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Tank 241-A-105 Leak Assessment

Prepared for the U.S. Department of Energy
Office of Environmental Restoration
and Waste Management

Westinghouse
Hanford Company Richland, Washington

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

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PREFACE

On April 27, 1989 the Department of Energy, Richland Operations Office (DOE-RL) requested Westinghouse Hanford Company (WHC) to conduct a review of estimated leak volumes for the single-shell tanks (ref. 8901832B DOE-RL letter, "Single-Shell Tank Leak Volumes" G.J. Bracken to President, WHC).

Subsequently, WHC undertook a comprehensive review of leaks from the single-shell tanks located on the Hanford Site. On September 28, 1990, Mr. Roger Stanley of the State of Washington, Department of Ecology issued a letter to DOE-RL raising specific concerns about the volume of cooling water added to waste tank 241-A-105 and potential leakage of waste from this tank.

As a result of DOE-RL and Ecology inquiry, in January, 1991, WHC contracted with Ebasco Services Inc. to provide an independent assessment of the volume and radioactive content of the effluent that leaked from waste tank 241-A-105. Ebasco was directed to review all previous leak studies pertaining to the tank with respect to validity of assumptions and quality of data. Ebasco was further directed to seek out all new data available on this tank and apply this data to develop an updated leakage assessment. The following study is the result of an exhaustive and lengthy literature search and a careful engineering analysis of the results of that search.

TANK 241-A-105
LEAK ASSESSMENT

June 7, 1991

Submitted to
WESTINGHOUSE HANFORD COMPANY
Task Order No. E-91-10 of Order MLW-SVV-037106

Prepared by
EBASCO SERVICES INCORPORATED
Richland, Washington

DISCLAIMER

EXECUTIVE SUMMARY

Tank 241-A-105 is one of 149 single shell tanks constructed at Hanford to contain and store highly radioactive wastes originating from the processing of spent nuclear reactor fuel. Records indicate that the tank was breached in 1965, but was used to contain liquid waste until August 1968. Following sluicing to remove the bulk of the settled waste sludge, water was sprinkled on top of the residual sludge for eight years to prevent overheating as a result of the thermal decay of radioisotopes contained within the sludge. Since 1978 cooling of the tank has been accomplished by drawing outside air through the tank vapor space and exhausting it back to the atmosphere following filtration.

Radiation detection and temperature monitoring devices installed beneath the tank indicate that several episodes of leakage of waste from the tank have occurred. Previous estimates of water leaking from the tank have ranged from 5,000 gallons to 960,000 gallons. The aim of this study was to evaluate the previous estimates and reanalyze the data to provide a more accurate estimate of leakage from the tank.

The principal conclusions of this study are as follows:

1. Earlier investigators estimated leakage prior to August 1968 at 5,000 to 15,000 gallons. Their estimate appears reasonable.

2. Leakage while the tank was being sluiced (8/68 - 11/70) probably exceeded 5,000 gallons, but probably did not exceed 30,000 gallons. Insufficient data are available to be more precise.

3. Cooling water added to the tank during the sprinkling phase (11/70 - 12/78) was approximately 610,000 gallons. Sufficient heat was generated in the tank to evaporate most, and perhaps nearly all, of this water. Although some activity was seen in the radiation laterals under the tank, no evidence was found of significant leakage of radionuclides during this period, compared with the previous periods.

4. Radionuclides escaping into the soil under the tank cannot be estimated directly because of many uncertainties. Based on a range of leakage from 10,000 to 45,000 gallons, assumed compositions, and decayed to 1/1/91, radioactivity under the tank is expected to be in the range of 85,000 - 760,000 curies. Of this, 99.9% is from Cs-137, 0.1% from Sr-90, the same ratio of these radionuclides that existed in the waste supernate. We assume no sludge leaked from the tank.

