, has been in operation since 1963. This facility currently treats industrial, low-level waste (LLW), and transuranic (TRU) wastewater that is collected from 15-different technical areas within the LANL. Sixty-three buildings within these technical areas feed 1,800 different sources to RLWTF. The existing facility is 19 years beyond its original design life of 25 years.

The Radioactive Liquid Waste (RLW) system at LANL is a "mission essential" capability within the Readiness in Technical Base and Facilities (RTBF) program. However, the existing facility does not meet current authorization basis criteria for a Hazard Category 2 nuclear facility and its design is inconsistent with current International Building Code requirements. This limits the flexibility of operations to meet regulatory requirements and respond to system failures as they occur. The aging facility is also vulnerable to major system failures that could shut down the capability for both LLW and TRU wastewater treatment. [1]

The new RLWTF is being designed as a complete replacement for the existing facility that will receive liquid waste feed, treat the liquid stream, collect and package any solid wastes, and then discharge the treated effluent to a new Zero Liquid Discharge (ZLD) system. The new RLWTF will be designed as a single facility constructed to treat both the LLW and TRU waste. The new facility is being designed to process approximately 9.5 million liters per year of LLW, 42 thousand liters per year of TRU acid liquid waste, and 42 thousand liters per year of TRU caustic liquid wastes. The project's ultimate goal is to provide an RLW treatment capability that is safe, reliable, and effective for the next 50 years while supporting the primary missions at LANL.

The RLWTF is a line-item capital project, executed under Department of Energy (DOE) Order (O) 413.3, Project Management for the Acquisition of Capital Assets, and is classified as a Hazard Category (HC) 2, Performance Category (PC) 2 nuclear facility. DMJM H&N executed the designs under the requirements of 10CFR830, Nuclear Safety Management, Subpart A, Quality Assurance Requirements and ASME-NQA-1, Quality Assurance Requirements for Nuclear Facility Applications.

RLWTF PRELIMINARY DESIGN

Treatment Building Design

The new RLWTF design is a two-story building located west and slightly south of the existing treatment facility. An architectural rendering of the facility design is provided in Figure 1. The treatment building will house the process equipment and operational support space for the treatment of LLW and TRU wastewater.

Fig. 1. Architectural Rendering of the North East Side of the New RLWTF.

The treatment building's dimensions are approximately 19.0-m by 37.3-m and include a 19.0-m by 4.6-m below-grade sump floor at the south end of the building. The layout was developed on the principles of separation (e.g., keeping hazardous or potentially contaminated operations physically separate from non-hazardous, cleaner operations), personnel circulation (e.g., preventing the co-mingling of personnel in anti-contamination clothing with personnel in street clothing), compartmentalization (i.e., locating process equipment to maximize adjacencies thus minimizes length of piping runs), material movement (e.g., providing for the vertical and horizontal flow of materials into and within the building), and economy (e.g., locating facility and process equipment that do not have to be in the treatment building, in less expensive support buildings or outside under covered storage). A 3-dimensional model (developed in AutoCAD® MEP) of the treatment facility's upper and lower levels is provided in Figure 2.

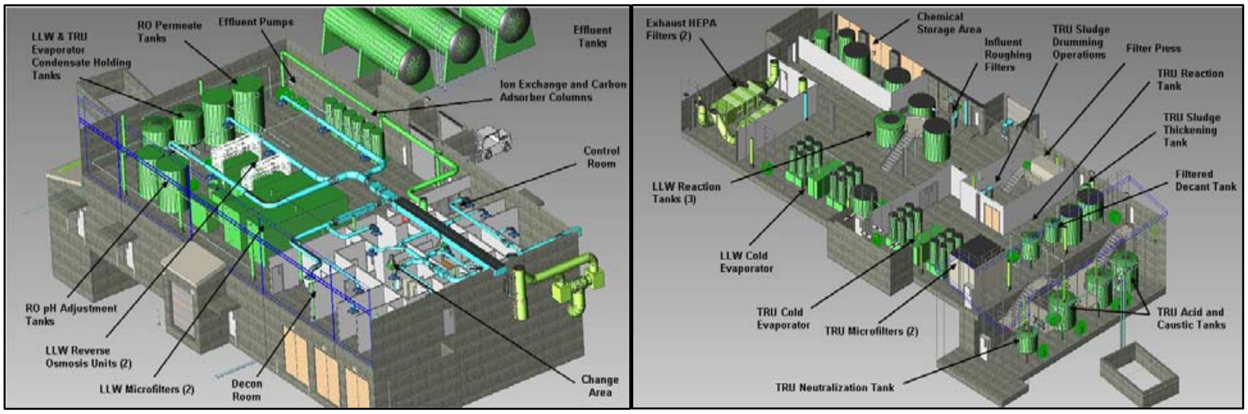

Fig. 2. 3-D model of the proposed design of the RLWTF upper and lower floors.

