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RADIOACTIVE LIQUID WASTE
TREATMENT FACILITY

by

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ABSTRACT

The Radioactive Liquid Waste Treatment Facility (RLWTF) at Argonne National Laboratory-West (ANL-W) in Idaho provides improved treatment for low-level aqueous waste compared to conventional systems. A unique, patented evaporation system is used in the RLWTF. SHADE (shielded hot air drum evaporator, U.S. Patent No. 4,305,780) is a low-cost disposable unit constructed from standard components and is self-shielded. The results of testing and recent operations indicate that evaporation rates of 2-6 gph (8-23 L/h) can be achieved with a single unit housed in a standard 30-gal (114-L) drum container. The operating experience has confirmed the design evaporation rate of 60 000 gal (227 000 L) per year, using six SHADE's.

I. INTRODUCTION

Conventional systems for evaporation of radioactive liquid waste are plagued with several significant problems, including high capital costs, radiation buildup, operation and maintenance difficulties, and disposal of by-products. The SHADE concept alleviates many of these problems by combining evaporation, shielding, and storage in a single, inexpensive unit. The SHADE eliminates many processing steps associated with conventional evaporator systems such as filtration, condensate collection, ion exchange, and solids disposal.

The SHADE uses standard 30- and 55-gal (114- and 208-L) drums as primary and secondary containment vessels for an adiabatic saturation process, wherein moisture is absorbed by hot dry air moving through cascading spray and over standing liquid. The relatively low cost of construction allows the SHADE to be considered disposable, and thereby eliminates expensive maintenance associated with conventional evaporation

systems. In addition, the SHADE is provided with integral shielding which reduces radiation exposure to operations and maintenance personnel.

Three other similar applications for the use of disposable evaporators contributed to the invention of SHADE. The first was reported by E. W. Bloore for the United States Army Nuclear Defense Laboratory, Edgewood Arsenal, Maryland, in 1968.¹ By use of a standard 55-gal (208-L) drum and an internal steam coil, 21 000 gal (79 000 L) of low-level radioactive liquid was evaporated at a rate of 55-66 gph (208-250 L/h). However, this system retained many of the troublesome features of conventional evaporation systems such as condensers, filters, and ion exchangers.

The second application involved the use of a standard 55-gal (208-L) drum cast in a concrete shield, with multiple internal steam coils to solidify evaporator bottoms. This system was developed by W. C. Persky at Argonne National Laboratory in 1973.

The third application was a preshielded disposable evaporator developed at Westinghouse Electric Corporation's Naval Reactors Facility by Wayne W. Stevens.² The Westinghouse evaporators use hot air passing over liquid holding trays, which are continuously replenished by a recirculation pump. The trays are contained in a stainless steel box with dimensions of 2.5 x 5 x 3 ft (0.76 x 1.52 x 0.91 m). The box, which has a volume of 340 gal (1300 L) is encased in concrete shielding. Two of these units have processed over 30 000 gal (114 000 L) of radioactive liquid since 1978.

The following unique features of SHADE distinguish it from previous evaporators:

- (1) Cascading of liquid over circular stacked trays to maximize the air/water interface in a minimum-volume container.

- (2) Unique design of air distribution to equalize the volume of airflow at each tray level.
- (3) Use of standard drums to house the evaporator in a compact modular design.
- (4) Elimination of condenser, vapor trap, ion-exchange system, filters, condensate storage, and handling required in the Army evaporator concept and in conventional evaporation systems.
- (5) Improved evaporation rate compared to the Westinghouse design in a package 1/3 the size and 3/8 the weight.
- (6) Elimination of maintenance and radiation-buildup problems encountered with expensive conventional evaporation systems.

II. DESCRIPTION

A. Facility Design

The Radioactive Liquid Waste Treatment Facility (RLWTF) processes low-level radioactive liquid at Argonne National Laboratory-West (ANL-W). The facilities supported by the RLWTF are Experimental Breeder Reactor II, Hot Fuel Examination Facility, Transient Reactor Test Facility, Zero Power Plutonium Reactor, and ANL-W support facilities. The RLWTF is capable of evaporating approximately 60 000 gal (227 000 L) of radioactive liquid annually, with the resulting solidified residue packaged and stored in an environmentally acceptable form for interim storage or shallow land burial.

