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Design Report on the Test System Used to Assess Treatment of Trench Water from Waste Area Grouping 6 at Oak Ridge National Laboratory, Oak Ridge, Tennessee

T. E. Kent
P. A. Taylor

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EXECUTIVE SUMMARY

New liquid waste streams will be generated as a consequence of closure activities at Waste Area Grouping (WAG) 6 at Oak Ridge National Laboratory (ORNL). It is proposed that these waste streams be treated for removal of contaminants by adding them to the ORNL wastewater treatment facilities. Previous bench-scale treatability studies indicate that ORNL treatment operations will adequately remove the contaminants, although additional study is required to characterize the secondary waste materials produced as a result of the treatment. A larger scale treatment system was constructed to produce secondary wastes in the quantities necessary for characterization and U.S. Environmental Protection Agency toxicity characteristic leaching procedure (TCLP) testing. The test system is designed to simulate the operation of the ORNL process waste treatment facilities and to treat a mixture of ORNL process wastewater and WAG 6 wastewater at a combined flow rate of 0.5 L/min. The system is designed to produce the necessary quantities of waste sludges and spent carbon for characterization studies and TCLP testing.

1. INTRODUCTION

1.1 BACKGROUND

Solid Waste Storage Area 6, which is included in Waste Area Grouping (WAG) 6, has been used since 1969 for disposal of solid waste contaminated or potentially contaminated with radioactive and hazardous compounds. Plans are currently being prepared for closure of the disposal area by 1997. The closure plans involve stabilization of the buried waste materials and the diversion of surface water around the area so that leaching of contaminants into surface waters is prevented. Before it is discharged to the environment, the water that is removed from trenches prior to grout stabilization activities and other wastewater generated during closure activities will require treatment for removal of pollutants. It has been proposed that these wastewaters be treated by using existing systems at the Oak Ridge National Laboratory (ORNL) process waste treatment facilities.

Bench-scale treatability testing[1] indicated that the ORNL treatment facilities could adequately remove radioactive contaminants, heavy metals, and organic contaminants from WAG 6 wastewaters. However, the bench testing could not produce enough secondary waste sludges for the testing required to determine the level of hazardous Resource Conservation and Recovery Act (RCRA) constituents. The U.S. Environmental Protection Agency (EPA) toxicity characteristic leaching procedure (TCLP) requires that at least 100 g of the solid waste material be used to perform the test. At least 200 gal of wastewater would need to be treated to produce 100 g of sludge from the alkaline precipitation process used at the Process Waste Treatment Plant (PWTP). Also, at least 1200 gal of wastewater would need to be treated to exhaust 100 g of granular activated carbon (GAC), assuming the wastewater contains 1 mg/L adsorbable organics and the exhausted carbon contains 0.05 g of organic material per gram. This volume of wastewater cannot be treated with bench-scale equipment. A larger-scale test system will be needed to produce the required amount of secondary solid wastes for TCLP tests.

1.2 PURPOSE

The purpose of this project is to construct a test system that simulates the wastewater treatment operations of the ORNL PWTP and the Nonradiological Wastewater Treatment Plant (NRWTP). The test system must be designed to produce secondary solid wastes in quantities that can be used to conduct TCLP testing.

[1]Taylor, P. A., *Treatability Study for Wag 6 (SWSA 6) Trench Water*, ORNL/ER-17, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1991.

2 SYSTEM DESCRIPTION

2.1 ORNL WASTEWATER TREATMENT FACILITIES

The facilities used to remove pollutants from ORNL process wastewater include the PWTP and the NRWTP. The PWTP collects and treats wastewaters for removal of radioactive ^{90}Sr and ^{137}Cs. The principal contaminant is ^{90}Sr, which is usually present in the wastewater at concentrations between 500 and 1000 Bq/L. Also present in the waste stream is ^{137}Cs, although the concentration is typically below regulatory concern. DOE Order 5400.5 limits discharges of ^{137}Cs to 111 Bq/L and ^{90}Sr to 37 Bq/L. The PWTP uses a combination of alkaline precipitation and ion-exchange methods for removing ^{90}Sr. The wastewater entering the plant is pH adjusted to 11.5 before entering the softener/clarifier (L-1), where water hardness compounds such as calcium carbonate and magnesium hydroxide precipitate. Coagulants are added as the wastewater enters L-1 for settling of precipitated solids. The solids are periodically removed from the bottom of L-1 and transferred to a sludge holding tank (L-6). From L-6 the sludges are transferred and dewatered through the use of a recessed-plate filter press. The filter cake is typically about 75% water and 25% solid material. The softening process also removes about 80% of the incoming ^{90}Sr and 20% of the incoming ^{137}Cs. As a result, the sludge must be handled and stored as a radioactive waste material. The effluent wastewater from the clarifier flows to a surge tank, where pumps are used to transfer the wastewater through granular media filters and ion-exchange columns downstream of the filters. The effluent from the ion-exchange columns flows to a concrete basin (Clear Well L-5) where the pH is adjusted to between 7 and 8.

After pH adjustment, the wastewater flows to a pumping station from which it is then transferred to the NRWTP. The PWTP effluent stream is received at the NRWTP Non-metals Equalization Tank F-1002, where it combines with other nonradiological process wastewaters. From F-1002, the wastewater is pumped through granular media filters to the air stripper. Just upstream from the air stripper, the wastewater passes through a pH-adjustment station where the pH is adjusted to about 7.5. The wastewater passes through the air stripper to a pump station for transfer through the GAC columns. The wastewater flows through two GAC columns in series and on to the effluent tank. The wastewater pH is adjusted as necessary in the effluent tank before final discharge to White Oak Creek. A flow diagram of the existing PWTP and NRWTP is given in Fig. 1.