The main personnel entrance into the facility will be located on the west side of the building. Access into the facility will be controlled using badge scanners to enter the main door, and once inside the main entrance, personnel can access a work room, and/or the operator can allow access to the control room or the change room. Personnel requiring access to the processing area will be buzzed in by the operator and will then proceed to the change rooms to change into anti-contamination clothing prior to entering the process areas. Two separate change rooms for men and women both include showers, lockers, and clean anti-contamination clothing storage. Personnel exiting the change room will enter an area with hand/foot monitors and step-off pads. Once past these control measures, personnel will enter into the processing area.

Personnel entering the facility may also proceed directly to the control room without first going into the change room. The control room is located adjacent to the entrance hall but outside the process areas. The control room will have a large window between the entry hall and the control room allowing visual confirmation of all personnel entering the facility. The control room will include all monitoring and control instrumentation as well as a work station. The operator will also be able to look out onto the process area through a window on the south wall.

A large double-door airlock provides access to the upper level process area for supplies, maintenance, and change out of the process equipment from the west side of the building. Stairwells provide vertical circulation to the lower level. The upper level contains the control room, fire riser, telecommunication room, radiological support areas, change rooms, the LLW microfilters, reverse osmosis units and permeate tanks, pH adjustment tanks, evaporator condensate tanks, and the polishing filters (ion exchange and carbon adsorbers). It is divided into a clean (i.e., non-radiological) work area and a radiological work area.

The lower level is below grade or partially below grade on three sides (north, west, and south). Another large double-door airlock on the east side provides access to the lower process area. The lower level is divided into six containment areas, including a segregated ventilation plenum with high-efficiency particulate air (HEPA) filters. LLW and TRU process equipment (such as roughing filters, influent reaction tanks, TRU microfilters, evaporator supply tanks, a TRU drum loading station, evaporator drum loading stations, and associated pump skids) are located on the lower level. The lower level also houses the bulk chemical tanks (sodium hydroxide, hydrochloric acid, magnesium chloride, and ferric chloride) in separate containment areas. The transuranic waste collection tanks, neutralization tank, and associated pump skids are located on the sump floor at the south end of the building. This sump area is below grade to allow for gravity feed of liquid waste into the collection tanks from exterior sources.

The HVAC intake and exhaust equipment are located at the northwest corner of the treatment building. The standby generator concrete pad and transformer concrete pad are located north of the treatment building.

Auxiliary Building Design

Located outside the main treatment building will be various facility support structures. The new Central Utility Building will be located just west of the treatment building and a covered drum storage area will be located on the north side of the treatment building.

The Central Utility Building is 8.0-m wide by 9.8-m long and provides approximately 77.3 m^2 of floor space. It will house the air compressor, natural gas fired boilers, electrical panels, hot water heater, the chilled water, and heating water pump skids. It is located approximately 18.0 m to the west of the treatment building. Between the treatment building and Central Utility Building are three horizontal effluent tanks and three air-cooled condensers.

The 50.4 m^2 covered drum storage area consists of three concrete masonry unit walls (north, west, and south), and a metal roof deck supported by metal roof joists. The east side of the drum storage area is chain link fence with swing out gates to allow forklift access to the drum pallets. This covered area will be used to store drums of LLW and TRU waste until the drums can be shipped to a permanent disposal site. Once four drums are accumulated inside the RLWTF facility, they will be palletized with 4 drums per pallet and then taken by forklift from the lower level service area directly to the covered storage area. The pallets will be stacked two pallets high and positioned with a 1-m walk way between the pallets, which will allow visual inspections to be conducted on each drum. The drum storage will be sized to store a maximum of 170 drums for up to 90 days.

Zero Liquid Discharge

Currently the effluent from the existing RLWTF is discharged approximately 4.8 km from the facility to Mortandad Canyon. As part of the upgrade of the RLWTF, a Zero Liquid Discharge (ZLD) system is being designed to collect and process the RLWTF effluent. The ZLD portion of this design consists of a transfer line from the RLWTF and three, 0.4 hectare, lined, concrete evaporation tanks.

The evaporation tanks are sized to allow the treated effluent from the RLWTF to evaporate rather than continue to be discharged into Mortandad Canyon. The tanks are designed to allow periodic removal of any accumulated dust and debris and will be double-lined with high-density polyethylene geomembrane liners and include an interstitial leak detection system as well as a sample collection system. The tanks are designed to normally be operated in series and allow for cascade overflow from tank 1 into tank 2 and from tank 2 into tank 3. Design elements also exist to allow transfer of liquid between tanks for cleaning or repair and also to allow the contents of the tanks to be discharged into Mortandad Canyon if required.

RLWTF PROCESS OVERVIEW

Influent Basis

RLWTF receives waste from a large number of generators at LANL whose activities are diverse. The types and concentrations of contaminants vary greatly between the different batches sent to RLWTF. Future waste characteristics are unpredictable; therefore, the design of the facility to treat all types of waste is impractical. In order to design the process and size the equipment, an influent basis had to be determined.

Before the start of conceptual design, LANL conducted an analysis to provide an influent design basis for volumes, radiological constituents, and chemical/mineral constituent boundaries. Historical analytical data, operational knowledge, and knowledge of future LANL mission activities and pollution prevention/waste minimization projects were used to develop these boundaries.