To judge the extent of leakage, the writers reviewed the contents of 89 boxes of documents from the Federal Records Center in Seattle, Washington. Included in these boxes were the original logs of radiation probe traverses through pipe laterals installed in a horizontal plane 10 feet below the tank. The measured radiation peaks were nearly all located directly below the perimeter of the tank and, except in rare cases, they showed no tendency to spread horizontally. Had the leaks been large, and backed up by the static pressure of a liquid head, horizontal spreading would have been observed. Moreover, the maximum radiation readings detected are a very small fraction of the radiation reading in the tank. This is the basis for the conclusion that the rate of leakage and, most likely, the quantity leaked, was small.

Archival records provided a basis for estimating the amount of water added to the tank between 1971 and 1978. Data on heat produced by the sludge were also evaluated and corrected for radioactive decay. The heat required to evaporate the water added to the tank was determined and compared to the heat generated by the sludge. The heat generated in the sludge agrees closely with the amount of heat required to evaporate all the water added to the tank. Hence, the conclusion that nearly all the water was evaporated.

No evidence was found of water intrusions from sources not recorded in the operator's logs.

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TANK 241-A-105 LEAK ASSESSMENT

1.0 INTRODUCTION

This report has been prepared by Ebasco Services Incorporated (Ebasco) as part of WHC Task Order MLW-SVV-037106. The work was performed under Task E-91-10, Environmental/Safety Evaluation of Waste Tank Historical Data, Subtask Tank 241-A-105 (Tank 105-A) Leak Assessment. The intent of the work was to evaluate previous leak estimates for Tank 105-A and to determine if these are accurate based on all available information. Since these estimates ranged from 5,000 gallons to 960,000 gallons, a better estimate is needed to determine what actually took place and to provide a firmer basis for future remediation planning. During the preparation of this report, Ebasco reviewed the contents of 89 boxes of documents from the Federal Records Center in Seattle, Washington. More than fifty documents from the archival boxes and other sources were read and evaluated. These documents are identified in the Bibliography. Principal sources used in the evaluation are the documents listed in Section 7.0, References and Comments.

Tank 105-A is one of 149 single-shell tanks used for storage of highly radioactive waste at the Hanford Site in Washington State. The waste originated from the processing of spent nuclear reactor fuel to recover plutonium for defense purposes.

Tank 105-A was constructed in the early 1950's as one of six one-millon-gallon capacity tanks in Tank Farm A (see Figure 1-1). The tank is constructed of reinforced concrete, with a steel liner on the bottom and up the vertical sides. The footings of the tank are approximately 55 feet below grade. Four temperature laterals (horizontal pipes) are under the tank, located six inches below the footings and about two feet below the concrete tank bottom. There are also three radiation leak detection laterals located approximately 10 feet below the tank bottom, and a number of vertical dry wells in close proximity to the tank; these were added after the tanks were built. Details are shown in Figures 1-2 and 1-3.