2.2 TEST SYSTEM GENERAL DESCRIPTION

The test system is designed to simulate the PWTP and NRWTP operations so that the secondary waste solids will closely resemble those of the actual system. A wastewater treatment flow rate of 0.5 L/min was chosen so that the secondary solid wastes could be produced in a reasonable time and so that the system vessels and equipment would be "off-the-shelf" and easy to procure. The materials used to construct the system are stainless steel and polyvinyl chloride (PVC). Stainless steel was chosen for the transfer lines and most of the process vessels because of its corrosion resistance and availability. The columns used for filtration, ion-exchange, air stripping, and activated carbon were constructed of clear PVC, with flanged heads of gray PVC. The clear PVC allows visual observation of the materials in the columns so that the accumulation of solids on filtering surfaces, the expanded height of the materials during backwashing, and the extent of algae accumulation can all be observed

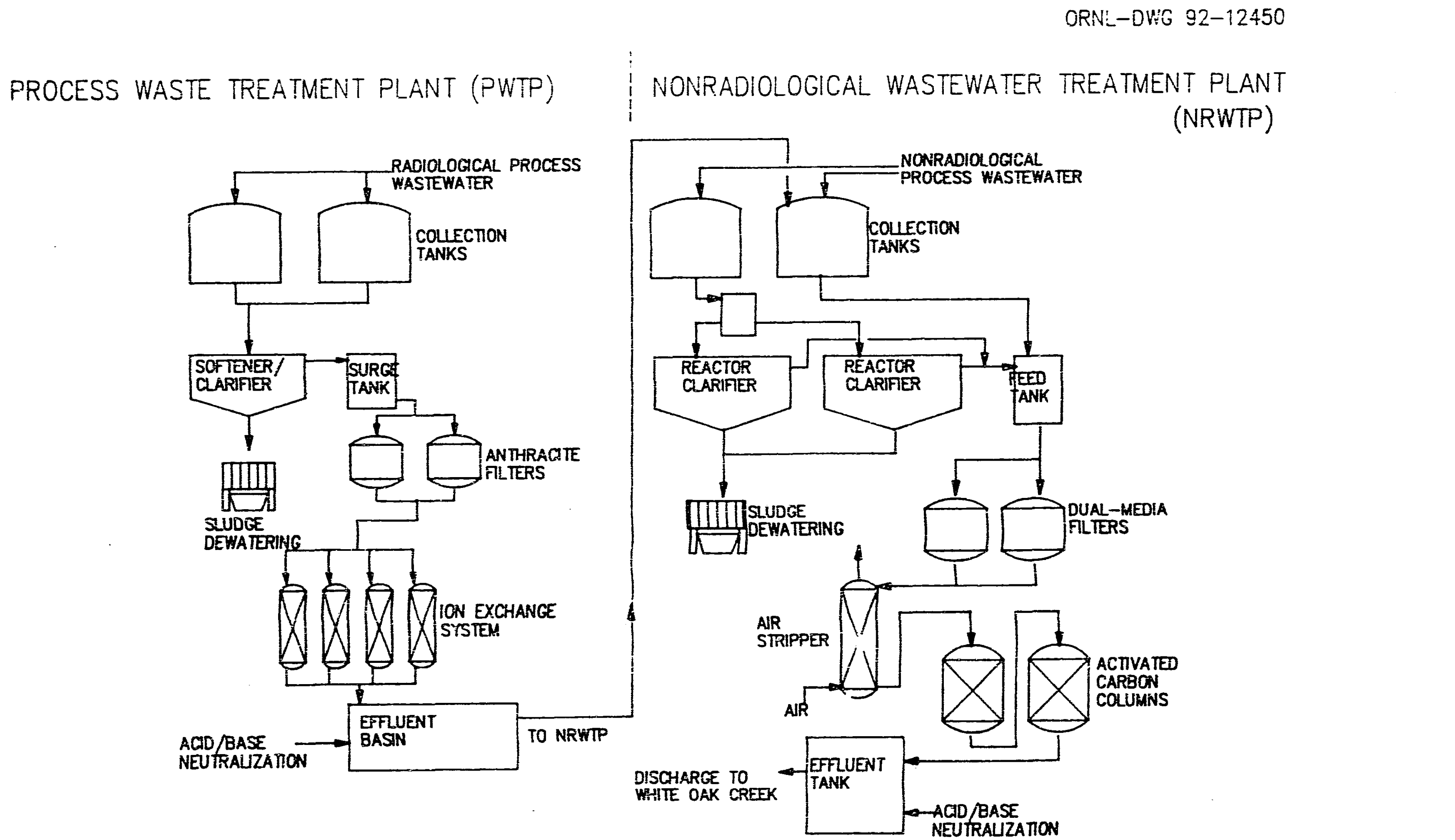

Fig. 1. Process wastewater treatment at Oak Ridge National Laboratory.

PVC is also corrosion resistant for this application. The peristaltic-type transfer pumps are positive displacement, self-priming, and easy to calibrate, and they deliver a relatively smooth flow of fluid. The system will require daily monitoring by a qualified technician, though it will be expected to operate for as much as 16 h/d unattended. As such, the system will be equipped with several automatic control systems for wastewater flow, level control, and pH. The system will also be equipped for automatic shutdown should wastewater leaks or vessel overflows occur for any reason. Data considered critical to the process will be monitored and recorded continuously while other data will be monitored and recorded periodically by the system operator. The test system will be housed in a 48-ft-long by 8-ft-wide trailer adjacent to the PWTP. The trailer will be equipped with a high-efficiency particulate air-filtered ventilation system and with all other necessary safety and fire protection systems.

A flow diagram of the test system is given in Fig. 2. Figures 3 and 4 are photographs of the front and rear of the test system prior to installation in Building 3544A, a trailer facility on the south side of the PWTP. The system consists of a series of process vessels designed to simulate the unit operations of the ORNL PWTP and NRWTP. Two 55-gal drums are used to separately collect ORNL process wastewater and WAG 6 wastewater. Wastewater from the feed drums is metered to a 1-gal rapid-mix vessel, where the wastewaters combine with the treatment chemicals used for the softening process. From the rapid-mix vessel, the waste flows to a larger 5-gal slow-mix vessel, where residence time is provided for the softening reaction and flocculation of precipitated solids. The effluent from the slow-mix vessel flows to the clarifier, where further softening occurs as a result of upflow contact with the sludge blanket and where separation of the sludge and wastewater is accomplished. Sludge that accumulates in the clarifier is periodically removed from the bottom of the vessel and transferred to a holding container. The clarifier effluent flows to an effluent tank that is provided for settling of any solid particles that may carry over from the clarifier. The effluent tank flows to a surge vessel that provides flooded suction for a metering pump that transfers the wastewater through the granular media filter and ion-exchange column. The effluent from the ion-exchange column flows to a mixed vessel used for pH adjustment of the wastewater before transfer to the air stripper. The air stripper is composed of two packed columns in series. Metering pumps are provided to transfer wastewater from the first-stage to the second-stage air stripper and on to a surge vessel. This vessel provides flooded suction for the pump that transfers the wastewater to the GAC column. The GAC column effluent stream flows to the test system drain, which is routed to the PWTP sump for recycle to the PWTP feed tanks.