The RLWTF is located within the ANL-W site boundaries on the Idaho National Engineering Laboratory, approximately 30 miles west of Idaho Falls, Idaho.

The facility is a two-story structure with 2500 ft² (230 m²) on the main floor, an equal area on the second floor, and an attached truck lock

of 500 ft² (50 m²). It is divided into two functional areas for purposes of radiological control: (1) controlled access and (2) uncontrolled access.

Controlled-access areas are the decon room, shipping preparation room, tank room, evaporator area, and equipment room No. 1. Other functional areas are the maintenance, electrical-equipment, truck-lock, control, health-physics, and equipment rooms.

The RLWTF process system has the following subsystems:

- Radioactive liquid waste fill
- Radioactive liquid waste supply
- Radioactive liquid waste return
- Radioactive liquid waste overflow
- Process air.

Radioactive Liquid Waste Fill (RLWF). The RLWF piping system provides a means for transfer of radioactive liquid waste from the truck-unloading station or the underground feed line to one of the four holding tanks.

Radioactive Liquid Waste Supply (RLWS). The RLWS system consists of piping, pumps, valves, holding tanks, and sample stations that serve the following functions: temporary storage; transfer to the SHADE's for evaporation; recirculation to keep particles in suspension; and sampling.

Radioactive Liquid Waste Return (RLWR). The RLWR is a piping system that carries radioactive liquid not drawn for use by the evaporators, and returns it to the holding tank.

It also provides a means of keeping particulates in suspension.

Radioactive Liquid Waste Overflow (RLWO). In the event that an evaporator overfills, the RLWO collects the excess liquid in an overflow

pipe. A liquid sensor closes the supply valve and indicates on the graphic control panel which evaporator is overflowing. The overflowing liquid flows by gravity to an overflow tank and is automatically pumped back to the holding tank supplying the SHADE's.

Figure 1 is a simplified diagram of the process liquid waste system at the RLWTF.

Process Air. The process air system includes an air-handling unit, ductwork, exhaust fans, and a stack. The system has enough capacity to provide hot air for six installed evaporator units plus six future units. Outside ambient air is drawn into the building through an air-handling unit containing two banks of steam-heating coils in series with one bank of prefilters and one bank of high-efficiency-particulate-air (HEPA) filters. In the air handler, the air is heated to 250°F (120°C) and enters a duct system for delivery to the six evaporators. Exhaust air from the SHADE's passes through two HEPA filters in series and flows through a monitored exhaust stack to atmosphere. Figure 2 is a diagram of the process air system.

In addition to the features described above, the RLWTF process has a number of safety design features to prevent or mitigate the results of an accident. They are:

- (1) Radioactivity in the stack results in an alarm and subsequent shutdown of the process.
- (2) High temperature in the evaporator exhaust results in an alarm and process shutdown.
- (3) A dewpoint temperature approaching condensation in the process-air exhaust will result in an alarm and automatic process shutdown.
- (4) The pit in the holding-tank room is designed to hold the maximum liquid inventory should a spill occur.

Fig. 1. Process Liquid Waste System

Fig. 2. Process Air System

- (5) Trenches are located and designed to direct liquid leaks in the evaporator room into the holding-tank pit.

B. Evaporator Design

The shielded hot-air drum evaporator (SHADE) shown in Fig. 3 has the following major components: a 30-gal (114-L) containment drum, an air-distribution manifold, evaporation trays, a recirculating-pump tube, an inlet and an outlet for air, and a 0.5-in. liquid-fill inlet for waste solutions. The SHADE uses a cylindrical 30-gal (114-L) drum as the primary housing. Donut-shaped, or toroidal, evaporation trays are positioned coaxially within the drum to form a vertical stack. As shown in the figure, there are six trays spaced apart from each other and from the top and bottom of the drum. Each tray has a circular outer wall and a circular inner wall. The topmost tray has an outer diameter that is smaller than that of the tray below. The height of the outer wall of the topmost tray is less than the height of its inner wall; this forms a dam or gate, forcing excess water filling the topmost tray to cascade over the tray's outer edge, where it falls in countercurrent flow past an updraft of hot air flowing along the side of drum. The liquid is then collected in the tray below.

