B. POTENTIAL EFFECTS OF ABNORMAL OPERATION OF WASTE STORAGE AND HANDLING FACILITIES

1. HIGH-LEVEL LIQUID WASTE TANKS

This section describes postulated deviations from normal operation of the two SRP waste tank farms and potential consequences that could accompany any such abnormal or accident conditions. Environmental effects are evaluated for two sets of conditions defined as follows for the purpose of this analysis:

Abnormal Operations. Operational transients that are a result of equipment malfunction, unforeseen process reactions, or operator error. These events could cause a release of up to a few hundred curies of radioactivity, but no offsite effects would be expected.

Accidents. Hypothetical low-probability events with potential for offsite consequences.

ABNORMAL OPERATIONS

Spills During Waste Transfer

Waste is transferred to waste storage tanks, from tank to tank, to and from evaporators, and from tank farm to tank farm in the normal course of operations. Primary containment for the waste transfers is provided by welded pipelines of either stainless or carbon steel. Stainless steel is used for all new construction. Transfer lines with carbon steel primary containment are being replaced with stainless steel. Secondary containment is provided in the form of carbon steel pipe, stainless steel pipe, transite pipe, or concrete encasement. Secondary containment using transite and concrete will be replaced. All connections in transfer lines are provided with secondary containment such as diversion boxes, waste-tank inlet risers, or evaporator enclosures. Minor leakage from connectors occurs occasionally when piping jumpers are changed; however, these connectors are contained in concrete diversion boxes (usually stainless steel lined) so that the leakage is readily collected and returned to storage.

Formerly, some intertank transfers of waste relatively low in gamma radiation, including aged high-level sludge, were made through above-grade lines without secondary containment. Leaks were encountered in two such transfers and, subsequently, secondary containment has for many years been mandatory in transfer of high-level waste. In August 1962, a conventional bolted flange connection in an above-grade unjacketed line leaked some low-level waste being transferred from Tank 19 in F Area. This leakage contaminated about 200 ft^2 of waterproofed ground surface. The contaminated soil and asphalt, totaling 186 cubic yards, were removed to the burial ground. No significant activity remained in the ground at the leakage site. In February 1967, waste containing an estimated 200 Ci of mixed fission products leaked when a flexible metal hose linking one of four slurry pumps to a discharge header at Tank 10 in H Area ruptured. This spill contaminated some tools, concrete block shielding, and about 1000 ft^2 of paved ground surface. The tools and about 200 cubic yards of contaminated soil, blocks, and asphalt were removed to the burial ground.

The only failures to date in stainless steel waste transfer lines have resulted from chloride-induced stress cracking of concrete-embedded primary lines where they enter through the walls of concentrate-transfer-system (CTS) pump pits in both tank farms. In this case, as with many waste transfer lines, the carbon-steel secondary jackets terminate at the outer surface of the concrete walls of boxes, risers, or similar containment structures entered by primary lines. In the CTS pump pit, the portions of the embedded stainless steel lines which failed were wrapped with insulation and over-wrapped with polyvinyl chloride tape. Radiation and heat apparently decomposed the polyvinyl chloride and generated mobile chlorine compounds which migrated through the insulation and catalyzed the cracking of the stainless steel piping. Leaking waste then migrated and escaped along the pipe-to-concrete interface and reached the soil outside the secondary containment. All such embedded process lines known or suspected to be wrapped with chloride-bearing tape are being or will be replaced with chloride-free materials. In addition, the secondary jacket piping will be continued through and embedded in the concrete wall of the box or riser.

Dry-well monitoring (discussed below) in the vicinity of the failures of F-Area CTS lines led to an estimate of <100 Ci of ^{137}Cs contaminating some 210 ft^3 of soil in this vicinity. The contaminated soil and concrete are being removed to the burial ground; activity remaining in the unexcavated soil is expected to total less than one Ci. Waste leakage to the ground from the H-Area CTS pump pit was substantially less than in F Area, but no quantitative estimate of the actual leakage has been made.

Here, as in F Area, the contaminated soil will be removed and the secondary containment of process lines will be revised as discussed above.

All other SRP waste spills encountered in conjunction with waste transfers have resulted from conditions at the transfer line termination rather than from failures of the lines themselves. These spills include the following (each is discussed below):

- Overflow from a waste concentrate inlet riser at Tank 9.
- Overflow into and from the secondary containment encasement of the inlet line to Tank 8.
- Overflow from an open vent connection into the 242-F evaporator cell.
- Leakage from Riser 6 of Tank 3 through a poorly grouted line entry point.

The largest above-grade spill occurred in May 1967 when a 2-ft-diameter vertical inlet riser to Tank 9 plugged with crystallized salt that formed from waste concentrate discharging from an evaporator via a 2-inch pipe. About 200 gallons of waste concentrate containing an estimated 1500 to 2000 Ci of ^{137}Cs overflowed from the plugged inlet riser to the ground surface above the waste tank. Most of the spilled activity was removed by digging up about 1000 cubic yards of contaminated soil and moving it to the burial ground. Up to several hundred Ci reached a storm sewer and was retained by a temporary dam placed in the storm sewer outfall. Water from the impoundment was transferred to a seepage basin, and the outfall stream bed was rerouted. About 32 Ci of ^{137}Cs migrated from the outfall to Four Mile Creek during the seven months following the spill. About 6 Ci of the ^{137}Cs remaining in the outfall desorbed from the stream bed and reached Four Mile Creek during the next four years. Most of this cesium remains in the bed of Four Mile Creek, although about 1.0 Ci is desorbed and reaches the Savannah River Swamp each year. It is highly unlikely that another spill of this nature will contaminate the creek because of the changes which have been made in facilities and monitoring. As part of these changes, the facilities for the discharge of waste concentrate to waste tanks have been modified to prevent pluggage of the risers, gamma radiation detectors have been installed to indicate and alarm if waste accumulates in the riser, and facilities have been installed to divert and retain contaminated runoff water for decontamination or return to tank storage or seepage basins.

In one instance in April 1961, waste was unintentionally allowed to exceed the normal fill level in Tank 8 and several thousand gallons of waste leaked through an asbestos-packed expansion joint around the fill line into a concrete encasement that provides secondary containment for the waste entering Tank 8. Most of this leaked waste was collected in an installed collection tank and returned to another waste storage tank, but some waste escaped from the secondary containment into the ground several feet below grade as discussed below. The level of waste in Tank 8 was decreased to normal by transfer of some of its contents to another waste tank. The overfill resulted from errors in calibration of a reel tape and in the method of converting reel tape readings to liquid levels. These errors are unlikely to be repeated because of modified reel tape designs and procedures.

In 1974, a new series of wells was installed in the waste farm area to sample the ground water. One of these wells was contaminated with ruthenium, and a program was undertaken to establish the source of the contamination. Contaminated soil was detected 12 ft below the ground surface near the junction of Tank 8 and its fill line encasement. This contaminated soil extended over a horizontal area of 200 to 300 ft^2. Samples of soil from the upper surface of the zone of contamination contained a ratio of $^{137}Cs/^{134}Cs$ equivalent to waste aged about 14 years. The age of this contamination indicates that it probably leaked into the ground when Tank 8 was overfilled in 1961. It is postulated that the waste leaked to the soil from the junction of the fill line encasement and the outer concrete wall of the waste tank when the liquid leaked through the expansion joint into the fill line encasement as previously described. Details of the Tank 8 overfill and the resultant soil contamination are found in Reference 34.