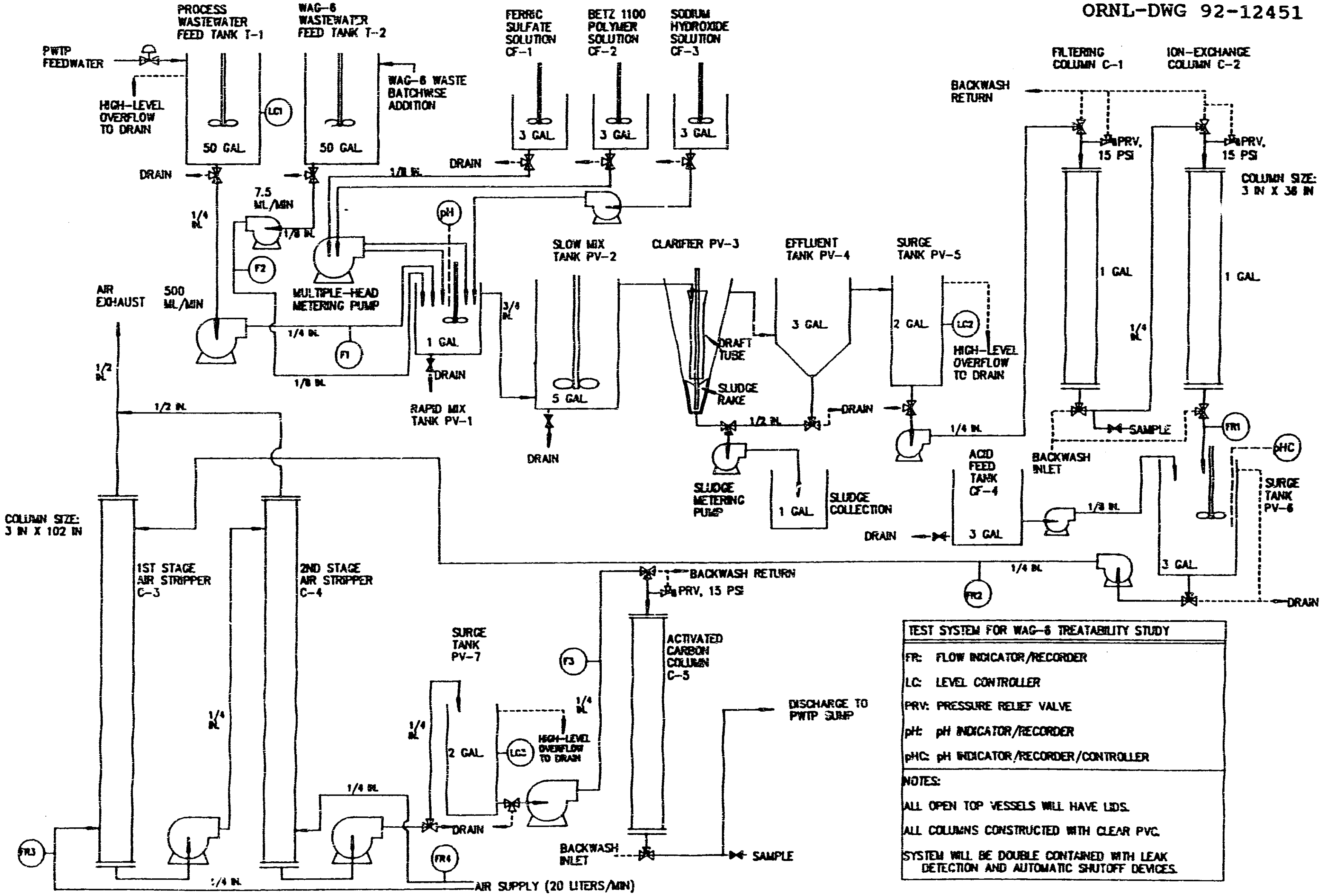

Fig. 2. Test system for WAG 6 treatability study.