The influent basis, documented in the Influent Boundary Condition Assessment [1], was used to develop the material balance for the intended process during the conceptual and preliminary design phases. The design, however, allows for uncertainty in the influent and flexibility within the facility design to add or change equipment/processes.

Low-Level Waste Treatment Process

The LLW treatment process separates suspended solids, precipitated metals, and removes radionuclides and constituents of concern (COC), including cations and anions, perchlorate, and organics, from the influent.

Nominal (i.e., design) throughput for the low-level waste treatment operations is 9.5 million liters per year using a single shift operation. The facility will process LLW waste an average of 36 weeks per year, 3 to 4 days a week, 127 days per year, and 6 treatment hours per day. The maximum design throughput is 12,100,000 L/yr pretreated LLW. This increased throughput will be managed via an extended work day, work week, and/or multiple shifts. Both the main low level and the secondary waste processes will be operated in a continuous operational mode during the operating day.

As shown in Figure 3, LLW wastewater is received from the influent tank farms at approximately 208 liters per minute (L/min) for the 6-hour operating duration. The wastewater is fed through one of two roughing filters, which removes large particulate and suspended solids larger than 200 microns from the influent stream. Solids from the roughing filters are collected in 208-L (55 gallon) drums at a rate of approximately 8 liters a day. The drums are packaged with vermiculite and transferred to TA-54. The roughing filter solids will fill approximately 4 drums per year.

The roughing filter filtrate is fed to reaction tank #1, which is an 11,356 liter tank. Hydrochloric acid is added to this reaction tank to lower the pH to 4.5. Ferric chloride and magnesium chloride are also added to the tank proportional to influent to promote flocculation and precipitation. The chemicals are completely mixed with the wastewater via the tank mixer. Approximately 29,148 liters per day of RO concentrate is recycled into reaction tank #1.

Reaction tank #1 overflows to reaction tank #2 at a rate of approximately 76 L/min. Reaction tank #2 is also an 11,356 L tank equipped with a mixer. The pH of the wastewater is adjusted to

10.5 in reaction tank #2 with the addition of NaOH while mixing. During filter press operations, the filter press filtrate is recycled back to reaction tank #2. Sludge thickening tank decant is also recycled back to reaction tank #2 periodically.

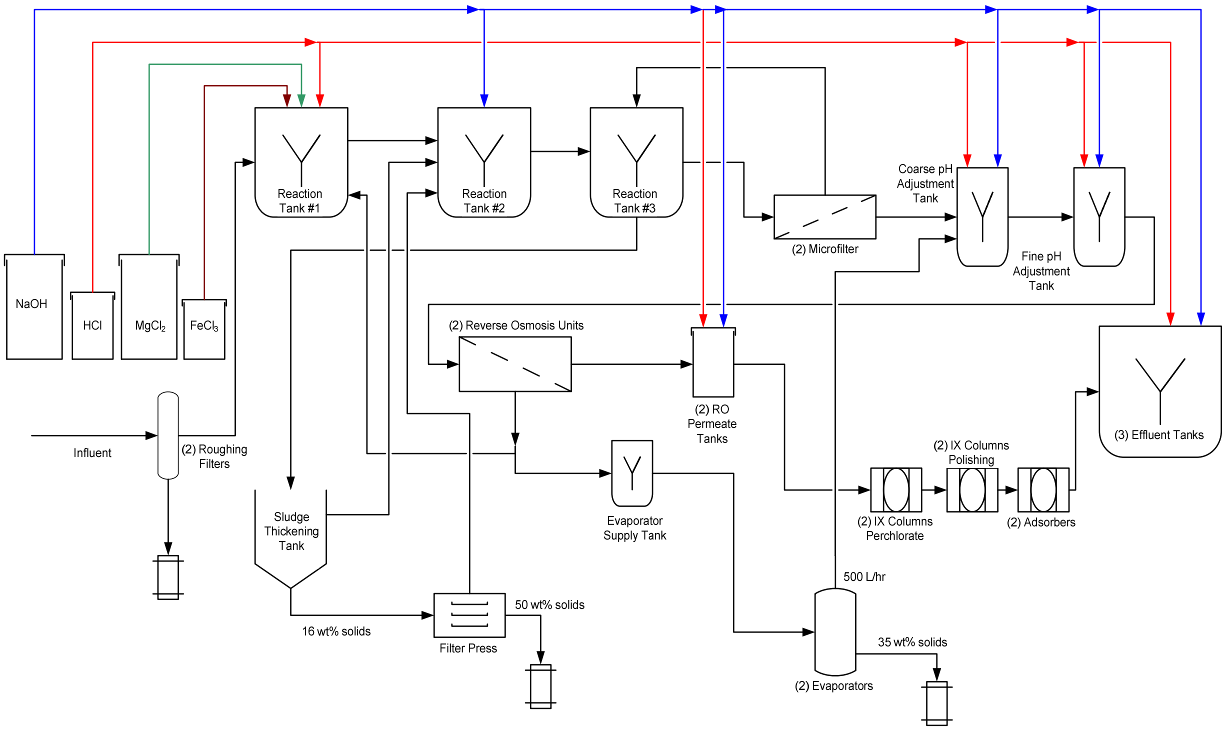

Fig. 3. Process overview of new radioactive liquid waste treatment.