The depth of the zone of contamination was determined by driving pointed solid-wall tubes through the zone and measuring radiation readings through the tube wall. These radiation readings indicated that the thickness of the contaminated zone varies from 1 to 14 feet. This zone of contamination contains an estimated 5000 Ci of ^{137}Cs and smaller but uncertain amounts of ^{90}Sr and ^{147}Pm, depending on the fractions of those isotopes that had settled into the sludge phase in the waste tank before the supernatant liquid overflowed and leaked into the soil. Two samples of soil taken from the center of the contaminated zone indicated that the ^{90}Sr content of the zone may be less than 1 Ci; ^{147}Pm was not detected. Most of the ^{137}Cs and probably the ^{90}Sr and ^{147}Pm which leaked into the soil are contained in 800 to 1100 ft^3 of soil near the point of leakage. Other radionuclides contained in this zone are less than a few curies. An additional 5000 ft^3 of contaminated soil, containing a small fraction of the waste, surround the central 800 to 1100 ft^3 which contain most of the fission products.

The lower surface of the outer zone of slightly contaminated soil is 14 to 18 ft above the maximum level of the water table. Sorption of the radionuclides by the soil, pluggage of soil pores due to dispersion of clay aggregate, and entrapment of these dispersed particles in spaces between sand particles resulted in a very slow rate of movement of the radionuclides. Only small amounts of ruthenium have moved more than 15 ft from the point of leakage, and most has decayed since the leak occurred. It will be many years before the ^{137}Cs and ^{90}Sr could reach the water table, and then many more hundreds of years before the ground water from this location exits into a surface stream. Investigation and monitoring of the contaminated zone are being continued.

Radionuclide movement through the saturated zone is influenced by the motion of the ground water, which transports and disperses these radionuclides, and by the sorptive capacity of the soil, which delays the movement of the different radionuclides by varying degrees. The tank farms are located in an area of very low flow of ground water, and the ground water flow path, distance, and rate indicate that 200 years would be required for ground water from the vicinity of the F-Area waste tanks to reach the creek. The sorptive capacities of the soils for ^{137}Cs and ^{90}Sr in alkaline waste are high, thus reducing the rate of movement and providing decay times of hundreds of years before existing streams are reached.

In April 1961, pluggage of the 242-F evaporator bottoms line led to the overflow of waste concentrate through a vent line into the evaporator cell. The high-level alarm on the cell sump was inoperative, and waste concentrate filled the cell to a level above the existing liner and seeped through the cell walls. To prevent recurrence, the height of the evaporator cell liner was increased from 1.5 to 11 ft, and instrumentation for the cell sumps was modified to indicate when the high-level alarm is inoperative.

In the course of removing an eight-year-old supernate transfer jet and line at Tank 3 in 1975, in conjunction with the upgrading of several transfer lines in the area, a high radiation field and some soil contamination were found below grade beside Riser 6. This contamination apparently resulted from seepage through cracks or voids in the concrete poured around the jet piping to reseal the hole in the riser wall through which the lines entered. It is believed that the waste liquid resulted from a leak of one of the jet gaskets causing a waste accumulation in the riser. The amount of activity that leaked into the soil has been estimated at 50 Ci of ^{137}Cs in 30 to 40 ft^3 of soil. Present plans are to remove most of the contaminated soil from around the riser; at that time a better estimate of the leaked activity will be obtained. Leakage detection alarms have also been installed in many of the risers.

Studies to determine the potential for unknown leaks into the soil have been made. All cases in which a significant quantity of waste leaked from the primary containment into the secondary containment have been examined and monitoring is underway to ensure that unknown zones of contaminated soil do not exist. Over three dozen dry monitoring wells have been or are being installed and periodically surveyed adjacent to potential leakage sites. These sites include diversion boxes DB-1 in F Area and DB-1 and -2 in H Area, both evaporator cells, and the CTS pump pit in H Area; well locations are shown in Figure III-14. Of 32 wells (exclusive of Tank 8 wells) already in use (Table III-35), none have revealed any ground contamination. Several of the wells have shown local radiation zones distinctly greater than background, but all such cases, except at Tank 8, are attributable to penetrating gamma radiation from adjacent diversion boxes and associated process lines. Soil corings near the well having the highest such reading showed no contamination in the soil.

Plant locations with residual contamination from past spills of radioactive waste to the environment are given in Tables 6 and 10 of Appendix A.

If both the primary and the secondary transfer lines should leak during future transfers, the result would be either a surface spill or an underground leak. In the event of a surface spill, area monitors would alarm, and the transfer would be stopped. Contaminated soil would be removed to the burial ground. If the spilled waste should reach a storm sewer, the runoff would be diverted to lined retention basins installed in F and H Areas in 1972. In the event of an underground leak from both the primary and secondary containment, soil and water contamination would occur in the immediate vicinity of the leak. Spread of this contamination would be very slow due to (1) the location of waste-handling facilities in an area of very low flow of the ground water, (2) the ion exchange capacity of the soil, and (3) the tendency of diluted alkaline waste to disperse clay particles and plug the soil. No offsite effects are expected for spills or leaks of the magnitude just described.

Leak from a Waste Tank

High-heat and low-heat wastes have been stored in large underground tanks at the Savannah River Plant for more than 20 years. Although stress cracks in several of the steel primary tanks have allowed waste to pass into the secondary pans under and around the primary tanks, leakage outside the secondary container into the surrounding soil occurred only once. This leakage resulted from overflow of the Tank 16 secondary pan. This overflow allowed an estimated 10 to 500 Ci of ^{137}Cs in tens of gallons of water to enter the soil. This tank has been removed from service and only contains a heel of sludge plus some dried waste salt in the secondary pan which is to be removed during 1976. The investigation of the fate of the radioactivity has been reported in DP-1358.[35]

Eight of the original 16 cooled tanks have experienced slow leakage from the primary tank to the annulus space inside the secondary container. Multiple leak sites have been identified on the three cracked tanks where most of the vertical surface is visible through existing access holes into the annulus. The number of leak sites is about 15 in Tank 15, about 50 in Tank 14, and about 350 in Tank 16. In Tanks 1, 9, 10, 11, and 12, only 30 to 40% of the tank surface is visible through existing access holes. The maximum leak rate observed in any of the leaking tanks was about 4 gpm at Tank 16. 75-gpm steam jets installed in the secondary space return any liquid waste that leaks into this space back to tank storage. Dehumidified air circulated through the annulus space evaporates moisture from slow leaks and causes the contained salt to crystallize and partially or completely seal the leak site. The dehumidification system discharges to the atmosphere through particulate filters.

Ground water monitoring wells are located both within the tank farm areas (Figures III-15, III-16, and E-9) and regionally toward existing streams (Figure E-8). The wells are sampled periodically. Except for some radioactivity in wells around Tank 16, which leaked some waste into the ground from the annular space in 1960 (described above), no radioactivity that could be associated with tank leakage has been found in these monitoring wells. This fact lends confidence in the soundness of the secondary pans of tanks but does not constitute proof of integrity. Minor amounts of ground water have been found in the secondary pan of several tanks in the past, particularly during very wet weather. This water had come through imperfectly sealed inspection ports at the surface and seeped through small imperfections in the concrete structure; these leaks were repaired. The current status of waste in the annulus and tanks of those double-wall tanks that have a history of leakage is given in Appendix C.