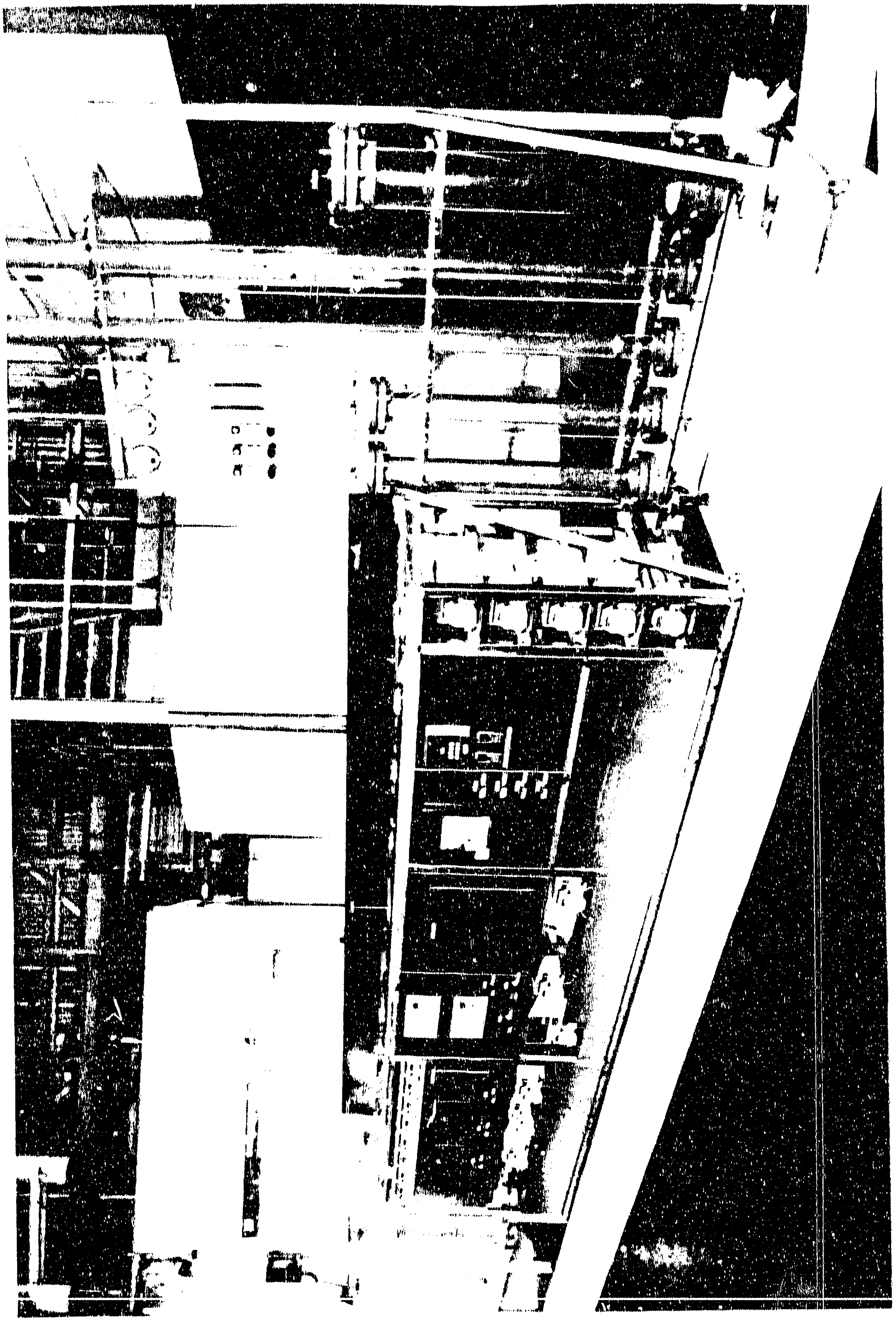

Fig. 3. Front view of test system.

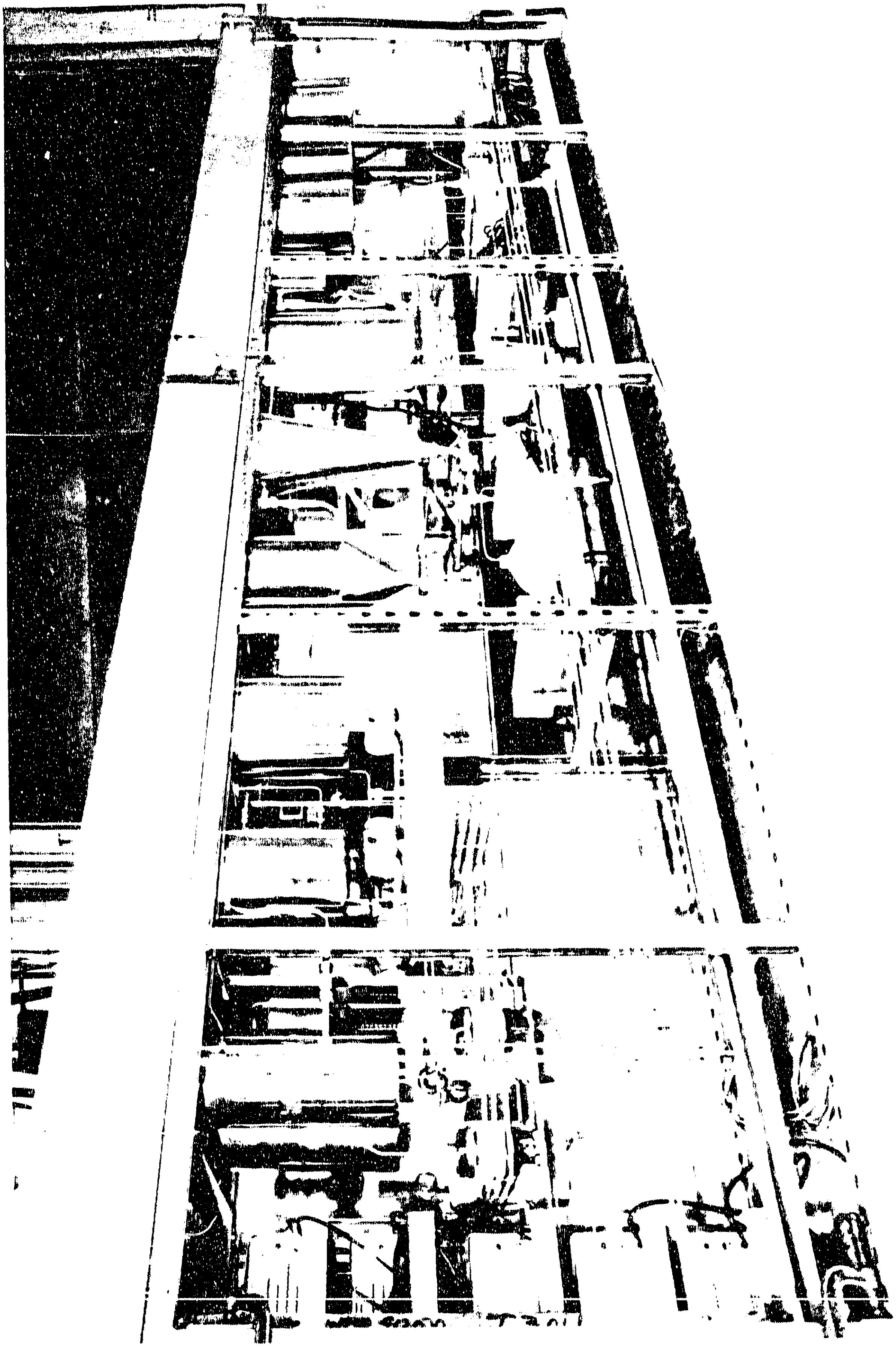

Fig. 4. Rear view of test system.