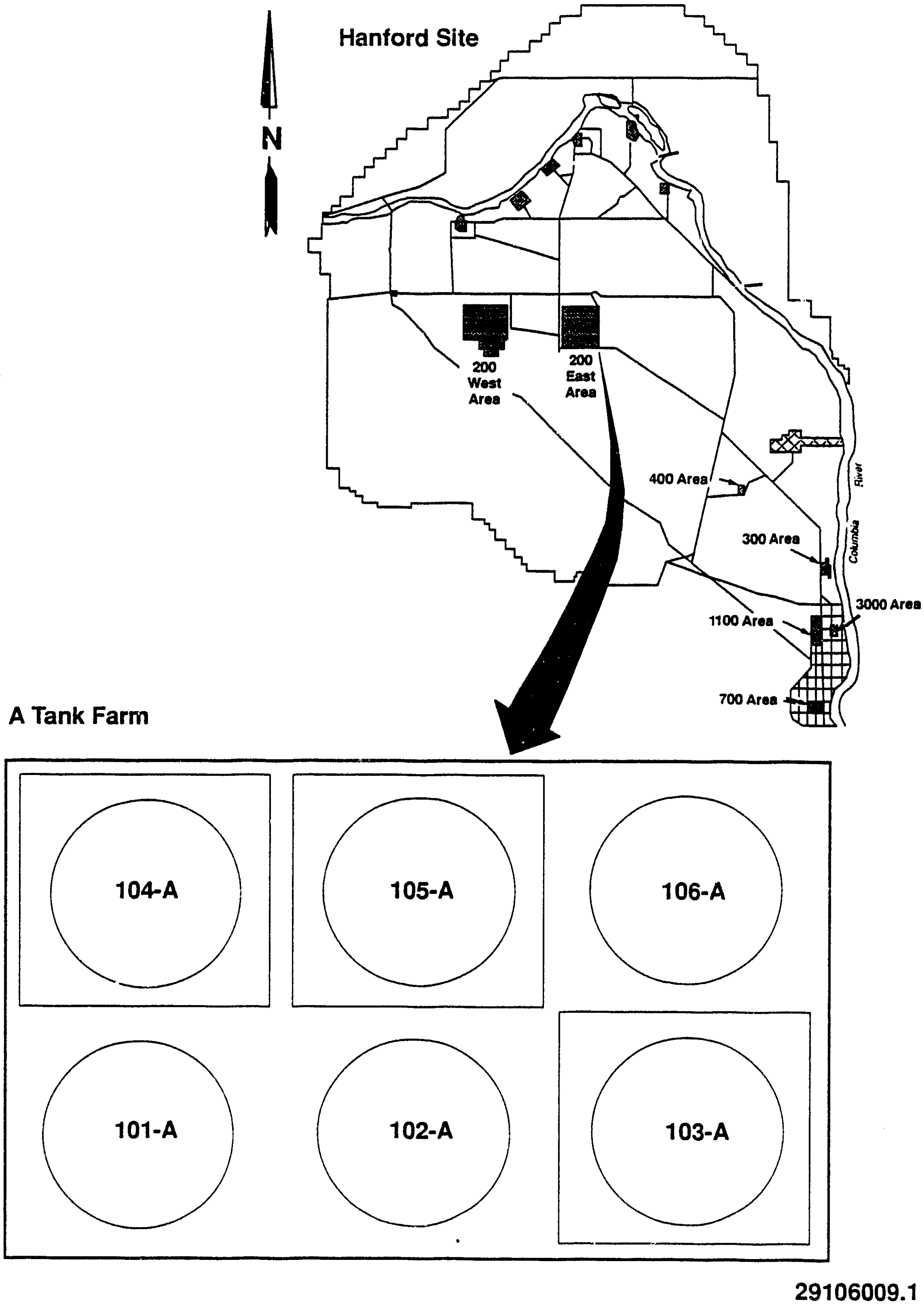