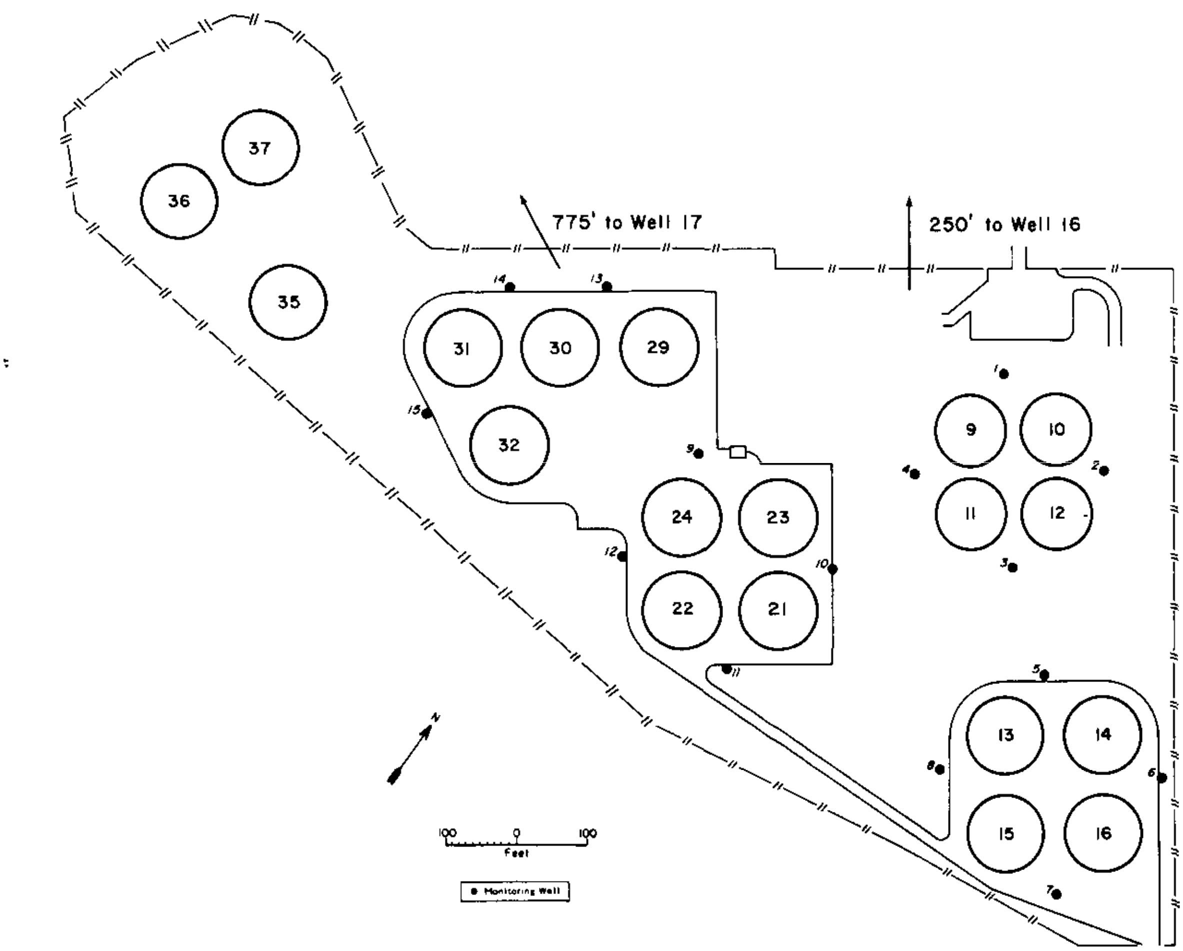

FIGURE III-16. H-Area Tank Farm Ground Water Monitoring Wells (Tanks 35-37 are under construction; ground wells are not shown.)

Minor leakage past a secondary barrier would not have any significant offsite effect. The rate of movement of ground water and the retention of ^{137}Cs and ^{90}Sr by the soil will provide decay times of hundreds of years before these nuclides can reach existing streams. The F-Area site is near the water table divide between Upper Three Runs and Four Mile Creek; ground water in this vicinity moves mainly toward Four Mile Creek with an estimated travel time of about 200 years. In H Area, ground water in the vicinity of the tank site moves toward Upper Three

Runs with an estimated travel time in excess of 50 years and probably approaching 350 years. The longer travel times to plant streams calculated for ground water from the tank farm areas than ground water from seepage basin areas result from the higher location of the tank farms (near the ground water divide where the pressure gradient to cause flow is low) and the fact that the water in a seepage basin provides an additional pressure gradient.

Assessment of Waste Tank Leaks

The purpose of this section is to indicate the bases for the conclusion that no high-level liquid waste has leaked from a waste tank structure into the surrounding ground or ground water other than from Tank 16. The conclusion is based on data and judgments developed as a result of knowledge of tank construction details, annulus and sump inspection programs (visual and sampling), leak detection instrumentation, waste properties, hydrology of the area surrounding the tank farms, and ground water monitoring programs. Information on tank design and history may be found in Section II.A.4 and Appendix C. The following discussion is organized by groups of tanks of the same design in the same general environment.

Tanks 1-8 (F Area, Constructed 1951-53)

These tanks have a 5-ft-high secondary pan and a 1-ft-10-in.-thick concrete encasement. Tank 1 is the only waste tank in the group with leakage from the primary tank into the annular pan. The leakage evaporated leaving two small deposits of dry salt. The salt deposits showed no significant change between the 1969 and later inspections, indicating the fault had sealed due to crystallization of the waste. Because the leakage into the Tank 1 annulus was not enough to cover the bottom of the annular pan, and because other tanks in this group have no evidence of leakage into the annulus, leakage of waste into the soil is highly unlikely. For the waste in the Tank 1 annulus to reach the soil would require cracking of both the annular pan and concrete encasement and the waste to follow a tortuous path. Escape of waste to the sub-surface soil at Tank 8 was not the result of primary tank failure, and major improvements in instrumentation and procedural controls have been adopted to forestall recurrence of a similar incident.

Tanks 9-12 (H Area, 1951-53)

These tanks are of a similar design as Tanks 1-8 in F Area (thus the annular pan and concrete encasement offer significant protection against leakage as discussed above), but have additional external waterproofing protection against inleakage of ground water. These tanks are, in addition, located below the water table. The bottom of the concrete encasement is exposed to a hydrostatic head of about 30 ft of ground water. If the concrete encasement and annular pan should leak, ground water would enter the annular space and preclude leakage of waste from the annular pan. The primary containers of Tanks 9 and 10 have leaked and the annular pans contain about 9 and 2 inches of damp crystallized salts, respectively. In 1974, single leak sites in Tanks 11 and 12 were identified by an accumulation of dried salt on the primary tank wall. No waste has been observed in the annular pans of these tanks (11 and 12).

Tanks 13-16 (H Area, 1955-56)

These tanks have a 5-ft-high secondary pan and a 2-ft-9-in.-thick concrete encasement. The primary containers of three of these tanks (14, 15, and 16) have leaked. The annuli of Tanks 14 and 16 contain 14 and 15 inches of damp crystallized salts, respectively. No salt is observed in the bottom of the Tank 15 annulus but 15 salt deposits are observed on the tank wall. The annular pan and concrete encasement of Tanks 13-16 offer significant protection against escape of waste to the ground as discussed for Tanks 1-8.

Tanks 13-16 were constructed with their bottoms near the water table. A soil hydration system was installed below the concrete slab below the four tanks to inject water into the soil, if needed, to prevent uneven drying of the ground by the heat from the waste contained in the tanks. The soil hydration system has never been needed for water addition to the soil, but has been used as a large well for sampling activity that seeped into the soil in September 1960 as a result of waste overfilling the annular pan of Tank 16. This system has been pumped periodically since the Tank 16 leak to establish the amount of waste that leaked into the soil. The ratio of $^{137}Cs/^{134}Cs$, an indicator of the age of the waste found in the soil hydration system, indicates that the only leak from this group of tanks was the 1960 leak from Tank 16. A full assessment of the Tank 16 leak indicates that the most likely path of waste leakage was through a construction joint located 5 ft above the tank bottom rather than through a crack in the concrete encasement. The level of waste in the annular pans has never reached this level in any other tank.

Normally the hydraulic head from the water table exceeds the waste head in the annular pans of these tanks, thus precluding leakage through the pan and concrete encasement. The normal fluctuation of the water table, however, provides times when this situation does not exist, but water table levels have never decreased below the soil hydration system.

The extensive monitoring of ground water following the waste leakage from Tank 16 has not indicated additional leakage of high-level liquid waste from Tank 16 or any leakage from Tanks 13, 14, or 15.