3. TEST SYSTEM DESIGN

3.1 WASTEWATER FEED SYSTEMS

Two 55-gal drums are used for separate collection of ORNL process wastewater and WAG 6 wastewater. The process wastewater drum is fed from a 0.5-in. line routed from the PWTP wastewater feed header. Flow of wastewater to the drum is controlled by a pneumatic level control device. The static pressure exerted by the wastewater in the drum is sensed with a differential pressure (DP) cell, and the signal from the controller manipulates an air-operated valve on the wastewater feed line. The drum is also equipped with a high-level cutoff device that consists of a conductivity switch connected to a solenoid valve on the air supply to the wastewater feed control valve. If the wastewater level reaches the switch, the solenoid valve is deactivated and the air supply for the air-to-open valve is shut off. The WAG 6 wastewater is supplied in 30- to 50-gal batches. The wastewater is collected at the WAG 6 trench site and transported by truck to the test system trailer. The wastewater is pumped from the transport drum to the test system drum. Since the batch size is less than the capacity of the feed drum, level control devices are not needed. Peristaltic feed pumps feed the wastewater streams to the rapid-mix vessel at a controlled rate. The ratio of process wastewater flow to WAG 6 waste flow used for the tests is 50:1. Rotameters are used on both wastewater streams to verify the correct flows.

3.2 CHEMICAL FEEDS FOR SOFTENING OPERATION

Three 3-gal vessels are provided for feed chemicals used in the wastewater softening operation. A dilute sodium hydroxide (NaOH) solution is used to elevate the pH of the wastewater to 11.5. Two other feed chemicals, Betz* 1100 polymer and Ferri-Floc,† a ferric sulfate solution, are also added to facilitate coagulation and flocculation of the precipitated hardness compounds. A 0.15% solution of Betz polymer is used in the full-scale PWTP feed tank and is added to the wastewater at a concentration of 0.3 mg/L. The chemical feed pumps chosen for the test system are the peristaltic type, which are capable of feed rates as low as 3 ml/min. To feed the equivalent of 0.3 mg/L polymer to the wastewater of the test system, the Betz concentration in the feed vessel will be reduced to 0.004% at a maximum volume feed rate of 4 mL/min. The ferric sulfate solution used in full-scale operation is 10.2% by weight as iron. This solution will be diluted further for the test system feed to 0.3% while using a volume feed rate of 4 mL/min. This ferric sulfate concentration and volume feed rate will result in the equivalent PWTP feed rate for the test system of 2.5 mg/L as Fe in the wastewater. The NaOH solution used to elevate pH must also be diluted so that a feed rate of 3 to 5 mL/min will result in a wastewater pH of 11.5 ($\pm$0.2). The volume feed rates of the three chemical feeds will be checked periodically by monitoring pump speed and by direct measurement of delivery volumes to the rapid mix vessel.

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*Trademark of Betz Laboratories, Inc.

†Trademark of Tennessee Chemical Company.

3.3 SOFTENING AND CLARIFICATION PROCESSES

The full-scale PWTP softener/clarifier is an 11,000-gal rectangular vessel divided into two sections. The NaOH and ferric sulfate are metered into the wastewater feed line. An in-line static mixer is used to mix the NaOH and ferric sulfate with the wastewater before it flows into the softener/clarifier inlet trough. The Betz 1100 polymer solution is added to the wastewater at the inlet trough. The wastewater (pretreated with chemicals) flows into the inlet trough, from which it is distributed along the length of the vessel and flows downward into the slow-mix section of the unit. A large paddle-type mixer provides a high-volume, low-shear mixing action to the wastewater, which enhances coagulation and flocculation of the precipitates. The wastewater then flows uniformly under the baffle that separates the slow-mix section from the clarifier section. The clarifier section is vee-shaped so that the upflow velocity of the wastewater gradually decreases. Near the bottom of the clarifier section, the upflow velocity is high, and flocculated precipitates are carried upward. As the vee widens at higher levels in the clarifier, the upflow velocity decreases and the precipitates are no longer carried upward by the current. This results in a visible interface between the clarified wastewater and the wastewater/sludge mixture or sludge blanket. The flow of wastewater through the sludge blanket not only provides some filtration of the wastewater but also provides nucleate sites for further precipitation of hardness compounds.

Three process vessels are used to simulate the operations of the PWTP softener/clarifier for the test system. The rapid-mix tank is a 1-gal cylindrical vessel that is used to mix the wastewater with the three feed chemicals. A high-volume, variable-speed paddle mixer is provided to mix the wastewater and chemicals before they flow by gravity to the slow-mix vessel. The slow-mix vessel capacity is 5 gal, and it uses a much larger mixer that operates just fast enough to maintain a uniform wastewater/precipitate mixture. Both flocculation and wastewater softening are enhanced in the slow-mix vessel. From the slow-mix vessel, the wastewater/precipitate mixture flows to the draft tube of a cone-shaped clarifier. The draft tube directs the incoming wastewater to the lower portion of the cone below the level of the sludge blanket. The wastewater flows upward through the sludge blanket and decreases in velocity as the cone widens. The diameter of the cone was chosen so that the upflow velocity of 0.05 ft/min would be lower than that of the PWTP clarifier at the sludge blanket interface, estimated to be about 0.15 ft/min. This was to ensure that adequate clarification could be accomplished even if slightly higher wastewater flows were used for the testing. The depth of the cone was chosen to maximize sludge blanket volume while allowing for the physical size limitations in constructing the system. The level of the sludge blanket interface will be controlled by periodic removal of sludge from the bottom of the clarifier. A sludge rake is provided to help facilitate removal of the sludge and to deter plugging of the clarifier sludge outlet. The rake is operated continuously at a very low speed so that sludge blanket turbulence and carryover of precipitates is minimized.

The residence time of wastewater in the PWTP softener/clarifier is about 70 min at a flow of 160 gal/min (maximum flow). Based on the cumulative volume of the three test vessels, the residence time for the test system softening and clarification process is 65 min at a flow of 0.5 L/min. The wastewater contact time with the sludge blanket, however, is 14 min for the test system and 21 min for the PWTP system. The shorter sludge blanket contact time of the test system may reduce the extent of the softening reaction compared with that of the PWTP system, though the composition of the sludge will not be significantly different from the PWTP sludge.

The sludge blanket level for the PWTP system is controlled by periodic removal of sludge from the bottom of the clarification section. Automatic sludge removal is accomplished by on/off control of the pump at specific time intervals. The automatic pumping is usually supplemented by manual operation of the pump as needed to maintain a certain sludge blanket level. The sludge blanket level in the clarifier of the test system will be maintained by manual pumping only. A second vessel has been provided to allow settling of solids should carryover from the clarifier occur.