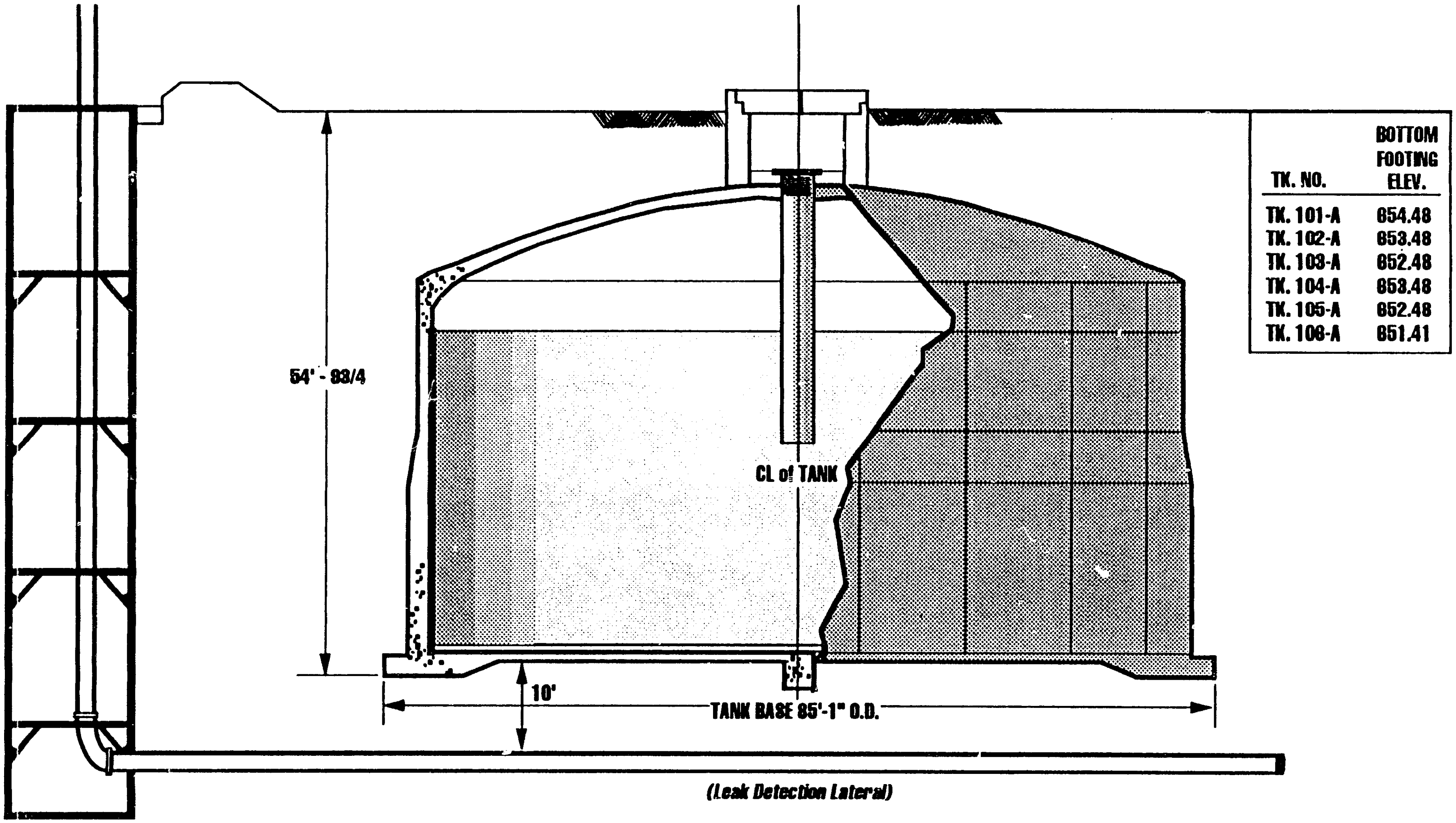