Each of the lower trays is also formed in the shape of a toroid. However, for trays beneath the top tray, the diameters of all outer walls are equal and the diameters of the inner walls reduce progressively from upper to lower trays. A lower tray thus catches the water cascading from the next higher tray. Cascading water and spray increase the surface area of water exposed to the hot, dry air and thereby increase the rate of evaporation. The air flows radially outward along the surface of the water stored in a tray and through the cascading spray.

A pump tube extends down the length of the drum, and is connected to the pump motor located at the top of the drum in a position where the motor can be removed and reused. Water from the bottom of the drum is pumped up through the pump tube and out through an exit tube positioned so that the water is recirculated and deposited in the top tray. A liquid fill pipe extends into the drum and discharges into the upper tray.

Fig. 3. Shielded Hot-air Drum Evaporator (SHADE)

An air-distribution manifold extends down the center of the drum through the holes of the toroidal trays, and protrudes through the top of the drum where it is connected to an air-inlet tube. The air-inlet tube is connected to a source of forced air. The air-distribution manifold is equipped along its length with openings located above and in close proximity to the position of the toroidal trays.

The openings in the air-distribution manifold are of increasing size as it extends down toward the bottom of the drum so that an equal mass of air is delivered to each tray. Relatively dry, heated air passes through the air-inlet tube, then through the air-distribution manifold, where it absorbs moisture by an adiabatic saturation process as it passes over the water temporarily stored in the trays. From the air-distribution manifold, the air passes through the cascading water spray as illustrated by the large arrows in Fig. 3.

The humidified air is removed from the drum by an air-outlet tube connected to an opening in the top of the drum. The outlet tube is centered at the top of the drum and around the inlet tube, forming a tube outside a tube and providing for uniform removal of the humidified air. The air removed from the drum still has a low relative humidity so that at an air temperature of 120-130°F (49-54°C), the air can pass through high-efficiency filters (not shown) located outside the SHADE. The high-efficiency filters are used to ensure that small amounts of radioactivity that may become airborne do not escape.

Two level probes extend down the length of the drum and provide for a "high" and "low" control of liquid level within the drum. An overflow outlet is located near the top of the drum and provides a means whereby radioactive water can be handled safely in the event of excess filling by returning the excess back to its source.

A steam-heating coil is wrapped around the lower area of the 30-gal (114-L) drum to heat the water standing in the drum. To reduce heat loss from the 30-gal (114-L) drum, the annular space between it and the 55-gal (208-L) drum is filled with granular insulation.

The 55-gal (208-L) drum assembly is encased in 6 in. (0.15 m) of high-density concrete to provide a shield. The shield is contained within a 36-in.- (0.91-m) dia corrugated metal pipe, which provides support for the concrete while it is being placed and also provides structural reinforcement. The corrugated metal pipe extends above the initial concrete shield to provide support for a layer of concrete to be placed for final sealing and preparation for shipment.

Waste solutions pass over the series of donut-shaped trays as cascading water sprays. As heated air passes through the central air-distribution manifold and over the liquid in the trays, the air absorbs the water vapor by an adiabatic saturation process, in which relatively dry air picks up moisture and is then removed from the drum via the outlet tube. The pump inside the drum recirculates all the free liquid over the toroidal trays. The heating coil wrapped around the outside of the 30-gal (114-L) drum speeds the evaporation process. Evaporation rates of 2-6 gph (8-23 L/h) can be achieved with 200 cfm (0.09 m³/s) of room air heated to 200-250°F (93-121°C). The water in the drum is heated by the heating coil to 100°F (38°C). However, the system is very flexible and can be operated to match the accumulation rates of radioactive liquid waste for optimum efficiency and energy conservation.