Tanks 29-32 (H Area, 1967-70) and 33 and 34 (F Area, 1969-72)

These primary tanks are stress-relieved and the secondary tanks are full height with a 2-ft-6-in.-thick concrete encasement. None of the primary tanks show evidence of leakage.

Tanks 17-20 (F Area, 1958)

These four tanks are single-wall tanks that are equipped with a leak detection system to collect waste that might leak from the primary tank as well as ground water which leaks slowly through the prestressed concrete encasement. No contamination has been found in the leak detection sumps of three of the four tanks, and low levels of activity (maximum 3 nCi/ml) were encountered in the sump of Tank 19 in 1973 (see discussion for Tanks 21-24 below). Normally, the water table is above the tank bottom. Because the water level in the sump is kept below the tank bottom, ground water inflow would be expected. Ground water monitoring near these tanks has not indicated tank leakage.

Tanks 21-24 (H Area, 1962)

These single-wall tanks are similar to Tanks 17-20 in F Area. Two of these tanks (21 and 24) have low levels of activity (maximum 5 nCi/ml) in their leak detection sumps. This activity is attributed to either water condensing on the inner surface of the domed tank top and leaking down the interface between the steel tank liner and its concrete encasement into the collection sump, or to vapor escaping from the tank and condensing on the outside of the tank walls. The ground around the tanks has 4 to 7 ft of perched water above the tank bottom. Because the water level in the sump is kept below the tank bottom, the perched water should eliminate leakage of contamination into the soil because leakage through the concrete encasement would be into the sump. Ground water monitoring has not indicated any tank leakage.

Cooling System Leaks

The waste storage tanks are equipped with cooling coils which are supplied with water from a closed-loop cooling system, which, in turn, is cooled by heat exchangers supplied with well water. Cooling water in both systems is monitored continuously for radioactivity. The tanks had twice as many coils installed as required to provide spares in case of coil leaks.

The closed-loop water circulates at pressures above the hydrostatic pressures of the stored wastes, and leakage of a coil results in the loss of closed-loop water to a waste tank and causes a low-level alarm to sound for the closed-loop surge tank. Leaking coils are valved off, and blank flanges are installed to remove the coils from service. On two different occasions, the closed-loop water was found contaminated with about 3 Ci of ^{137}Cs (by diffusion of liquid waste into the residual water in the coil) when valves on the leaking coils were reopened. Most of the cesium was returned to a waste storage tank by flushing the closed-loop system; the remainder was either sent to seepage basins or remained temporarily in the closed-loop cooling system. Subsequently, most of the remaining activity was removed by passing a side stream through a small zeolite bed. In the more than 20 years of operation, 63 of 610 cooling coils have leaked and have been removed from service.

Well water flows through the heat exchangers at a pressure above the pressure of the closed-loop water, and a heat exchanger leak results in the addition of well water to the closed-loop system and causes a high-level alarm to sound for the closed-loop surge tank. The heat exchangers are bypassed temporarily while leaking units are replaced. While the heat exchangers are bypassed, the large volume of aged, relatively cold waste in the tank farm absorbs the heat produced by the fresh waste, so that overall waste temperatures rise only a few degrees. Minor heat exchanger leaks have occurred about twice a year, and have not caused contamination of well water.

Loss of Cooling

Loss of cooling in a waste tank containing fresh high-heat waste, a tank with a maximum rate of heat generation, would cause the temperature of the waste to increase to the boiling point over a period of about a week unless corrective action were taken. The maximum sludge temperature and the maximum supernate temperature for each waste storage tank is recorded daily so that adequate time would be available to identify a cooling deficiency and to restore full cooling or to initiate supplementary cooling to avoid overheating. In addition to a backup cooling water supply, each cooled waste tank is provided with a condenser as a backup for its cooling coils.

On one occasion (December 1956), when the closed-loop cooling system was shut down to tie in cooling coils for new waste storage tanks, air binding in the cooling coils in Tank 12 interrupted cooling. Cooling was restored by purging air from the coils after about 6 days. Loss of cooling in Tank 12 resulted in waste temperatures that approached the boiling point, visible discharge of condensing steam through the vent filter, and release of less than 1 Ci of airborne activity. There was no appreciable spread of contamination beyond the immediate vicinity of the tanks. Operating practices have been revised as described above so that it is highly unlikely that loss of cooling would persist long enough for material in a waste tank to boil.

Releases from Tank Ventilation System

Tank ventilation keeps the concentration of radiolytic hydrogen substantially below the flammability limit. Ventilating air is filtered to remove entrained activity-bearing particles. The filters accumulate radioactivity, and several existing filters now retain an estimated 2 Ci (primarily ^{137}Cs).

Although they are unlikely, there are several ways in which the integrity of the filters could be threatened. Transfer of organic solvent to tanks has occurred on several occasions, and some exposure of filters to decomposition products is to be expected. There is a low but finite probability that a filter could burn and release some of the activity it contained. Not more than one such incident would be expected in 50 years* with some small fraction of the contained radioactivity that is released contributing to doses offsite. Release of the entire maximum filter contents as an aerosol would give a maximum dose of 0.18 mrem to an offsite individual, based on the calculations described below for accidents.

Leak from an Evaporator

The stainless steel evaporators have not leaked, and it is unlikely that they will leak in the future. An inspection of one of them after nine years of service showed no corrosion of the inside of the evaporator shell (the primary containment barrier) although some loss of metal from the outside surface of the stainless steel tubes was visible. If an evaporator should leak, the waste would be contained by the secondary containment barrier, the stainless steel liner of the evaporator cell.

* Probability estimates are discussed at the end of this section.

Leakage of about 40 gal of waste to an evaporator cell would cause a high-level alarm for the cell sump to sound and make it possible to shut down the evaporator and transfer the leaked waste to a storage tank. If leakage from the evaporator continued without corrective action, the excess over 60 gal would overflow through a pipeline to Tank 21 in H Area or accumulate within the evaporator cell in F Area. The cell liners are 11 ft high in F Area and 1.5 ft high with overflow to a waste tank in H Area. They provide secondary containment for 20,000 and 2,700 gal within the liner, respectively, or more than the normal content of an evaporator (1,600 gal). Thus in the event of complete failure of the sump alarms and overflow, waste should not overflow the cell liners.

In the unlikely event that waste penetrated both containment barriers (the evaporator shell and the cell liner), the waste might be contained by the concrete cell structure, or it might become a ground surface spill. A surface spill would cause radiation monitors to alarm and corrective action to be taken. Contaminated soil would be removed to the burial ground. If the spill should reach a storm sewer, the drainage would be automatically diverted to a lined retention basin. No offsite effects are expected from leaks in evaporators.

Evaporator Steam Bundle Leaks

The evaporator steam bundles have leaked on two occasions, one bundle after 9 years of service and another bundle after 8 years of service. In both instances, the leaks were discovered when radioactivity monitors for the segregated cooling water systems alarmed. The contaminated water was diverted to the seepage basins and unlined retention basins. The two incidents combined resulted in the release of 2 Ci of ^{137}Cs to the seepage basins and unlined retention basins. Since these two leaks occurred, lined retention basins have been provided. If future leaks in evaporator steam bundles result in contamination of segregated cooling water, the contaminated water will be diverted to the new lined retention basins, and this should prevent any significant release to plant streams. About 0.01 Ci of ^{137}Cs, at concentrations within guidelines for unrestricted release, could be released to the environment after deionization of the water in the retention basins.

Waste Storage Tank Overflow

Overflow from storage tanks to other storage tanks and to other containment structures such as catch tanks, pump tanks, and diversion boxes is not expected to occur more often than once in 20 years. It is prevented by keeping liquid levels 10 inches or more below overflow levels by means of design, instrumentation, equipment, and procedures.