Figure 1-1. Location of Tank Farm 241-A



TK. NO.	BOTTOM FOOTING ELEV.
TK. 101-A	654.48
TK. 102-A	653.48
TK. 103-A	652.48
TK. 104-A	653.48
TK. 105-A	652.48
TK. 106-A	651.41

Figure 1-2. Typical 241-A Tank Elevation

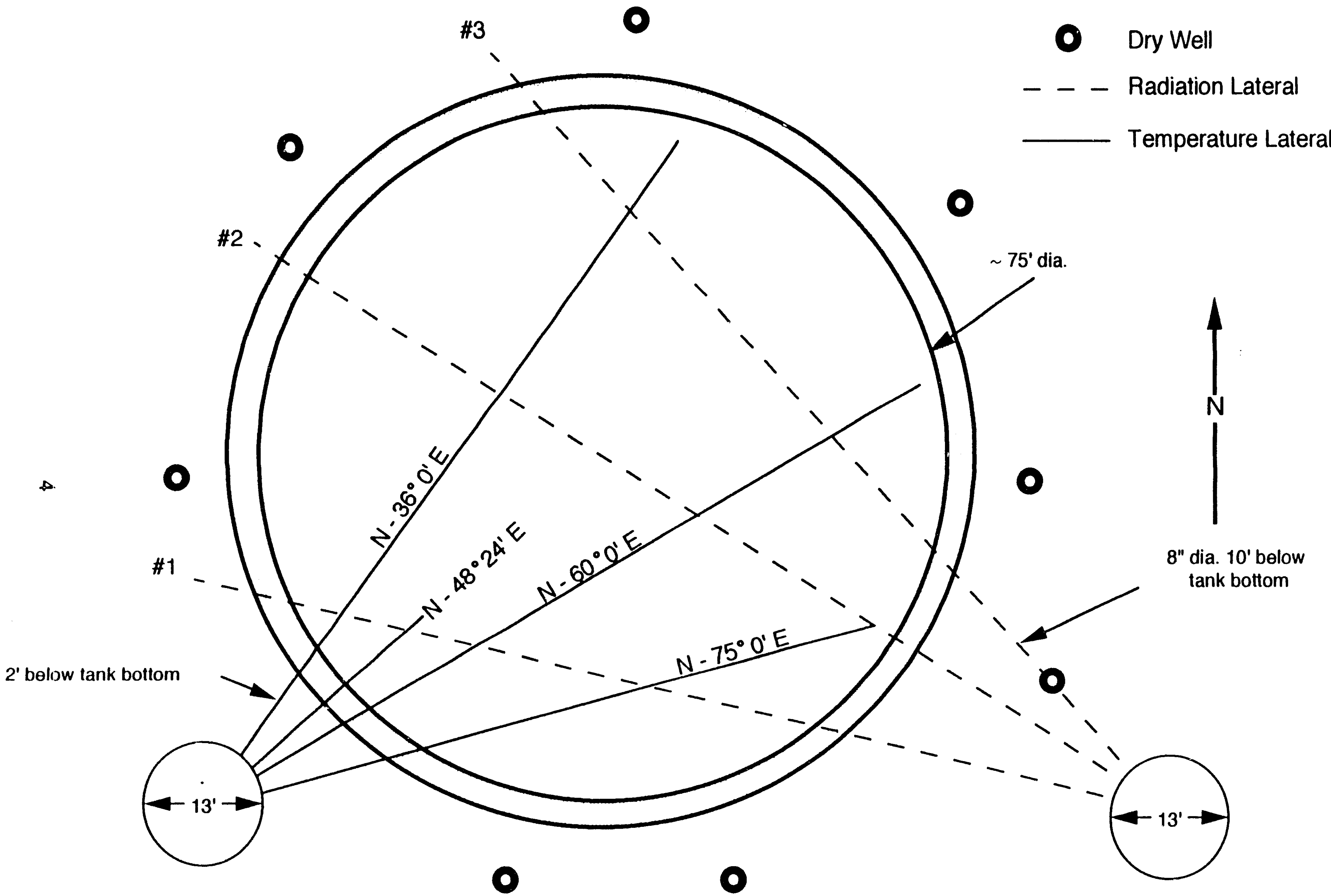


Figure 1-3 . External Features of Tank 241-A-105
(not to scale)

Tank 105-A was selected for the first of a series of leak evaluations because it was the source of major safety concerns in the past and because large quantities of cooling water were added to the tank after it was established that the tank had leaked. Tank 105-A is unique considering that it released a large amount of steam during a brief period of instability, it has an 80,000 gallon void under a bulge in the mild steel liner which is also ripped open, it was the subject of safety evaluations addressing possible sludge overheating and hydrogen build up, and it had a vent hole chemically milled in the top of the bulged liner bottom to relieve a hypothetical hydrogen accumulation under the bulge.

The evaluation of leakage from Tank 105-A was divided into four time periods consisting of operations (waste storage), removal of waste (sluicing), temperature stabilization of residual waste (cooling water additions), and air cooling. Appendix 8.1 provides a chronology of Tank 105-A activities from 1955 to the present time.

This report analyzes the processes that have been occurring inside Tank 105-A from the point of view of a physical chemist or chemical engineer. The heat balance in the tank has been examined, and conclusions formed as to the likely amount of leakage.