Reaction tank #2 overflows to reaction tank #3 at a rate of approximately 291.5 L/min. Reaction tank #3 functions as a concentration tank for the microfilters. Wastewater from this reaction tank is pumped at a high flow rate (~2,905 L/min) to the microfilter to remove entrained particulates. The microfilter filtrate is collected in the RO coarse pH adjustment tank. The microfilter concentrate is fed back to reaction tank #3 at a flow rate of approximately 2,615 L/min.

The sludge (i.e., solids) concentration in the tank increases as the filtrate leaves the process through the microfilter at a rate of 291 L/min. When the sludge builds up in the tank to approximately 5 wt% solids content, small volumes of sludge are pumped to the sludge thickening tank intermittently. This occurs approximately every ten minutes for 15-30 seconds. Every day, nearly 329 L of sludge is fed to the sludge thickening tank. Of this feed, approximately 237 L of liquid is decanted from the sludge thickening tank a day and is staged in the sludge thickening decant tank until it is transferred to reaction tank #2.

The microfilter filtrate is pH adjusted with 31 wt% hydrochloric acid in the RO pH adjustment tanks to a pH of between 6.5 and 7.5. The pH adjusted stream is then pumped through a reverse osmosis unit at a rate of 300 L/min. Approximately 210 L/min of RO permeate is collected in the RO permeate tanks. A small portion (3,237 L per operating day) of the RO concentrate is sent to the evaporator supply tank. The remainder is recycled back to reaction tank #1. Each of the low temperature evaporators can process 500 liters per hour. The evaporator produces a concentrate with a solids content of approximately 35 wt%, which is packaged in 208-L drums along with a small addition of vermiculite. The evaporators will produce forty-three 208-L drums of sludge per year.

Nearly 75,708 L a day of RO permeate is passed through two sets of ion exchange units for perchlorate removal and polishing and a set of carbon adsorbers for removal of organics before it is collected in one of three effluent tanks. If pH adjustment is needed to meet final discharge criteria, NaOH or HCl is added to the tank and the contents are mixed. After sampling, the effluent is recycled for use throughout the treatment facility, transferred to the outfall, or processed to meet ZLD guidelines.

The sludge that accumulates in the sludge thickening tank is periodically dewatered in a filter press and packaged in 208-L (55 gallon) drums. This operation occurs approximately 15 times a year and processes a total of 3,100 L. The filter press dewaters the sludge to a solids content of at least 50 wt%. The filtrate is recycled back to reaction tank #2 and the cake is packaged in 208-L drums with a handful of vermiculite. The drums are sealed and are staged in the drum storage unit until being transferred to TA-54. If the drums contain TRU waste, they will be transferred for final disposal to the Waste Isolation Pilot Plant (WIPP).

Transuranic Waste Treatment Process

The Transuranic (TRU) treatment process will be operated on a monthly campaign basis. The work will be performed in batches on weekly intervals with actual treatment time scheduled to occur for 4 hours per day for the main treatment process (e.g., microfilter) and 6 hours per day for the secondary process equipment (e.g., low temperature evaporator). The process will treat 42,088 liters per year of caustic waste and 41,682 liters per year of acid waste from TA-55.

The acid and caustic waste is collected throughout the month in the influent collection tanks located in the TRU vault. Each batch of either caustic or acid waste (~3,407 L) that had accumulated in the influent collection tanks is pumped to the neutralization tank at approximately 76 L/min. The neutralization tank is a 9,464 L vessel equipped with a mixer, a pH meter, and a cooling jacket. The tank is a closed vessel with a HEPA filter vent. Sodium hydroxide, at a concentration of 25 wt%, is added to the neutralization tank to adjust the pH of the waste to 10.5. The contents of the neutralization tank are then allowed to cool overnight via a cooling jacket.

The cooled wastewater from each batch is transferred to the reaction tank where it is treated with chemicals and mixed. The reaction tank is a 4,543 L closed vessel equipped with a mixer and a HEPA filter vent. Magnesium chloride and ferric chloride are added to the reaction tank to allow the precipitation of silica and magnesium and calcium hardness and to aid in coagulation of suspended particles from the wastewater. When the wastewater is completely mixed and the chemicals have been given sufficient time to work, the wastewater is pumped through a microfilter to remove any remaining suspended solids at a flow rate of approximately 189 L/min. The microfilter filtrate is sent to the filtered decant tank at a design flow rate of 19 L/min, and therefore, the microfilter concentrate is recycled to the reaction tank at approximately 170 L/min. This process is repeated for approximately 4 hours or until the suspended solids are built up in the reaction tank to 5 wt%. At that time, the microfilter is shut down and the wastewater remaining in the reaction tank is fed to the sludge thickening tank.