Eventually, radioactive sediment builds up in the bottom of the drum and reduces the evaporation rate. The low cost of the component parts allows the system to be treated in a disposable manner. The unit is capped with high-density concrete and sealed before shipment for storage. In sealing the SHADE, the air inlet and outlet tubes are disconnected and sealed from the assembly in close proximity to the drum. Connections to the pump motor, liquid fill pipe, fluid-level probe, steam and condensate connections, and overflow outlet are also sealed.

The capped air inlet and outlet tubes, and the area above the drum defined by the corrugated metal pipe extending upward above the drum, are covered with concrete, and this effectively seals the evaporator contents.

III. INITIAL TESTING AND RESULTS

Two series of tests were initially conducted to verify the performance of the SHADE concept.

The first test series was conducted using a full-scale glass-cylinder test model, sized to approximate a standard 18 x 30-in.- (0.45 x 0.76-m) high 30-gal (114-L) drum. A series of 35 tests of 1-h duration were conducted using clear water. Room-temperature air was used first and resulted in evaporation rates of approximately 0.5 gph (2 L/h). Next, heated air was introduced to the test unit in the range of 145-260°F (63-127°C), at air flows of 200 cfm (0.09 m³/s) at 70°F (21°C) and 5100 ft (1550 m) elevation. Evaporation rates of 1.5-2 gph (6-8 L/h) were observed. Humidity ratios of 0.005-0.014 lb H₂O/lb dry air were noted in the air entering the evaporator. The humidity ratios of exit air ranged from 0.009-0.033 lb H₂O/lb dry air.

When the water temperature in the evaporator was maintained at 100-130°F (38-54°C), evaporation rates increased to 4-6 gph (15-23 L/h). Exit humidity ratios also increased to 0.033-0.042 lb H₂O/lb dry air. In the most extreme case, the humidity ratio was at 92% of saturation.

The second test series was conducted using a full-scale SHADE. Figure 4 shows typical psychrometric conditions for the process. The initial testing was accomplished with clear water to verify operating parameters. Next, radioactive liquid was evaporated during the day shift with an operator in continual attendance. Finally, automatic shutdown and safety features were added to the test equipment to allow for continuous, unattended operation. From November 1980 through June 1982, 10 000 gal (38 000 L) of low-level radioactive liquid was processed in a single SHADE at evaporation rates of 2-3.5 gph (8-13 Lph) or 14 000-25 000 gal (53 000-95 000 L) per year, at an 80% plant factor. The radioactivity in the evaporated liquid was primarily ¹³⁷Cs and totaled 1.5 Ci based on gross alpha, beta, and tritium activity. The design life of an evaporator is 10 000 gal (38 000 L) or 2.5 Ci (based on a maximum of 50 mR/h at the outside surface of the shielding). The

Fig. 4. Psychrometric Chart for SHADE Operation, 5100 ft Elevation
 [Conversion Factors: $^{\circ}\text{C} = (^{\circ}\text{F} - 32)/1.8$; 1 ft = 0.305 m.]

design life can vary considerably, depending on the solids contained in the feed liquid. For the design basis with solids in the liquid feed of 0.01 lb/gal (1 g/L) and with a solids density similar to that of mud, it was projected that 10 000 gal (38 000 L) of feed liquid would yield approximately 0.75 ft³ (0.02 m³) of solids. The test was terminated at 10 000 gal (38 000 L).

IV. OPERATING EXPERIENCE

The RLWTF became operational in June 1983 with six installed SHADE's. Figure 5 shows the evaporator area of the RLWTF. Figure 6 shows the control panel.

Normal operating procedure is as follows: Radioactive liquid waste is brought through underground lines from other facilities to four 1500-gal (5678-L) holding tanks at the RLWTF. Tanks are filled to only 1000 gal (3785 L) as a precaution against overflow. Only one 1000-gal batch is processed per "run," as a convenience in record keeping.