Once a fluid has leaked from the tank, other processes will come into play in the affected area. At least four potentials exist to provide driving forces for these processes. Long time periods are typically available to allow these potentials to effect substantial changes. These potentials are:

1. Gravity
2. Radioactive decay
3. Temperature gradients
4. Transpiration of air

Evaluating the effects of these potentials, and predicting the fate of the material which has escaped from the tank, are outside the scope of this report. However, as an aid to understanding and evaluating the observations recorded, a number of factors influencing the transport of liquid through the soil under the tank have been investigated. (Ref. 45, 46)

Well drilling logs (Ref. 46) indicate that the sediments underlying Tank 105-A are highly conductive. That is, a slow leak of clear liquid can percolate downward through the sediments with little horizontal spreading. A flow of this type, directly between the radiation laterals, would show only localized radiation; conceivably, it could be missed completely. What horizontal spreading occurs would be due to capillary action unless the liquid encountered an impervious layer, at which it would flow horizontally.

If the leak from the tank were large enough to build up a static pressure - that is, if flow due to gravity alone could not move the liquid at the rate that it was leaking - the flow would spread horizontally to relieve the pressure. No evidence of this occurring was found in the documentation.

The sorptive capacity of the soil is another consideration in the leak evaluation. Nearly all the radioactive species are absorbed or adsorbed by the soil, shortly after entering it. Ruthenium-106 is the primary mobile radioactive isotope (in relatively new waste) that will move with the moisture front (Ref. 49). Most others will accumulate close to the point of leakage, so long as the leaking fluid remains alkaline.

Yet another characteristic affecting leakage is the filtration ability of the soil. Any solid particles contained in the leaked fluid will be filtered out and, by blocking the flow passages, tend to seal off the leak.

2.0 DEFINITIONS

The tollowing definitions are provided as an aid to understanding terms used in this report.

AIR LIFT - a device for raising liquid by means of compressed air. Compressed air is introduced into the lower end of a vertical pipe, which is submerged in the liquid and open at both ends. The air and liquid mixture, being lighter than liquid alone, rises in the pipe.

AIR SPARGER - a device used to introduce air below the surface of a liquid as small bubbles; essentially a perforated pipe, in many cases.

ARCHIVES - preserved documents from the entire site, stored here in Richland or in the Federal Records Center in Seattle.

CAISSON - a vertical hole of relatively large diameter, lined to prevent cave-ins, and used as a working space to bore horizontal holes under the surface of the earth.

CIRCULATOR - a device installed in a tank to induce movement of liquids and entrainable solids. Circulators in Tank 105-A are of the air-lift type.

CORE DRILLING - the process of boring holes with a device that recovers a continuous core sample of the material through which it passes.

DATA BASE - an accumulation of information on the subject of interest.

INHIBITED SULFURIC ACID - sulfuric acid that contains an inhibitor to minimize or prevent its attacking the steel liner of the tank .

LEAK DETECTION LATERAL - one of three horizontal pipes, located 10 feet beneath the bottom of Tank 105-A, which allow monitoring of radioactivity.

MAXIMUM ALLOWABLE SALT CONCENTRATION LIMIT - maximum sodium concentration is 7-8 molar, set by operating procedure to avoid temperature control problems in the sludge layer.

PRIMARY DOCUMENTATION - records consisting of log books, instrument recordings, released drawings and procedures, incident reports, and other real-time documents utilized in the operation and maintenance of the tank farm. Only original documents, signed and dated, were used as "Primary Documentation."

RAW WATER - water which is piped in from outside the tank farm, not the condensate formed by cooling the vapor leaving any of the tanks.

SECONDARY DOCUMENTATION - records consisting of leak-evaluation reports, correspondence, and other summarizing documentation that was generated as part of tank farm operations.

SELF-CONCENTRATION - the process by which the contents of a boiling tank increase in concentration when the water vapor leaving the tank is not condensed and returned to the tank.

SLUDGE - the solid material which settles to the bottom of the tank. It is much more radioactive than is the supernate.

SLUICING - the process of using hydraulic jets to loosen and suspend the settled sludge, then pumping it out of the tank.