Waste tank overflow to the ground above the tanks via the risers or to the ground beside the uncooled tanks by flowing over the top of the steel liners is highly unlikely because of the large volumes required. Overflow to the ground above the tanks would require filling of the vapor spaces of the tanks. The volumes in excess of maximum fill volumes amount to 60,000 gallons for Type I tanks, 70,000 gallons for Type II tanks, and over 90,000 gallons for Type III tanks. The volume in excess of maximum fill volume for overflow of the Type IV uncooled tanks exceeds 110,000 gallons. Waste transfer to a tank, at 75 gpm/min, would have to continue for more than 13 hours beyond scheduled termination at maximum fill to amount to 60,000 gallons.

Overflow of a waste storage tank to the ground surface has not occurred in over 20 years of operation. There has been one instance of underground leakage resulting from overfilling of a waste tank; this has been described in an earlier section "Spills During Waste Transfer." An overflow to the ground surface would be similar to a surface spill, which has been considered in the same earlier section. On the other hand, leakage of waste to the soil below grade, although harder to detect, is less hazardous than a surface spill because immediate run-off to flowing streams via the storm sewer system is precluded.

Loss of Tank Ventilation

The waste tanks containing high-heat waste have forced ventilation to prevent the buildup in the vapor space of hydrogen (H_2) from radiolysis and/or corrosion. Extended interruption of this ventilation could allow H_2 to accumulate to concentrations within the flammable range (flammability limit for H_2 in air = 4.1 vol %).

The concentration of H_2 in a waste tank following cessation of ventilation is a function of the specific H_2 evolution rate, the radioactivity content of the tank, and the vapor space volume. In addition, if tank cooling is lost, dissolved H_2 can desorb from the waste solution as the solution warms. The specific H_2 evolution rate has been evaluated on at least three occasions in three different tanks containing high-heat waste. The values were 1, 2, and 6 ft^3 H_2 per hr per million Btu/hr of fission product heat. On the basis of the highest of these figures, and with a full waste tank containing the maximum fission product heat experienced in a waste tank (6×10^6 Btu/hr), the flammability limit of H_2 in air could be formed in about 10 hours. Normally the time required would be 50 hours or more because of a combination of much less heat generation and more vapor space volume.

Proper ventilation blower operation is monitored continuously, and hydrogen concentration is measured weekly. Hydrogen concentration is monitored every few hours when circumstances require extended interruption of forced ventilation. Backup emergency electrical power is provided to the blowers.

ACCIDENTS

This section describes the potential offsite consequences of postulated accidents in the radioactive liquid waste storage facilities in the two tank farms. The categories of accidents that were analyzed include:

- Sabotage, diversion of fissionable materials, and acts of war.
- Spill of radioactive liquid waste during transfer.
- Chemical explosion in a waste tank.
- Chemical explosion in a waste evaporator.
- Nuclear excursion in a waste tank.
- Earthquakes.
- Tornadoes and hurricanes.
- Floods.

Where applicable, an estimate is given for the potential dose commitment at the plant boundary that an offsite individual might receive as a consequence of a postulated accident. Rough estimates are also given of the relative probabilities of those accidents expected to result in offsite doses.

The potential population dose commitment is greatest from postulated accidents that could release ^{137}Cs and/or ^{90}Sr to the Savannah River through storm sewers and Four Mile Creek. These accidents are explosions in a waste tank or an evaporator and spills of high-level liquid waste that is being transported to or within the tank farm. Storm sewer diversion systems were installed in F and H Areas to prevent such releases by diverting contaminated surface drainage to lined retention basins in each area. If some of the released activity should reach the river, the exposure to population groups that use river water for drinking and industrial purposes can be minimized by an offsite warning system and a river monitoring program. Thus, the largest potential hazard from accidental releases to the sewer is to the unlikely individual who might be overlooked by consequence-limiting procedures. Exposure of large population groups is unlikely because corrective measures could be initiated in ample time.

The maximum dose is calculated for a hypothetical individual who withdraws water from the river for drinking purposes during the brief passage of the released activity. The calculated maximum dose is based on a release quantity that could occur only if the diversion system were inoperative at the time of one of the very unlikely accidents postulated for analysis purposes.

Some effects of a large release could persist beyond the time of the postulated accident because of deposition and subsequent slow elution of radionuclides from plant streams and the swamp. The magnitude of any persisting effects and the length of time would depend on the details of the particular release. In all cases, the maximum individual doses would be small, and population doses would be minimized by limiting use of the water and taking other corrective actions based on continuous monitoring of river water, fish, and other wildlife.

Sabotage, Diversion of Fissionable Materials, and Acts of War

The Savannah River Plant has a formally developed program to provide physical security for all operating facilities. Some of the measures used that deter ordinary sabotage are:

- Multiple physical barriers between operating facilities and uncontrolled access areas.
- Personnel access/mobility controls by implementation of carefully developed administrative controls.
- Fixed and mobile guard positions with redundant communications and outside law enforcement/military backup capability.

Acts of sabotage such as bombings of waste tanks or transfer lines have been considered. Such acts are highly unlikely because of the limited access to waste storage facilities and the low potential for any significant effects. Sabotage would not be expected to result in much greater damage than the most extreme process accidents analyzed below. Highly sophisticated sabotage such as delivery of nuclear devices would compare more with nuclear attack, discussed below.

Plutonium and enriched uranium are present in stored wastes in low concentrations, because of unavoidable small losses in fuel processing. However, theft of waste as a method of obtaining material for fission weapons would be highly improbable from the standpoint of technical and economic practicability. Recovery of these materials without exposure to lethal radiation would require the use of complex heavily-shielded facilities of advanced design. Because recovery of these products is the major purpose of the SRP separations plants, only those amounts that cannot be recovered without adding extremely expensive equipment are allowed to be stored with the wastes.

The potential impact of an enemy attack on waste storage has been assessed.[36] The USAEC investigated the vulnerability of radioactive waste storage facilities to nuclear attack using the Savannah River complex as a model. Even with extremely large yields, multi-weapon attacks with reasonable accuracy would be needed for acceptable probabilities of success. A successful attack could release a very high level of long-lived radioactive waste. However, in the sense of near-term infliction of casualties, the radioactivity content of the waste is of the same range of magnitude as to be expected from high-yield weapons. If the goal of the enemy is to inflict casualties, a direct attack on urban areas would probably produce more casualties because the SRP waste storage facilities are sited in a relatively remote area.

Spill During Liquid Waste Transfer

A maximum sustained spill rate of 100 gal/min of fresh high-heat waste (HHW) is hypothesized for the purposes of analysis. One hundred gal/min is the maximum pumping rate (at normal pressure) of the steam jets used to transfer fresh HHW from the canyon buildings to the waste tanks. This waste contains the highest radioactivity per unit volume that could be involved in a spill because it represents the waste with the minimum cooling time.

Many of the radioactive isotopes would be in the sludge portion of the waste, which consists mainly of colloidal particles of $Fe(OH)_2$ and MnO_2. In the waste tanks, the sludge is a settled layer at the bottom of the tanks; however, the sludge contained in the fresh HHW being transferred from the canyon would be suspended in the supernate. Therefore, the sludge is initially assumed to be uniformly distributed throughout the fresh HHW waste postulated to be spilled. The ^{90}Sr in the sludge provides most of the calculated dose on this basis.

It is assessed that the maximum spill rate could continue for no more than 5 minutes before operating personnel handling the waste transfer would take corrective action to stop the transfer in response to monitor indications and alarms. No more than 10% of the released waste would reach the river directly because of absorption of the liquid in the ground near the spill and deposition and ion exchange in the storm sewers, Four Mile Creek, and the swamp. Following large spills that might release radioactive materials to the river, a health physics team assesses the effects of the release by sampling river water and following high-concentration pulses downstream. Any waste remaining dissolved in leakage that reaches the sewers and Four Mile Creek would reach the river about 24 hours after the event, and after mixing with the river water its maximum concentration would persist at any one location for no more than about 5 minutes.