3.4 FILTRATION AND ION-EXCHANGE SYSTEM

In the PWTP system, the clarifier effluent stream flows to a surge tank. From the surge tank, the filter-feed pumps transfer the wastewater through the anthracite filters and on to the ion-exchange system. The level in the surge tank is controlled by automatic positioning of a control valve on the discharge line of the filter feed pump. Each of the anthracite filters is designed for a maximum flow of 200 gal/min; however, the flow rarely exceeds 160 gal/min due to the limitations of the softener/clarifier. The diameter of an anthracite filter is 8 ft. At 160 gal/min, the flow per unit area through the filter is 3.18 gal $\cdot$ min^{-1} $\cdot$ ft^{-2}. When the pressure drop across the filter reaches a predetermined level of about 40 psig, the filter is backwashed at flow rate of 500 gal/min to wash the collected solids from the anthracite. The filtered wastewater is routed to the ion-exchange system, which consists of four columns in parallel, each containing about 45 ft^3 of Dowex* HCR-S strong-acid cation-exchange resin. The diameter of each column is 3 ft and the height is 12 ft. The maximum flow through each column is 100 gal/min, giving a flow per unit area of 14 gal $\cdot$ min^{-1} $\cdot$ ft^{-2}. Two columns are used in parallel when the flow exceeds 100 gal/min.

The principal purpose of the ion-exchange system is the removal of ^{90}Sr from the wastewater. The resin removes not only ^{90}Sr but also other divalent cations such as calcium and magnesium. The upstream softener precipitates a major portion of the hardness compounds (calcium, magnesium, and strontium) and thus increases the wastewater throughput of the resin before exhaustion. Hardness compounds calcium and magnesium typically break through the resin just prior to ^{90}Sr breakthrough; therefore, a wet titration for total hardness is used to determine the extent of resin exhaustion. When the total hardness in the ion-exchange column effluent exceeds 2 mg/L, the resin is considered exhausted and the column is taken out of service for regeneration operations. A 2.7 *N* solution of nitric acid is used to regenerate the exhausted resins.

The test system will be operated in much the same way as the PWTP system. The wastewater from the effluent tank flows to a surge tank, where a level control device is used to maintain a constant level while transferring wastewater to a downflow filter column. The column is 3 in. in diameter and 36 in. tall and is packed with the same anthracite material used in the PWTP filters. At a wastewater flow of 0.5 L/min, the flow per unit area for the filter is 2.7 g $\cdot$ $^{-1}$ $\cdot$ ft^{-2}, which is just slightly lower than the PWTP filters at maximum flow. The depth of the anthracite is 24 in., the same as that of the PWTP filters. The test system filter is equipped with pressure indicators at the entrance and exit of the filter to monitor pressure drop. If the filter becomes plugged and the pressure drop approaches 15 psi, the

*Trademark of Dow Chemical Company.

filter may be backwashed to remove the accumulated solids. Process water will be used to backwash the filter at a flow necessary to raise the anthracite bed height about 8 in. above the settled bed height.

The flow from the test system filter is routed to the test system ion-exchange column. Like the filter column, the ion-exchange column is 3 in. in diameter and 36 in. tall. The column is packed with 2 L of the same resin used in the PWTP ion-exchange system. The flow per unit area for the test system column is 2.7 g · min^{-1} · ft^{-2}, which is lower than the typical flow per unit area of 10 g · min^{-1} · ft^{-2} for the PWTP columns. The wastewater residence time in the test column of 4 min is close to that of the PWTP columns, which is typically 4.8 min. The difference in flow per unit area may have an impact on the performance efficiency of the resin; however, the composition of the effluent wastewater will adequately simulate that of the full-scale operation. Like the PWTP operation, the extent of resin exhaustion will be monitored by performance of total hardness titrations on column effluent samples. When the total hardness exceeds 2 mg/L, the resin will be replaced. If 2 L of resin is used in the column, exhaustion is likely to occur every 10 to 14 d, depending on the performance of the test system softener. For the sake of simplicity and expediency, the test system's resins will not be regenerated upon exhaustion. The exhausted resin will be removed from the column and replaced with fresh resin. The accumulated exhausted resins will be regenerated at a later date, prior to disposal. The pressure drop across the ion-exchange test column will be monitored with a pressure gauge on the column inlet. The column effluent flows to an open vessel; therefore, the pressure is atmospheric and will not require monitoring. The column is equipped for backwashing should the pressure drop become elevated from accumulation of solids.

Each of the above-described columns was constructed of clear PVC pipe for the column and gray PVC flanges for the top and bottom heads. The pipe is rated for a working pressure of 130 psi and the flanges are rated for 125 psi. Pressure relief devices set for 15 psi are installed on the top flange. The peristaltic pumps used to feed wastewater to the columns are not likely to generate pressures over 30 psi. The discharge from the relief valves is piped to the test system drain line.

3.5 pH ADJUSTMENT AND AIR STRIPPING

The PWTP effluent wastewater from the ion-exchange columns flows to a concrete basin where the pH is adjusted to a value between 9 and 10 before transfer to the NRWTP Nonmetals Tank. At the NRWTP, the PWTP effluent combines with other process wastewaters and is pumped through granular media filters to the air stripper. Before entering the air stripper, the wastewater passes through a second pH-adjustment station consisting of an in-line static mixer and acid feed line. At this station, the pH is adjusted to a level between 7 and 8. The wastewater enters the top of the air stripper and is discharged through spray nozzles onto the air stripper packing material. The packing disperses the wastewater, which makes contact with a 7000-scfm air stream flowing upward from the bottom of the column. Volatile organic compounds are desorbed or stripped from the wastewater into the air stream. The organics are released into the atmosphere in the gaseous form. The air stripper effluent wastewater is transferred to the GAC system for removal of less volatile organic compounds.