The sludge sent to the sludge thickening tank from the reaction tank is allowed to settle. During this time, the tank is periodically decanted and the liquid decant is gravity fed back to the reaction tank. When the TRU sludge reaches a certain percent solids content, the sludge is placed into 208-L drums and is solidified. Each drum can hold 83 L of sludge. The remainder of the drum is filled with cementation materials (i.e., cement, sodium silicate, vermiculite). The drum contents are mixed and are allowed to solidify. The drums are allowed to accumulate before they are transported to TA-54. TRU operations will produce enough sludge to fill nearly 4 drums per year.

The filtrate in the filtered decant tank is processed through a low-temperature evaporator. The evaporator concentrate (i.e., bottoms) is packaged in 208-L drums for disposal at TA-54. The drums are filled with evaporator concentrate and a small amount of vermiculite to absorb any free liquid in the drums. TRU operations will fill approximately 220 drums per year (18 drums per campaign). The evaporator distillate is transferred to the LLW process reaction tanks for further processing.

IMPROVEMENTS TO RADIOACTIVE LIQUID WASTE TREATMENT

Chemical Separation

Chemical separation is used in both the LLW and TRU processes to remove suspended solids and radioactive material and to precipitate silica and hardness (i.e., magnesium and calcium) from the influent stream. Separation occurs in reaction tanks that are covered, cone bottomed and operated at atmospheric pressure. The tanks are mechanically agitated to aid in the mixing of the influent and the added chemicals. The settled solids are removed from the bottom of the reaction tanks.

Chemical separation is achieved by the use of magnesium chloride and ferric chloride as the flocculation and precipitation agent. Flocculation occurs by the bridging of particles by a polymer chain, which causes the formation of flocs or larger aggregates. The flocs are easier to remove from the system by sedimentation or filtration. Precipitation is the formation of solid from a soluble species in a solution during a chemical reaction.

In order to optimize the settling of the solid material, the pH of the wastewater is adjusted by the addition of acid (hydrochloric acid) or caustic (sodium hydroxide), as required.

Ferric chloride ($FeCl_3$) hydrolyzes in water, forming positively charged soluble iron complexes. The ferric ion in slightly basic water reacts with hydroxide ion to form a floc of iron (III) hydroxide [$Fe(OH)_3$]. The flakes of iron hydroxide make the impurities in the water coagulate and adsorb to the hydroxides.

$$Fe^{3+} + 3OH^- \rightarrow Fe(OH)_3 \qquad \text{(Eq. 1)}$$

Ferric chloride also reacts with the natural or added alkalinity in the sludge to form hydroxides that act as flocculants. [2]

$$2FeCl_3 + 3Ca(HCO_3)_2 \rightarrow 2Fe(OH)_3 + 3CaCl_2 + 6CO_2 \qquad \text{(Eq. 2)}$$

$$2FeCl_3 + 3Ca(OH)_2 \rightarrow 2Fe(OH)_3 + 3CaCl_2 \qquad \text{(Eq. 3)}$$

Magnesium chloride reacts with water, which at high pH values (e.g., 11.0 to 11.3) will precipitate out as magnesium hydroxide.

$$Mg^{2+} + 2OH^- \rightarrow Mg(OH)_2 \quad \text{(Eq. 4)}$$

Filtration Technologies

Roughing Filters

The objective of the influent metal screen (roughing) filters is to remove particulates greater than 200 microns. Two fully enclosed magnetically driven self-cleaning filters were chosen as the technology to replace the current influent filters. Each filter is sized for 100 percent of the design influent flow.

Filtrate flows from the top down and from the inside of the media toward the outside to increase retention of contaminants. The cleaning disc and flow continually drive undesirable solids downward, where they are concentrated in the purging chamber for easy expulsion. A hollow shaft at the center of the system contains a piston with powerful rare earth magnets. These internal magnets are coupled to external magnets housed in a carrier connected to the cleaning disc. Pneumatic actuation moves the inner magnet up and down the shaft, with the cleaning disc following. [3] This allows for continuous operation, even during cleaning cycles. These solids are collected and packaged in 208-L drums.

Microfilters

The LLW Microfiltration treatment consists of two microfilter banks, each sized for approximately 40 gpm or 100 percent of the decant stream design flow from the reaction tanks. The purpose of the microfilters is to remove suspended solids from entering the pH adjustment tanks and prevent fouling the RO membranes.

The microfilters are tubular membrane filters for particle capture of particulate of 0.1 micron and greater. The microfilters are operated in cross-flow mode such that rejected particles are continuously carried away from the membrane surface, thereby minimizing buildup. This leaves the filter media free to reject incoming suspended particles. The microfilter permeate stream is sent to the coarse pH adjustment tank and the reject stream is returned to reaction tank #3.

Reverse Osmosis

The RO system will remove radioactive materials and other dissolved solids from the pH-adjusted feed stream. The LLW Reverse Osmosis Treatment skid consists of a two-pass, permeate staged, reverse osmosis system. The system includes two pH adjustment tanks, two permeate tanks, and a clean in-place skid. The RO system is designed to utilize spiral-wound, semi-permeable, high pressure, cellulose acetate (CA) seawater membranes designed specifically for treating water with high levels of dissolved solids. The RO membranes are protected from fouling by first passing the RO feed through a set of microfilters and then adjusting the pH. The preconditioned wastewater stream is then repressurized to approximately 4,137 kilopascal before entering the RO membranes.