Fig. 5. Evaporator Area of RLWTF, with Prototype SHADE Model in Foreground and Six Operating SHADE's in Background. (ANL Neg. No. 103-13145).

Fig. 6. Control Panel of RLWTF. (ANL Neg. No. 103-E9448.)

Two operators are needed for transfers of liquid waste to holding tanks, but one operator is sufficient for process startup. After startup, the RLWTF continues automatically until the 1000-gal batch is completed, when it shuts down automatically. The RLWTF is unattended during a run except for once-a-shift monitoring. Any malfunction alarms are annunciated in nearby facilities that are manned around the clock.

The six initial SHADE's were used in a manner untypical of later operations. After initial tests with clear water, they were run from Aug. 18, 1983, to Jan. 5, 1984, to dispose of accumulated sludge in the holding tanks of the old radioactive-liquid-waste treatment facility. The solids content of some of this feed material was way above the design basis of 10 lb/1000-gal batch (1 g/L). After a throughput of about 6000 gal (22 700 L) per SHADE, the evaporation rate had slowed down to below 1 gph (3.8 L/h) per SHADE; therefore these initial SHADE's were removed for disposal. The solids content per SHADE at this time was only in the range of 38.8 to 47.8 lb (17.6 to 21.7 kg), or about one-third of the design basis. The sludge content of the feed material for five of the 1000-gal batches amounted to 54% of the total solids in only 13% of the total volume. The peak batch was No. 8, with a solids content of 46.1 lb/1000 gal. The average for the five high-solids batches was 28.6 lb/1000 gal. This rapid accumulation of solids is believed to have led to a premature blockage of air passages, with a resulting slowdown of the evaporation rate.

The second group of six SHADE's went into operation in March 1984 and has been in operation about four months at this writing. The feed material has been normal rather than high-sludge material. With a throughput to date of slightly over 3600 gal (13 600 L) per SHADE, the evaporation rate has remained normal.

Tables I and II present operating data for the first and second group of SHADE's. Figure 7 compares the cumulative solids for the two groups and projects the future cumulative solids for the second group.

TABLE I. Operating Data for SHADE's 1-6^a

Batch No.	Batch Size, gal (L)	Solids Content, lb (g)	Solids lb/1000 gal g/L	Cumulative Solids lb (kg)
Clear Water Test	20000 (75708)	48.0 (21773)	2.4 (0.29)	48.0 (21.8)
1	1250 (4732)	1.0 (473)	0.8 (0.10)	49.0 (22.2)
2	1000 (3785)	32.0 (14528)	32.0 (3.84)	81.0 (36.7)
3	1000 (3785)	27.0 (12250)	27.0 (3.24)	108.0 (49.0)
4	1000 (3785)	6.6 (2994)	6.6 (0.79)	114.6 (52.0)
5	930 (3520)	8.2 (3720)	8.8 (1.06)	122.8 (55.7)
6	1000 (3785)	9.3 (4240)	9.3 (1.12)	132.1 (59.9)
7	1000 (3785)	9.5 (4315)	9.5 (1.14)	141.6 (64.2)
8	1000 (3785)	46.1 (20931)	46.1 (5.53)	187.7 (85.1)
9	640 (2423)	5.8 (2638)	9.1 (1.09)	193.5 (87.8)
10	1000 (3785)	8.4 (3823)	8.4 (1.01)	201.9 (91.6)
11	380 (1438)	1.9 (860)	5.0 (0.60)	203.8 (92.4)
12	1000 (3785)	20.1 (9126)	20.1 (2.41)	223.9 (101.6)
13	1000 (3785)	5.0 (2260)	5.0 (0.60)	228.9 (103.8)
14	1000 (3785)	3.6 (1635)	3.6 (0.43)	232.5 (105.5)
15	1000 (3785)	3.8 (1720)	3.8 (0.45)	236.3 (107.2)
16	1000 (3785)	4.4 (1990)	4.4 (0.53)	240.7 (109.2)
17	900 (3407)	17.6 (8000)	19.6 (2.35)	258.3 (117.2) ^b
18	925 (3501)	6.8 (3100)	7.4 (0.89)	265.1 (120.2) ^b

^a SHADE's 1-6 were removed after batch 18.