The NRWTP air stripper is filled to a height of 26 ft with a high efficiency packing (3.5-Lanpac, Lantec Products, Inc., Agoura Hills, California). Correlations supplied by the packing manufacturer show that the air stripper should have about nine net transfer units at normal operating conditions. Since the packing used in the NRWTP air stripper is not available in small sizes, the operating conditions of the NRWTP air stripper cannot simply be duplicated in the test system. The goal is to have the same concentration of organics exiting the test air stripper as would be present in the effluent from the NRWTP air stripper treating the same wastewater. This can be accomplished by designing and operating the test air stripper to provide nine transfer units, as is the case at the NRWTP. The experimental data from the earlier laboratory-scale treatability tests show that 15 ft of 0.25 in. ceramic saddles with a gas-to-liquid volume ratio of 40:1 will provide the same organic removal as the NRWTP air stripper. In the test system operation, the ion-exchange column effluent flows to a mixed-surge vessel used to decrease the pH of the wastewater to a level between 7 and 8. From the surge vessel, the wastewater is transferred to the first stage of the air stripper. The test air stripper consists of two 3-in.-diam columns, each 8 ft in height and packed with ceramic saddles. The wastewater enters the top of the first stage air stripper and onto the column packing where it is dispersed and exposed to an upward-flowing 20-L/min air stream. The wastewater effluent from the first-stage column is transferred to the top of the second-stage column through the use of a peristaltic pump. The effluent from the second stage column is pumped to a surge vessel for transfer to the test system GAC column. The exhaust air stream from the stripper is discharged through a knockout container to remove any water droplets from the air stream. From the knockout container, the air is routed to the trailer ventilation system exhaust duct.

In the PWTP and NRWTP operation, the PWTP effluent stream is combined with other nonradiological process wastewater at the NRWTP Nonmetals Equalization Tank. Though the actual PWTP (radiological) process wastewater is used in this study, it was not feasible to combine the actual nonradiological process wastewater with the PWTP effluent for the test system air stripping and GAC system operations. Different sources of nonradiological process wastewater enter the NRWTP Nonmetals Equalization Tank from several distant areas. The costs of routing sample lines from these sources thousands of feet to the location of the test system would have been enormous. The alternative costs and logistics of drumming and trucking nonradiological wastewater samples to the site would also have been prohibitive. For the purpose of this study, it was assumed that using the PWTP process wastewater only could be justified by considering this to be a "worst case" study in which the WAG 6 contaminants were not allowed the additional dilution of the nonradiological wastewater. From the standpoint of the hazardous nature of the secondary solid GAC waste, the fraction of contaminants removed from the WAG 6 wastewaters will be higher than that expected for full-scale operation.

3.6 GAC SYSTEM

The NRWTP GAC system consists of three columns piped in series. Each column has an overall height of 20 ft and a diameter of 10 ft. Each column contains about 22,000 lb of Cecarbon* GAC 30 granular activated carbon. If we assume a bulk density of 30 lb/ft^3, each

*Trademark of Atochem Inc., Ceca Division.

column contains about 730 ft^3 of carbon. At the average NRWTP flow of 320 gal/min, the flow per unit area for a column is 4.1 gal · min^{-1} · ft^{-2} with a wastewater residence time of 17 min. In normal operation, the wastewater effluent from the air stripper is routed through two of the GAC columns in series while the third column remains in standby mode. The GAC system effluent flows to a 26,000-gal effluent tank equipped for mixing and acid/base addition should final pH adjustment be necessary. From the effluent tank, the wastewater flows through an National Pollutant Discharge Elimination System monitoring station before final discharge to White Oak Creek.

The test GAC system consists of a surge vessel, a metering pump, and a 6-in.-diam, 36-in.-tall GAC column filled with 24 in. (10 L) of Cecarbon GAC 30 activated carbon. The test system GAC column has the same aspect ratio (height to diameter ratio) as the NRWTP GAC system. The flow per unit area for the test column is 0.67 gal · min^{-1} · ft^{-2} at 0.5 L/min with a wastewater residence time of 20 min. The lower flow per unit area as compared with NRWTP GAC columns may slightly decrease the sorption rate of organics onto the carbon, though overall performance is expected to be comparable. The column is constructed of clear PVC with a working pressure rating of 45 psi. The flanges used on top and bottom of the column are rated for 125 psi, and the column is equipped with a pressure relief valve set to relieve at 15 psi.

At least 100 g of solid waste is necessary to perform the EPA TCLP test. In the case of the carbon waste from the GAC system, it will be necessary that the carbon be at or near exhaustion. If it is assumed that 100 g of GAC will remove 10 g of organic carbon and that the wastewater contains 1 mg/L of adsorbable organic carbon, the equivalent volume of wastewater necessary to provide 10 g of adsorbable carbon is 10,000 L. Fourteen days will be required to treat 10,000 L of the WAG 6 process wastewater mixture at a flow of 0.5 L/min. After a test duration of 30 days, two 100-g samples of activated carbon will be removed from the top surface of the carbon bed for the TCLP testing. The GAC column carbon bed will not be backwashed or otherwise disturbed during the 30-d test period.

4. TEST SYSTEM INSTRUMENTS AND CONTROLS

Test parameters will be monitored and controlled through the use of a variety of instrumentation. The most important test parameters for simulation of real operating conditions include flow of wastewater, flow of air for the air stripping operation, and pH of the wastewater. These parameters will be monitored continuously and recorded by chart recorder. Other less critical parameters, such as tank level, pressure, and mixer revolutions per minute, will be monitored and recorded periodically by the test system operator.

4.1 FLOW MONITORING

Flow rate of various fluids will be monitored at nine locations throughout the test system. The volume feed rates of two chemical feeds will be monitored periodically by the test system operator by checking pump speed and by direct measurement of delivery volumes to the rapid-mix vessel. Variable-area flowmeters (rotameters) will be used to indicate the flow of the process wastewater and WAG 6 wastewater feeds to the rapid-mix tank, and the wastewater flow to the GAC column. Rotameters indicate flow by the use of a float (or rotor) suspended in a tapered tube through which the flow passes in an upward direction. The height of the float in the tube is proportional to the liquid flow. The accuracy of the rotameters is $\pm 2\%$ of full scale. Rotameter readings will be recorded on a data sheet by the test system operator on a periodic basis. Magnetic flowmeters will be used to monitor and continuously record the flow through the filter, ion-exchange column, and air stripper. In a magnetic flowmeter, the liquid flows through a magnetic field induced by coils surrounding a short length of tube. Electrodes mounted in the tube generate a voltage that is proportional to the velocity of the liquid through the tube. Accuracy for the magnetic flowmeters is expected to be $\pm 1\%$ of full scale. The flow sensor for the filter and ion-exchange column is on the ion-exchange column effluent line to prevent potential flow-sensing problems caused by suspended solids and accumulation of carbonate deposits. A second magnetic flowmeter is used to continuously monitor and record the flow entering the air stripper. The sensor is on the line exiting the pH-adjustment surge tank. The air flow to the air stripper is divided into two streams for each of the two air stripper stages. Mass flowmeters are used to continuously monitor and record both air feeds to the air stripper. The mass flowmeters measure flow of gases by applying heat to the air stream and measuring the upstream and downstream temperatures. The temperature difference is proportional to the mass flow of the gas. Accuracy for mass flowmeters is typically $\pm 2\%$ of full scale. All flowmeters will undergo initial calibration and periodic recalibration to ensure accurate flow measurement during the test program.