The RO system will also be equipped with conductivity monitors to monitor product quality.

Ion Exchange

The RLWTF treatment process consists of two ion-exchange columns for the removal of perchlorate (ClO^{4-}), two polishing ion exchange columns and two carbon adsorption columns for removal of organics. The two ion-exchange columns for perchlorate removal use Sybron SR-7 Strong-Base Anion exchange resin and are arranged such that one of the columns is operated as the on-line column and the second as the off-line column. When the lead column ion-exchange capacity shows breakthrough, the lag column becomes the lead column and the replaced lead column becomes the lag column. The resin in the former lead column will be disposed of as a unit.

The two ion-exchange columns for polishing are mixed-bed strong-acid cation exchange resin and Strong-Base Anion exchange resin combined in a single vessel. The individual grains of resin are thus arranged side by side, and the entire bed acts as an infinite number of anion and cation exchangers in series. The ion-exchange polishing columns are arranged such that the two columns will be operated as lead and lag columns. Replacement of exchange resin is accomplished in the same manner as described for the perchlorate ion-exchange columns.

The two adsorber columns use activated carbon to remove organics and other contaminants in the ion-exchange polished stream. The adsorber columns are arranged such that the two columns are operated as the lead and lag columns. Once spent, the activated carbon column is replaced in a manner similar to that described above for the ion-exchange columns.

The treated waste stream will then be sent to the effluent tanks and sampled prior to disposal.

Dewatering Technologies

Filter Press

A vacuum filter is currently in use at RLWTF to capture the LLW solids waste, but for the new facility a filter press was chosen in an effort to increase the filtration efficiency. The filter press will be a semiautomatic, pneumatic/hydraulic plate and frame press designed to treat the LLW discharged from the sludge thickening tanks. It will be capable of processing approximately 208 liters of sludge from the LLW thickening tank in a single batch. The sludge will be partially dried using compressed air to a moisture content of approximately 50% and then packaged in 208-L drums for eventual disposal. Filtered effluent from the press will be recycled back to the thickening tank.

The press will be approximately 4.9 m long, 1.2 m wide and 1.5 m high. The current design calls for the press to be elevated to allow a 208 L drum to fit under it to allow the contents of the press to be discharged directly into the drum. The sludge from the press is expected to be removed manually by properly attired staff. It is anticipated that the press will need to be unloaded only 8-12 times a year.

Low Temperature Evaporation

Currently, an evaporator trailer is brought to the site to reduce the volume of the secondary waste from the treatment processes on a campaign basis. Because there is not an evaporator on site, three 75,708L tanks are required to store the wastewater until a campaign is scheduled. In order to be more efficient, two low-temperature evaporators are being installed in the new facility for each of the LLW and TRU processes.

The selected low-temperature evaporators are ISA Model CE500 Cold Evaporation Systems. The dimensions for each evaporator are 4.6 m in length, 3.6 m in width, and 3.5 m in height. Each of the evaporators has the capability to process 500 liters of wastewater per hour or 8.3 L per minute. The low temperature process has a typical distilled water recovery rate of 80-95%.

Evaporation is a process that purifies water by boiling and subsequent condensation of the water vapor. As water boils, the change in physical state from liquid to gas removes all water soluble chemicals. When the vapor is condensed, it is purified and is free of contamination. Low temperature evaporation is an energy-efficient process that utilizes refrigeration in a heat pump cycle to reduce by 80% the energy required for water boiling and vapor condensation. Energy is continuously recycled in the system as water and refrigerant concurrently change physical state. [4]

The water evaporates at low pressures due to the vacuum pump which provides the vacuum on the system. The pump creates a vacuum pressure of approximately 25 mm of mercury, which allows the water to boil at approximately 20 to 30°C. The refrigeration system provides the heat pump that causes the water to alternately boil in the evaporator chamber and condense in the condensation chamber. The system gives up its heat of fusion to cause the water to evaporate when the refrigerant condenses, and causes condensation of the water when the refrigerant absorbs the heat of fusion from the water vapor.

Warm-refrigerant-filled coils in the evaporation chamber heat and boil out the wastewater. As the wastewater is boiled off, soluble salts become concentrated and are intermittently discharged by a pump. The evaporated water vapor is collected in the condensation chamber where it is condensed to pure water by the cold-refrigerant-filled coils. The distilled water is intermittently discharged by a pump.

REGULATORY REQUIREMENTS

LANL Waste Acceptance Criteria

The LANL waste acceptance criteria (WAC) [5] sets standards for determining whether liquid waste is acceptable for treatment by RLWTF. LANL generators of radioactive liquid waste are responsible for properly characterizing, segregating, and documenting their wastewater prior to release to RLWTF.

RLWTF Waste Acceptance Criteria for Transuranic Waste

The RLWTF WAC for Transuranic Radioactive Liquid Waste [6] sets forth criteria for acid and caustic liquid waste generated at TA-55. Recently, the WAC was revised, as shown in Table 1.