The calculated concentration of each radioactive isotope in the Savannah River for a 100-gal/min spill and the transport conditions just described are given in Table III-36. The 70-year dose commitment for one day's ingestion was calculated to be 0.3 rem whole body, 6.8 rem to the bone, and 22 rem to the lower large intestine. For comparison, the emergency whole body dose guideline for the evaluation of reactors is 25 rem,[37] and the emergency dose guideline for new plutonium facilities is 150 rem bone and 75 rem lower large intestine.[38] The assumed waste composition is that of fresh Purex HHW, from processing natural or depleted uranium, which contains at least as much of each fission product as fresh HHW from enriched uranium processing.

Chemical Explosion in a Waste Tank

The postulated chemical explosion could be caused by the reaction of radiolytically formed hydrogen with oxygen in the vapor space of a waste tank initiated by some unidentified spark source. With no ventilation,* the H_2 concentration in the vapor space over fresh HHW would be about 20% by volume.[39] An explosion in a 1.3-million-gallon tank one-half full of gas at one atmosphere (the tank is vented) containing 20% H_2 and excess O_2 could release a maximum of about 10^9 calories of energy.** It is estimated that

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* The hydrogen concentration in the vapor space of the waste tanks is maintained below the flammability limit by constant ventilation with air.

** Relatively small concentrations of other flammable materials may also be present in the gas phase (kerosene, butanol, etc.); however, explosion of the stoichiometric mixture of H_2 and O_2 postulated here represents the greatest energy release.

this could conceivably rupture the primary steel tank and cause the roof to collapse. Escape of waste liquid into the ground surrounding a tank is discussed qualitatively in the discussion of earthquakes below.

Atmospheric Dispersion

The concentration of radioactive material at the plant boundary resulting from an accident depends on many variables. The meteorological conditions at the time of the accident determine the amount of dispersion and dilution of the material before it reaches the plant boundary. The direction of travel from the release point to the boundary can be variable with time if the release takes place over a time period greater than several minutes. Other parameters associated with the physical properties of the radioactive material, such as gravitational settling velocity as a function of particle size, have a significant influence on the estimated concentrations at the plant boundary. Assumed release height based on the kind of accident also influences estimated dispersion.

The consequences of an accident depend on conditions prevailing when the accident occurs. To cover the entire spectrum of meteorological possibilities, a two-year data base of measured meteorology[29] is used to determine atmospheric dispersion properties. Consequences are determined according to procedures described in Appendix F for accident calculations. The consequences of accidents involving atmospheric dispersion are given for the 95th percentile, i.e., the magnitude that would not be exceeded for 95% of the meteorological conditions in the two-year data base.

The material properties of the radioactive effluent that affect dispersion cannot be described in precise quantitative terms because of the broad spectrum of possible properties. Although it is recognized that particle size, density, settling velocity, mass fractions in particle size grouping, impaction depletion, etc., influence concentration estimates, some simplifying assumptions are made that provide pessimistic estimates (tend to overestimate the concentration or dose). The basic assumption is that once the source term is defined, the material is released at ground level and dispersed under the influence of meteorological variables only. This is equivalent to maximizing the concentration estimates for all releases regardless of material properties.

The dilution factor at the nearest plant boundary for the 95th percentile is estimated to be 3.2×10^{-6} sec/m^3. For an active man, the breathing rate is 3.47×10^{-4} m^3/sec. Therefore, the fraction of the released material that can be inhaled is

1.1×10^{-9} at the 95th percentile of the meteorological conditions assuming an instantaneous release.

Particle Size and Quantity of Spray

The particles that would provide the greatest hazard in the event of an explosion would be less than 10 μm in diameter because larger particles do not penetrate an individual's respiratory system.[40,41] The maximum quantity of <10-μm spray produced by collapse of a waste tank roof is estimated by assuming that the supernate is converted to spray with the typical particle size distribution produced by small-diameter spray nozzles, so that ~0.01% (200 ℓ) is converted to <10-μm spray.[42]

Inhaled Intake after Explosion

Table III-37 gives the calculated offsite intakes and doses based on the preceding estimates of spray quantity and atmospheric dispersion.

The concentrations of various isotopes in the supernate were based on expected waste tank inventories. Some of the isotopes in the settled sludges in the tank were assumed to be present in the supernate as colloidal particles of sludge suspended by thermal currents. The concentrations given in Table III-37 for waste tank supernate are lower than the concentrations given in Table III-36 for a fresh HHW spill due mainly to the following factors: the sludge is settled in the waste tanks and not suspended in the supernate, the average age of this waste is greater than that of fresh HHW, and the high heat wastes have been mixed with other waste streams of lower activity in the waste tanks. The greatest inhalation hazards for a hypothetical explosion that ejects supernate spray from the tank are from ^{144}Ce-^{144}Pr, ^{137}Cs, ^{90}Sr, and ^{238}Pu (treating this activity as soluble after inhalation).

Although collapse of the tank roof cannot be ruled out as a consequence of an explosion, it is much more likely that the consequences of the explosion would be that only the plugs would be blown out and/or the filters would be ruptured. Some fine spray might be produced by splashes in the supernate. It is estimated that under these conditions 20 liters of supernate in the form of <10 μm particles might be produced and leave the tanks with the hot gases. In this case the estimates of Table III-37, which are already well below emergency dose values, would be reduced by a factor of 10.

Spill Resulting from an Explosion

Waste that was expelled from the tank but did not become airborne would be in the category of a spill. If the potential energy released by the postulated collapse of the tank roof were converted with 50% efficiency into overcoming gravitational forces in lifting waste out of the tank, approximately one-fourth (~150,000 gallons) of the supernate could be lifted to ground level. Essentially none of the sludge layer would be removed because it would be necessary first to mix the sludge into the upper layers of the supernate, and the energy released by total collapse of the roof would be sufficient to mix only a small fraction of the sludge into the supernate.

Even if the postulated 150,000 gallons of supernate were to be lifted to ground level, most of it would fall back into the tank cavity. It is assumed that 10% of the waste supernate lifted from the tank does not fall back into the tank but reaches the ground surface. It is further assumed that no more than 10% of this released waste would reach the river directly because of absorption of the liquid in the ground near the tank and deposition and ion exchange in the storm sewers, Four Mile Creek, and the swamp. Table III-38 gives the concentration of SRP waste tank supernate in the Savannah River, assuming some of the sludge is entrained in the supernate. The ^{90}Sr and the ^{137}Cs provide most of the calculated dose on this basis.

For conditions that give a minimum degree of longitudinal dispersion in Four Mile Creek (fully turbulent flow), the concentration level at any one location would be at its maximum for no more than about 15 minutes and would arrive in the Savannah River about 24 hours after the event. Most of the waste flowing directly to the river would pass a point in about one-half hour.

Concentrations in the Savannah River immediately downstream from Four Mile Creek were calculated for this postulated spill, and results are given in Table III-38. The dose commitment from one day's ingestion of water with the peak concentration of ^{90}Sr and ^{137}Cs would be approximately 3.9 rem whole body, 1.0 rem to the bone, and 4.8 rem to the lower large intestine. Typical emergency dose guidelines are 25 rem whole body,[37] 150 rem to the bone, and 75 rem to the lower large intestine.[38] Adequate time would be available to initiate corrective measures and warnings to prevent consumption by downstream users of the river water that might have these concentrations.

Chemical Explosion in a Waste Evaporator

Inhaled Intake

Potentially explosive materials that might be present in the waste evaporator include silver nitride, organics in contact with sodium nitrate, and possible other unstable inorganic compounds. One potential consequence of an explosion in an evaporator is the dispersal of fine spray into the atmosphere. The normal volume in an evaporator would be ∿1600 gallons, and the ^{137}Cs concentration is estimated to be as high as ∿45 Ci/gal or 12 Ci/l. The maximum quantity of <10-μm spray produced by a postulated explosion in a waste evaporator is estimated by assuming that the entire contents of the evaporator is converted to spray with the typical particle size distribution produced by small-diameter spray nozzles, so that ∿0.01% (∿0.15 gal) is converted to <10 μm spray.[42] A total of ∿7 Ci of ^{137}Cs would be present in this spray. Based on meteorological data at Savannah River, the probability is 95% that the release would cause a dose commitment of less than 1 mrem, which is less than 0.004% of the emergency guideline whole body dose.