^b Cumulative ²³⁷Cs activity after batch 18 was 2.32 Ci.

TABLE II. Operating Data for SHADE's 7-12^a

Batch No.	Batch Size, gal (L)	Solids Content, lb (g)	Solids lb/1000 gal g/L	Cumulative Solids lb (kg)
19	1000 (3785)	6.0 (2725)	6.0 (0.72)	6.0 (2.7)
20	1000 (3785)	4.2 (1915)	4.2 (0.51)	10.2 (4.6)
21	1000 (3785)	4.1 (1843)	4.1 (0.49)	14.3 (6.5)
22	407 (1541)	2.5 (1155)	6.3 (0.75)	16.8 (7.6)
23	580 (2196)	3.8 (1723)	6.5 (0.78)	20.6 (9.3)
24	1000 (3785)	5.7 (2604)	5.7 (0.69)	26.4 (12.0)
25	1000 (3785)	5.6 (2562)	5.6 (0.68)	32.0 (14.5)
26	965 (3653)	2.3 (1063)	2.4 (0.29)	34.3 (15.6)
27	1000 (3785)	9.0 (4107)	9.0 (1.09)	43.4 (19.7) ^b
28	611 (2313)	5.1 (2336)	8.4 (1.01)	48.5 (22.0) ^b

^a SHADE's 7-12 remained in service after batch 28.

^b Cumulative ²³⁷Cs activity after batch 19-28 was 0.11 Ci.

Fig. 7. SHADE Operating Experience, and Projection for Second Set.
(Conversion Factor: 1 lb = 0.454 kg.)

Cumulative ^{137}Cs activity was 2.62 Ci for the first group of SHADE's, and was 0.11 Ci for operation to date with the second group.

Two modes of heat application have been used: (1) only hot air for most of a run, with auxiliary steam in the steam-heating coils added at the end of a run; and (2) both hot air and auxiliary steam throughout a run. In the first mode, the normal evaporation rate for a SHADE has been 2.5 to 3 gph (9.5 to 11.4 L/h). In the second mode, the rate has been 3.3 to 3.8 gph (12.6 to 14.5 L/h). "Normal" in this context applies to the first half of SHADE operating life. However, there are not yet enough data with normal feed material to characterize the drop-off in evaporation rate during the second half of life.

Two minor problems were encountered during operation of the RLWTF. One was foaming of the feed material due to its content of detergent (Radiacwash) from decontamination facilities. The foaming was overcome by adding a defoaming agent to the feed material. The other problem was unreliable operation of radiation monitors due to high background temperatures (100-102°F or 37.8-38.9°C) in parts of the facility. The temperature problem is still under study; the possible fixes include adding temperature-compensating circuits to beta-gamma monitors, moving monitors to cooler areas, or improving the ventilation in the building.

Operating personnel found the new RLWTF much superior to the old processing facility, which had required constant attention and significant exposure to radiation. Total personnel exposure for the first year of operation amounted to 28 mR of nonpenetrating radiation and 435 mR of penetrating radiation. The highest individual exposure for this period was 28 mR nonpenetrating and 225 mR penetrating. The radiation exposures in the new RLWTF were reduced by a factor of two for the following reasons:

- (1) Attendance by personnel was largely eliminated except during startup of a run and during infrequent replacement of SHADE's.
- (2) The SHADE's are self-shielded during operation.
- (3) The new holding tanks were designed for easy periodic removal of sludge deposits, preventing buildup of radioactivity. Each tank is equipped with a hydroblaster wand, which is mounted in a rubber boot at the top of the tank. The wand is used to direct a 2000-psi (13 790-kPa) stream at the tank walls and bottom while they are viewed through a port with the aid of a portable spotlight. Figure 8 shows the holding-tank room.

The initial operating costs were untypically high because of the untypical sludgy feed material from the old facility and some initial calibration problems. However, the experience to date indicates that the normal operating cost should be about \$2/gal (\$0.53/L), including annual replacement of SHADE's.