4.2 LEVEL CONTROL

Level controllers are used on the process wastewater feed drum, the filter feed surge vessel, and the GAC column feed vessel. The level control on the process wastewater feed drum consists of a pneumatic controller and on/off operation of a control valve on the wastewater feed line. The static pressure exerted by the liquid in the drum is pneumatically transmitted to a DP cell. A proportional 0- to 15-psi pneumatic signal is transmitted from the DP cell to the controller, which sends the appropriate pneumatic signal to the control valve.

Due to the on/off nature of the controller, the level in the drum is allowed to fluctuate several inches. Since a peristaltic pump is used to meter the flow from the drum, the fluctuation of feed drum level is acceptable. It is important that the flow rate through the filter and ion-exchange column be the same as the flow through the softener/clarifier system; therefore, the level controller for the surge tank for the filter feed wastewater must operate under proportional control. The controller must be tuned so that changes in the surge-tank level are minimized and flow is reasonably constant. An electronic DP cell will sense the pressure exerted by the liquid level in the tank and transmit a 4- to 20-mA signal to the controller. The controller will send a 4- to 20-mA proportional signal to the speed controller of the filter feed pump. The level controller for the surge tank for the GAC system feed will operate in the same fashion in order to maintain a constant tank level and flow through the GAC column. Level controllers will undergo initial calibration to ensure adequate level control. Recalibration of level controllers will not be necessary during the test program as long as adequate levels are maintained. To prevent uncontrolled spills of wastewater, the process wastewater feed drum and all of the surge vessels are equipped with overflow lines connected to the system drain line.

4.3 pH MONITORING AND CONTROL

For the softening process, the pH of the wastewater is elevated to about 11.5 by addition of NaOH to the rapid-mix tank. The pH of the wastewater in the rapid-mix tank is monitored with a pH meter with the sensing electrode immersed in the rapid-mix tank. The NaOH-metering-pump speed is adjusted manually by the test system operator to maintain a pH of 11.5. Since the feed wastewater composition is reasonably consistent, manual pH control with the use of a chart recorder to monitor pH during unattended operation is expected to be sufficient to maintain the pH between 11.4 and 11.7. This pH range is typical for full-scale PWTP operation and is adequate for the wastewater softening reaction. The impact of low pH is inadequate softening and high total hardness levels. High total hardness levels result in quicker exhaustion of the ion-exchange resin and more frequent resin replacements. High pH levels result in unnecessary NaOH usage and increased sulfuric acid requirement for neutralizing the waste prior to air stripping.

The wastewater effluent from the ion-exchange column is neutralized to a pH between 7 and 8 prior to transfer to the air stripper. It is important to maintain this pH to prevent carbonate deposition on air stripper packing and to maintain consistent wastewater conditions for adsorption of organics by the activated carbon of the GAC column. The wastewater flows to a surge vessel equipped for mixing and addition of sulfuric acid. A dilute solution of sulfuric acid is fed by peristaltic pump to the surge vessel. A pH control system consists of a pH electrode immersed in the surge vessel and connected to a pH controller that sends the appropriate 4- to 20-mA signal to the speed controller of the acid feed pump. A chart recorder is used to record pH continuously. The pH meter and controller will be calibrated initially and recalibrated periodically to ensure accurate pH measurement.

4.4 PRESSURE MONITORING

It will be important that suspended solids from the wastewater not accumulate in the ion-exchange column, the air stripper, or the GAC column. The solids could cause plugging and reduction in flow rates for the test system. To monitor the accumulation of solids, pressure gauges have been installed for determining the pressure drop across the test columns. When the pressure drop exceeds a predetermined level, the columns will be backwashed or otherwise cleaned to remove the plugging deposits. Pressure gauges are installed on the inlet and outlet wastewater lines on the anthracite filter. The ion-exchange column and the GAC column both discharge to atmospheric pressure; therefore, pressure gauges are installed on the column inlet lines only. Experience with similar test systems indicates that the pressure drop across any of these columns is unlikely to ever exceed 15 psig. Pressure gauges with a 0- to 15-psig range were used for the filter, ion-exchange, and GAC columns. The air stripper is not likely to develop pressure drops greater than 2 in. of water. Magnahelic gauges are installed with a range of 0 to 2 in. of water for each of the two air stripper stages. The pressure gauges are factory calibrated and will not be recalibrated during the test program.

4.5 MIXER SPEED MONITORING

For the softening process, the speed of the mixer installed in the slow-mix tank and the sludge rake installed in the clarifier will influence the effectiveness of the softening reaction. The speed of the slow-mix tank mixer must be high enough to suspend the precipitates without breaking up the flocculated particles. The speed of the sludge rake must be high enough to keep the sludge from plugging the clarifier sludge outlet and slow enough not to upset the sludge blanket and cause excessive carryover of precipitates into the effluent tank. Excessive mixing in the slow-mix tank and carryover from the clarifier can result in high total hardness levels in the wastewater, which will increase the frequency of ion-exchange resin replacement.

Both the mixer and rake drive units have indicators for revolutions per minute. The speeds of both units will be monitored and recorded periodically by the test system operator. The indicators are factory calibrated and will not be recalibrated during the test program.

5. SUMMARY

WAG 6 closure activities will generate wastewaters containing radioactive, heavy metal, and organic contaminants. It is proposed that this wastewater be treated by adding it to the ORNL process wastewater treatment system. To demonstrate the effectiveness of the treatment and to characterize the secondary waste streams, a small-scale test system was needed for simulation of the ORNL PWTP and NRWTP operations. The test system described in this document will adequately simulate the treatment of WAG 6 wastewaters. The system will treat ORNL process and WAG 6 wastewaters at a combined flow rate of 0.5 L/min and produce the quantities of secondary solid wastes necessary for characterization and analysis of RCRA hazardous constituents.

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