Spill

An explosion or other major accident in a waste evaporator could conceivably release the entire contents of the evaporator (∿1600 gallons). It is assumed that 10% of the radioactivity in this spill could reach the river via the storm sewers and Four Mile Creek if it were not diverted to the retention basin by installed automatic equipment. Most of the waste would pass a point in the Savannah River in about 15 minutes some 24 hours after entering Four Mile Creek. The dose commitment from one day's ingestion of water with the peak concentration of ^{137}Cs would be about 1.9 rem whole body. Adequate time would be available to take corrective action and to initiate warnings to prevent consumption by downstream users of river water that might have these concentrations.

Nuclear Excursion in a Waste Tank

For a waste tank containing the highest concentration of ^{239}Pu in the sludge layer, calculations show that the ^{239}Pu would have to be concentrated by at least 100 times into a spherical volume (300 times if neutron absorbers known to be present are considered) to achieve criticality. For the same conditions, the ^{235}U in a tank would have to be concentrated by at least 10 times (30 times if neutron absorbers are considered) to achieve criticality. Isotopic measurements and measurements of nuclear reactivity made in 1973 in the tank containing the most ^{239}Pu and ^{235}U confirmed that the concentrations were all less than one-tenth the level of concern. Because there is no known mechanism to concentrate and rearrange the ^{239}Pu or the ^{235}U in this manner, this accident is not discussed further.

Earthquakes

Seismic conditions on and around the SRP site are discussed in Section II.C. Three centuries of available records show that only shocks of less than intensity VII on the Modified Mercalli Scale (MM) have been experienced at the SRP site. The largest was the 1886 quake centered near Charleston, S.C. Studies of the geology of the region, the geologic formations underlying the area, and historic tectonic activity show that the SRP site is a relatively stable region, and that there is no geological evidence for any increase in seismic activity. The area is one where there is a low probability that light-to-moderate ground shaking will occur. Shocks in the low range of intensity (I to III MM) may be expected in this area at a frequency of about one per five to ten years. However, seismometers installed in SRP reactor buildings are set at 0.2% of the acceleration of gravity (0.002 g) (about intensity II) and have not alarmed during operation over a 20-year period.

Earthquake criteria have been developed for the Savannah River Plant, and a design basis earthquake (DBE) has been specified. All new waste facilities are designed and constructed to maintain functional integrity in an earthquake producing ground accelerations at the site of 20% of the acceleration of gravity (0.2 g) at zero period. The criteria used in the design of existing facilities did not include a specification for resistance to earthquakes. Subsequently, a study of the effects of earthquakes on the existing waste storage tanks was undertaken. This study included both a geophysical program to accumulate data on the soil adjacent to and beneath the tanks and an analysis of the stresses imposed on each type of tank by the dynamic loading of the earthquake. It was concluded that: 1) the primary waste tanks would not be damaged by the levels of stress produced by the DBE provided fill limits are not exceeded, 2) the secondary metal structures would not be damaged, and 3) moderate cracking of the concrete structures could occur. The analysis was based on the specified original design and construction and did not consider any effects of changes in the tank or tank structure since original construction.

The effects of time and use that could be important in evaluating seismic resistance are listed below and are described further in succeeding sections.

- Structural weakening caused by general thinning of the tank wall or bottom by corrosion.
- Higher than design stresses caused by uneven settling of tank support structures.
- Effects of extra stress on a single crack or band of cracks.
- Cracks in the concrete portion of the secondary barrier of double-wall tanks with less than full height secondary metal walls.

Effect of General Thinning by Corrosion

A large number of thickness measurements made on all of the older (Types I and II) waste tanks in the past ten years indicated no decrease in wall plate thickness. Some of the tanks measured have been in service for 20 years. Bottom thickness measurements in three uncooled (Type IV) tanks also showed no decrease in thickness.

Effect of Uneven Settlement

Data for evaluating uneven settling have been accumulated semiannually on selected waste tanks by comparison of elevations to standard bench marks and on some tanks by settlement gages. No uneven settling has been found. The tanks were built on undisturbed soil of good bearing characteristics.

Effect of Earthquake-Induced Stress on Cracks

Five of the waste storage tanks (11, 12, 14, 15, and 16) have observable stress corrosion cracks (indicated by external salt deposits on the tank walls) normal to the girth seam welds, and on two of these tanks (15 and 16), cracks normal to the vertical seam welds have been observed. One area of cracking in Tank 16 was studied in detail in 1962, and at that time the longest lengths of cracks were 4 to 6 inches. Examinations when this tank was taken out of service in 1972 showed that the cracks had not lengthened. Such cracks could serve as initiation sites for increased leakage or mechanical fracture in the highly stressed conditions that a severe earthquake might produce. Crack propagation could be either ductile or brittle depending on the actual temperature of the tank wall relative to its nil-ductility-transition (NDT) temperature.

Analyses based on current loading limitations indicate that the stress limit for ductile tearing at crack tips would not be exceeded during a design basis earthquake.

Loading limitations on existing tanks are reviewed periodically based on tank condition as determined by the tank inspection program and on the measured density of the various types of waste (sludge, salt, and supernate). Means of controlling tank wall temperatures were investigated to minimize the probability of brittle crack propagation. The controls of the annulus ventilation intake air heaters of the double-wall tanks will be modified by the winter of 1976-1977 to preclude the possibility of localized regions of the primary tank walls becoming colder than 21°C.

Failure of a primary waste tank and subsequent seepage of waste through the secondary barrier (concrete portion) to the ground would not cause offsite effects for many years. Even if the waste were not recovered, the rate of ground water movement would provide estimated decay times of 200 to 400 years for the fastest moving radionuclide before it reached existing streams. The long-lived radionuclides of most concern would be expected to be held strongly by filtration and ion exchange with the soil for decay times of hundreds of thousands of years if climatic conditions and hydrology remain unchanged.[35]

Effect of Earthquake-Induced Stresses on the Secondary Barrier (concrete portion)

The effect of a DBE on the composite metal pan - concrete wall secondary of Tanks 1 through 16, on the metal secondary and concrete encasement of Tanks 29 through 34, and on the prestressed concrete shell and dome of Tanks 17 through 24 were considered in the seismic analysis described on page III-111. The study showed that moderate cracking of the concrete structures for these tanks could be expected, but that the metal wall (or five-foot-high pan for Tanks 1 through 16) and bottoms would not be breached.

Tornadoes and Hurricanes

Historical data indicate that any individual place at SRP may suffer a direct hit by a tornado of undefined intensity about once every 6700 years. Construction specifications for existing SRP waste storage facilities preceded the establishment of criteria for protection against tornadoes, but all new waste storage facilities will be designed to maintain functional integrity in a tornado or wind storm with the following characteristics:[38]

- 290 mph tangential velocity.
- 70 mph transverse velocity.
- Average 3-psi ambient pressure drop in 3 seconds.
- Wind-generated missiles.