Table 1. New WAC for Acid and Caustic Wastewater [*]

Constituents	WAC	Revised WAC	WAC	Revised WAC
	ACID (kBq/L)		CAUSTIC (kBq/L)	
Gross Alpha	3,704	3,704	166,667	92,593
Americium-241	619	619	27,778	27,778
Plutonium-238	619	619	27,778	27,778
Plutonium-239	619	619	27,778	27,778
Plutonium-240	na	na	na	na
Plutonium-238/239/240	na	na	na	na
U-235	2.2	22	3.7	3.7
Tritium	0.7	0.7	0.7	0.7
Ra-226	0.001	0.6	0.001	0.6
Np-237	0.4	0.4	1.9	1.9
U-234	1,852	1,852	83,333	85
U-238	0.2	22	0.4	0.4
Gross Beta	741	741	27,778	27,778
Gross Gamma	222	222	8,889	10,000

[*] Table extracted from RLWTF WAC for Transuranic Radioactive Liquid Waste, February 2007, Table 2 and 3. Converted to SI units.

Effluent Discharge Requirements

The RLWTF is being designed so that the discharged liquid effluent meets LANL's current National Pollutant Discharge Elimination System (NPDES) permit requirements and effluent requirements of the Clean Water Act. In addition, LANL has made a commitment to meet New Mexico Water Control Commission Regulation 3103 Ground Water Standards in every batch of effluent and also conforms to New Mexico Environmental Department (NMED) Groundwater Discharge Plan requirements. Discharge limits are provided in Table 2.

Table 2. Effluent Discharge Requirements for RLWTF

Parameter	Threshold	Units	Source
Aluminum (Al)	0.5	mg/L	Proposed NM Water Quality standard for Livestock Watering
Arsenic (As)	0.009	mg/L	Proposed NM Water Quality standard for Human Health
Barium (Ba)	1	mg/L	Current NM WQCC 3103 ground water standard
Boron (B)	0.75	mg/L	Current NM WQCC 3103 ground water standard
Cadmium (Cd)	0.005	mg/L	Proposed NM Water Quality standard for Livestock Watering
Chloride (Cl)	250	mg/L	Current NM WQCC 3103 ground water standard
Chemical Oxygen Demand	125	mg/L	Current and new draft NPDES permit limit
Chromium, Total (Cr)	0.05	mg/L	Current NM WQCC 3103 ground water standard
Cobalt (Co)	0.05	mg/L	Current NM WQCC 3103 ground water standard
Copper (Cu)	0.5	mg/L	Current NM Water Quality standard
Cyanide	0.0052	mg/L	Current NM Water Quality standard
Fluoride (F)	1.6	mg/L	Current NM WQCC 3103 ground water standard
Iron (Fe)	1	mg/L	Current NM WQCC 3103 ground water standard
Lead (Pb)	0.1	mg/L	Proposed NM Water Quality standard for Livestock Watering
Mercury (Hg)	0.00077	mg/L	Current NM Water Quality standard
Nickel (Ni)	0.2	mg/L	Current NM WQCC 3103 ground water standard
Nitrate-Nitrogen (NO3-N)	10	mg/L	Nitrate+Nitrite (as N) current NM WQCC 3103 ground water standard
Nitrite-Nitrogen (NO2-N)	10	mg/L	Nitrate+Nitrite (as N) current NM WQCC 3103 ground water standard
Perchorate (ClO4-)	NA	mg/L	NM WQCC Toxic Pollutant but no limit established
Selenium (Se)	0.005	mg/L	Current NM Water Quality standard
Silver (Ag)	0.05	mg/L	Current NM WQCC 3103 ground water standard
Sulfate (SO4)	600	mg/L	Current NM WQCC 3103 ground water standard
Total Dissolved Solids (TDS)	1000	mg/L	Current NM WQCC 3103 ground water standard
Total Suspended Solids (TSS)	30	mg/L	Current and new draft NPDES permit limit
Total Toxic Organics	1	mg/L	Current NPDES permit
Uranium (U)	0.007	mg/L	Current NM WQCC 3103 ground water standard
Vanadium (V)	0.1	mg/L	Current NM Water Quality standard
Zinc (Zn)	4.37	mg/L	Current NPDES permit
pH	6.0-9.0	s.u.	Current and new draft NPDES permit limit

Discharges will also conform to DOE O 5400.5, *Radiation Protection of the Public and the Environment*, Derived Concentration Guide (DCG) for radioactive constituents, which are shown in Table 3.