Fig. 8. Holding-tank Room of RLWTF. (ANL Neg. No. 103-E9409).

V. SHOP FABRICATION OF SHADE'S

The 13 SHADE's used to date were fabricated in the ANL-W Plant Services shop with standard methods and materials.

Carbon steel plate was cut and welded to make the tray and centerpost assembly. Jigs and assembly fixtures were devised to speed serial fabrication of these items.

The donut-shaped bases for the trays were cut from 1/8-in. (3-mm) steel plate on a circle burner, using circular patterns as guides. The sides of the trays were made by rolling 1/8-in. flat bar stock to a hoop shape, then welding it to the bases. Wire-feed welding was used for all welds.

The centerpost (air-distribution manifold) was made from flat bar stock that was 1/4 in. thick by 4 in. wide (6 by 102 mm). Airflow holes were cut on a pattern burner. Four of these flat pieces were then assembled in a fixture and welded together at the edges to make a centerpost with square cross section. Figure 9 shows the centerpost with three of the four sides in place (ANL Neg. No. 103-Y5716).

Crossbars were welded to the center-post at the proper elevations to support the trays; then the trays were welded to the centerpost with the aid of an assembly fixture. Figure 10 shows the trays and other SHADE parts before assembly. Figure 11 shows grinding of welds after assembly of the trays to the centerpost.

This assembled unit was put inside a 30-gal (114-L) steel drum, which had been wrapped with a copper-tubing steam-heating coil near the bottom. Sheet metal and caulking were installed around the steam coils. Inlet, outlet, pump, and overflow lines were welded in place, and a lid was seal-welded on the 30-gal drum.

The 30-gal drum was then placed on wooden spacer blocks within a 55-gal drum. The overflow connection was made through the side of the 55-gal drum. A cylindrical plastic lining was installed just inside the wall of the 55-gal drum. The space between this lining and the 30-gal drum was then filled with Gilsulate 500 (inorganic mineral) insulation. A lid was seal-welded onto the 55-gal drum.

The 55-gal drum was next lowered onto support legs within a 36-in.-dia (9.1-m-dia) section of corrugated steel pipe, as shown in Fig. 12. The overflow line was extended through the side of the corrugated pipe, rods with lifting eyes were emplaced, and then concrete shielding was poured into the 6-in. (152-mm) space between the drum and the corrugated pipe. This completed a SHADE for installation in the RLWTF.

After a SHADE has completed its service life, the inlet and outlet lines are disconnected, and then a further 12 in. (305 mm) of concrete is poured to seal the top.

After the first prototypes, the next six SHADE's cost an average of \$4000 each for fabrication and materials. Future SHADE's are expected to cost even less because jigs and fixtures are already available.

Fig. 10. Principal Parts for Air-distribution Manifold and Tray Unit. (ANL Neg. No. 103-Y5717).

Fig. 11. Grinding of Welds on Assembled Trays. (ANL Neg. No. 103-13148.)

Fig. 12. Assembled SHADE Components in 36-in. Corrugated Steel Pipe.
(ANL Neg. No. 103-Y5738.)

VI. CONCLUSIONS

The RLWTF and SHADE provide an excellent alternative to evaporation systems commercially available at present, as indicated in the following list of advantages:

- SHADE is constructed from low-cost standard components.
- Evaporator and storage vessels are combined in a single unit.
- Integral shielding greatly reduces exposure to radiation.
- Inexpensive construction and reuse of external components allow the unit to be considered disposable.
- Virtually no maintenance is required except for auxiliary support systems such as instrumentation, air-handling systems, and liquid-storage and -transfer systems.
- SHADE eliminates the need for condensers, vapor traps, condensate storage tanks, condensate pumps, ion exchangers, and liquid filters.
- The system can handle varying rates of radioactive liquid by adding or subtracting the number of SHADE's or by varying air temperature, airflow, or other operating parameters.
- The SHADE system can operate unattended with only occasional status checks.

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