A re-evaluation of tornado resistance of the present waste tanks leads to the following conclusions:

- Small high-velocity missiles and massive low-velocity missiles could damage above-ground structures (e.g., ventilation equipment) and disrupt electrical services. Activity release from the waste tank would be minor.
- The primary liner of any double-wall tank (1 through 16, or 29 through 34) will deform below the top knuckle if the annulus pressure exceeds the internal pressure by some specific amount, which ranges from 1.3 to 2.7 psi. Pressure differentials in that range are unlikely, inasmuch as the area of the annulus vent is about nine times that of the tank vent, and damage would probably increase the areas of the vents. A precise study of the probable venting relationship changes has not been made.
- It is possible that small lightweight plugs would be lifted from the tank and tank annuli and transferred into missiles. It was concluded that waste would not be entrained or aspirated from the tanks because the area of the openings exposed to liquid is relatively small, and the distance from the ground surface to the liquid surface is large.
- The center plug of one of the single-wall tanks in F Area (17 through 20) might be lifted and displaced, with the venting area increased manyfold and, therefore, with a greater likelihood of entrainment. The quantity of radioactivity, primarily ^{137}Cs, that might be released with the loss of a plug was estimated to be comparable to the 2 Ci released from the burning of an exhaust filter. The plugs have since been anchored.

The resistance of the waste farm evaporators to a similar tornado has not been studied in detail. The evaporator cell covers are similar to the larger plugs in the waste tanks and could be displaced with possible resultant damage to evaporator piping. The stainless-steel-lined cell should contain adequately any spill until transfer from the cell sump to a waste tank could be initiated. Some airborne radioactivity would occur; the volume of waste entrained is judged to be similar to that from loss of a center plug from Tanks 17-20.

The likelihood of release of radioactivity from waste handling and storage equipment as a result of hurricane-generated winds is much lower than that for a tornado. The maximum recorded wind speed of 75 mph for the plantsite occurred during passage of hurricane Gracie in 1959, and no significant damage occurred on the plant. This wind speed is about the maximum expected because of the inland location of the plant.

Floods

Release of activity by large-scale flooding of either of the waste tank areas is improbable. Both areas are on high ground, and the nearest streams are in broad valleys at least 50 ft lower in elevation than the tanks. The highest postulated flood level of the Savannah River is 141 ft above mean sea level, compared to a level of 84 ft at a normal flow of 10,000 cfs. This flood level would result from a combination of a large local storm and failure of the Jocassee Dam at the headwaters of the Savannah River system with subsequent overtopping of all the downstream dams.[32] Because the elevation of the tank farm areas is a minimum of 270 ft above mean sea level and the normal water table in the tank farm areas is a minimum of 230 ft above mean sea level, such a severe flood would have no significant effect on these areas.

The local basins in which some waste tanks are located could be flooded by rain water falling on and draining into the area only if the storm sewers were completely plugged. It is highly unlikely that the water level would reach the tops of the access risers on the tanks without observation and corrective measures being taken. The areas are under surveillance at least once every 8 hours. The risers are sealed with concrete plugs, so the only consequences of such local flooding would be a moderate leakage of rainwater into the tanks. Even in the extreme case where the high flood water level existed long enough to completely fill a tank through riser inleakage, relatively little radioactivity would be displaced from the tank because the encroaching water would float on top of the much heavier waste solution.

Offsite Risk Estimates

Offsite risks involved in the management of radioactive liquid wastes at the Savannah River Plant are a function of the probabilities of potential abnormal conditions and accidents as well as the consequences of these events. In this section, estimates of the relative probabilities of the various incidents discussed in the preceding sections are made in order to place the risks in proper perspective. The probabilities are based on the best judgment of experienced technical personnel at SRP and SRL.

Summary of Abnormal Operations and Accidents

There are three potential release paths for radioactive liquid wastes at the Savannah River Plant: 1) into the ground, 2) over the surface of the ground, and 3) into the atmosphere. The most significant paths from the point of view of safety are surface spills and atmospheric releases, because under extremely unfavorable conditions releases of materials by these paths could potentially result in the intake of toxic materials either by ingestion or inhalation (Figure III-17). The particular paths with the greatest potential for offsite uptake are shown as the heavy-bordered circles in Figure III-17.

The abnormal operations and accidents analyzed in this report are summarized in Tables III-39 and III-40 according to the path involved. In addition to the quantity released to that path, the estimated maximum potential offsite dose and the estimated probability of the event are given. Bases for the probability estimates are given below.

Probability Estimates

Analyses of the probability of accidents to the waste storage systems are based on pessimistic assumptions because actual experience and data are not available. The probabilities are estimated in order to provide perspective on the relative significance of the postulated accidents and abnormal events.

Surface Spills

Abnormal Conditions. The probabilities of the smaller surface spills that occur during abnormal conditions (Incidents 1 to 4 in Table III-39) are based on experience. Thus, if such an incident has occurred once during 20 years of operation, the probability per year is taken to be 0.05. Although the exact incident would not be expected to recur at such a frequency, it is assumed that a similar incident could occur at this frequency and release similar quantities of activity.

Evaporator Explosion. Pessimistic estimates of the probability of an explosion in an evaporator sufficient to rupture the evaporator varied from approximately 10^{-3} per year to 2×10^{-2} per year. The explosion summarized as Incident 5 in Table III-39 would be much less probable because it requires that the explosion not only rupture the evaporator but also the reinforced-concrete structure in which it is housed. The probability of an explosion of this magnitude is taken to be 1% of the probability of the explosion sufficient only to rupture the evaporator, giving a probability range for Incident 5 of 10^{-5} to 2×10^{-4} per year.

Waste Tank Explosion. A hydrogen explosion in a waste tank requires the successive failure of several equipment or procedural safeguards:

- Failure of tank ventilation system.
- Failure of pressure alarm to detect ventilation failure or failure of operating personnel to heed the warning.
- Spark initiation in tank after explosive gases have been generated in the tank.
- Failure of procedural safeguards (in routine check of blower operation, routine measurement of hydrogen composition in gas space of waste tank, etc.) to detect and correct ventilation failure.

Based on estimates of the individual probabilities of these conditions, a hydrogen explosion is estimated to have a probability of approximately 1×10^{-3} per year.

The waste tank explosion postulated in Incident 6 (Table III-39) involves failure and collapse of the tank roof. It is estimated that one tank explosion in 10 would result in such an extensive accident. The probability of the waste tank explosion postulated for Incident 6 is therefore about 10^{-4} per year.

HHW Spill. The probability of a 5-minute HHW spill including 1000 Ci of ^{90}Sr is estimated to be no more than 10% as great as the probability of the supernate spill described previously (Incident 4). The probability of Incident 7 is then estimated to be $(0.1) \times (0.05) = 0.005$ per year.

Atmospheric Releases

Ventilation System Release. The probability of a release due to overheating (Incident 8 in Table III-40) is based on one such incident in 20 years. A probability of 0.02 per year (once in 50 years) is estimated for a release of the contents of the filter (Incident 9).

Evaporator Explosion. The probability of an evaporator explosion sufficient to release the amount of spray considered in Incident 10 is estimated to be approximately 10% of the probability of an explosion sufficient only to damage the evaporator. The probability of Incident 10 is then estimated to be 10^{-4} to 2×10^{-3} per year. This probability estimate is 10 times higher than that for the postulated accident that would release the entire contents as a ground surface spill (Incident 5). In that case, additional damage to the concrete building housing the evaporator would be required.

Waste Tank Explosion. The probability of a hydrogen explosion was estimated previously at 10^{-3} per year, and this probability is assumed for the explosion postulated in Incident 11 (plugs lifted and filter ruptured). Incident 12 involves the explosion in which the roof collapses. The probability was estimated previously at 10^{-4} per year.

Further Considerations

The potential hazard due to ingestion of untreated river water during an accident appears to be greater than the potential hazard due to inhalation. However, it should be emphasized that the uptakes postulated for both paths assume that an individual is present at the plant boundary and, in the case of uptake from the river, it is further assumed that the individual drinks untreated water drawn from the river at the time when the peak concentration level passes. The peak concentration levels in the river that were estimated for the postulated spills do not persist for a period of more than about 15 minutes, and high concentration levels only occur for sudden large releases combined with failure of the storm sewer diversion system. Thus, the probability of an individual actually receiving uptakes as high as were postulated is much lower than the probability of the incident occurring.