Table 3. Derived Concentration Guidelines from DOE O 5400.5 Reported Annually for RLWTF [(a)]

Radioactive Isotopes	DCG, 5400.5 (Bq)	Radioactive Isotopes	DCG, 5400.5 (Bq)	Radioactive Isotopes	DCG, 5400.5 (Bq)	Radioactive Isotopes	DCG, 5400.5 (Bq)
Am-241 [(b)]	1.1	Cs-137 [(b)]	111	Rb-83	741	Th-232 [(b)]	1.9
As-74 [(b)]	1,481	Eu-152	741	Rb-84	370	U-234	18.5
Ba-133	1,481	I-133	370	Sc-46	741	U-235	22.2
Be-7 [(b)]	37,037	Mn-52	741	Sc-48	741	U-238 [(b)]	22.2
Ce-141 [(b)]	1,852	Mn-54	1,852	Se-75	741	V-48	1,111
Co-56	370	Na-22 [(b)]	370	Sn-113	1,852	Y-88	1,111
Co-57	3,704	Np-237	1.1	Sr-85 [(b)]	2,593	Zn-65	333
Co-58	1,481	Pu-238 [(b)]	1.5	Sr-89	741		
Co-60	185	Pu-239 [(b)]	1.1	Sr-90	37		
Cs-134	74	Ra-226 [(b)]	3.7	Tritium [(b)]	74,074		

[(a)] Table extracted from RLWTF Annual Report for 2003 (dated March 2004), Table 4-5. Converted to SI units.

[(b)] Denotes 14 radionuclides common to the RLWTF effluent. Three isotopes, Pu-238, Pu-239, and Am-241 typically account for greater than 90 percent of the sum of the ratios in the RLWTF effluent.

Before discharging, RLWTF effluent is sampled and characterized to verify compliance with these requirements. Effluent that meets the discharge standards may be recycled, discharged to Mortandad canyon via the NPDES permitted outfall #051, or discharged into the ZLD evaporation tanks. Effluent stored in the effluent storage tanks which does not meet these standards will be returned to the front end of the RLWTF for reprocessing.

Secondary Solid Waste Disposal Requirements

Radioactive solid wastes generated as a result of treatment operations will be disposed of in accordance with radioactive LLW and TRU waste disposal requirements. LLW secondary solid waste will be disposed of in 208-L drums at TA-54, Area G. Solid waste must meet the LANL WAC, Section 5.0, for disposal. TRU solid waste must meet the Waste Isolation Pilot Plant (WIPP) WAC for disposal. [7]

RLWTF has been designed in accordance with waste minimization strategies by minimizing the volume generation of secondary waste, while still meeting the LANL WAC for TA-54 and the WIPP WAC.

Seismic Criteria

A major factor that had to be considered when designing the facility was a new seismic requirement that was added to the facility design criteria. Specifically, the change was relating to the design basis ground motion based on the Maximum Considered Earthquake (MCE) Ground Motion – generally 2% probability of exceedance in 50 years from the seismic hazard maps, modified to account for local site effects. LANL adapted the International Building Code® for use in PC1 and PC2 design in Chapter 5, Section II of the Engineering Standards Manual (ISD 341-2). The previous recommendation allowed the following: Five-percent damped design spectra response acceleration at short periods, SDS = 0.54g, and at 1-second periods, SD1=0.26g.

Because the preliminary results were indicating that the seismic hazard was greater than previously thought, the seismic recommendation was changed to the following: Five-percent damped design spectra response acceleration at short periods, SDS = 0.75g, and at 1-second periods, SD1=0.64g. [8]

This change required that the facility be considerably more robust than what was originally proposed in the conceptual design. The structure went from being a steel frame building with 152-mm concrete tilt up panels to a facility with 406-mm thick poured-in-place concrete perimeter walls on the lower level and 305-mm thick poured-in-place concrete perimeter walls on the upper level.

CONCLUSION

The new RLWTF has been designed with a 50-year life in mind. The facility incorporates all current codes and regulations into its design and construction and allows for changes to be made to the process and layout of equipment as a result of changes in regulations, improvements in technology, or failures of equipment. Once completed, the facility will allow LANL to continue its mission with less risk regarding the ability to process wastewater and protect the surrounding environment.

REFERENCES

[1] Radioactive Liquid Waste Treatment Facility (RLWTF), Influent Boundary Condition Assessment. 2007. LA-UR-05-9001. Revision 3.0. Shaw Environmental, Inc., Los Alamos, NM.

[2] John Bratby. *Coagulation and Flocculation in Water and Wastewater Treatment*. October 2006. 2nd Edition. IWA Publishing.

[3] Eaton Corporation – Ronningen-Petter Brand. Mechanically Cleaned Filter System. www.ronningen-petter.com.

[4] The Environmental Warehouse. Water Purification Equipment - Cold evaporation. www.envirowarehouse.com.

[5] LANL Waste Acceptance Criteria. July 2006. PLAN-WASTEMGMT-002, R.4.2. Los Alamos National Laboratory, Los Alamos, NM.

[6] Waste Acceptance Criteria for Transuranic RLW. RLW-AP-04-01. February 2007. Los Alamos National Laboratory, Los Alamos, NM.

[7] Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant. November 2006. DOE/WIPP-02-3122. Revision 6.0. U.S. Department of Energy, Carlsbad Field Office.

[8] Memorandum, dated January 22, 2007 to Asa Kelly from D-5: Nuclear Design and Risk Analysis Structural Mechanics Team; Michael W. Salmon, Subject: *Recommended Seismic Design Parameters for Use in the Design of PC1 and PC2 Facilities*.