SORPTION - a surface phenomenon which may be either absorption or adsorption, or a combination of the two. The term is often used when the specific mechanism is not known.

SUPERNATE - short for supernatant solution, the liquid contents of a tank from which the solids have settled out to form a sludge layer.

SUPPORTING DOCUMENTATION - any document related to the tank farms that provides ways to increase the reliability of other documentation. Personnel interviews were placed in this category.

TEMPERATURE LATERAL - one of four horizontal pipes, two feet beneath the bottom of Tank 105-A, containing thermocouples to monitor temperatures at these locations.

TEST WELL - a well drilled to confirm conditions suspected or detected by other means, or to explore the extent of those conditions.

WATER HEEL - a low level of water introduced into an empty tank, for a specific purpose, and not pumped out.

3.0 OTHER LEAK EVALUATION REPORTS

Leakage from Tank 105-A prior to the sluicing operations has been estimated or reported by a number of other investigators. Principal among these are the following:

(1) Meeting minutes (Ref. 38) for 11/8/65 state that Battelle Pacific Northwest Laboratories has estimated a leak volume that would produce a temperature increase of 67 °F over the average background temperature beneath the tank. Depending on the location of the leak relative to the lateral, leak size could be 6,000 to 14,000 gallons. These values assume a hemispherical leak, dry soil, and a soil void fraction of 0.35.

(2) Meeting minutes (Ref. 38) for 2/28/66 state that the Tank 105-A leak is small in volume (less than 50,000 gallons) by comparison with data for tank leaks in the SX Tank Farm.

(3) The Battelle report by Jansen et al. (Ref. 2) analyzes the temperatures in the soil around the tank. From temperature measurements made in the radiation laterals 10 feet below the tank, the leak from Tank 105-A is estimated to be 5,000 to 15,000 gallons.

(4) Reference 39 states that the gallons leaked are "small," and that no data are available on radionuclides that leaked to the soil.

(5) The Final Environmental Statement, ERDA-1538 (Ref. 40), states that the estimated leakage is less than 5,000 gallons.

(6) Reference 42 states that the estimated amount leaked is small.

(7) Reference 43 states that the estimated leak volume is less than 5,000 gallons.

(8) Reference 44 states that the leak volume previously estimated and reported for Tank 241-A-105 is 5,000 gallons.

(9) Attachment 1 of Reference 23 estimates cooling water leakage at 50,000 to 960,000 gallons. The writer points out that large gaps existed in the data available to him, and that he had not yet made a thorough investigation into the amount of water evaporated.

(10) Reference 50 cites changing radiation profiles in the laterals as a probable indication that a substantial quantity of the water added to the tank was leaking into the soil. The author extrapolates a short-term fluctuation of 13,000 gallons per month to arrive at 1,500,000 gallons over the entire time since the tank was taken out of service. He makes the point that a substantial amount of water may be entering the sediment.

The figure of 1,500,000 gallons is an example of the risk inherent in extrapolating short-term observations over the long term. Based on operator's logs and other observations, the total cooling water added to the tank is estimated at 610,000 gallons, as described in Section 4.3.5.

Reference 50 was not intended to be an accurate estimate of leakage from Tank A-105. The writer used approximate figures to point out that large amounts of water were being added to the tank, then suggested that, as soon as possible, studies should be made to 1) make a mass balance to determine the fate of the water added to the tank, and 2) analyze the sludge in the bottom of the tank to determine the amount of radioactivity being leaked from the sludge.

(11) Reference 51 estimates that 335,000 to 366,500 gallons of water was evaporated from the tank. Combining that number with the 610,000 gallons of

water added to the tank (from this report) leads to the inference that 244,000 to 275,000 gallons of water leaked to the soil under the tank.

Of the first eight references cited above, only Jansen et al. did the analysis and evaluation required to prepare an independent estimate of leakage; the others cited Jansen's estimate or a modification of it. The ninth and tenth references are not understood as serious estimates of leakage. The final reference is to a current report by Allen (Westinghouse Hanford Co.) which estimates total evaporation during the 1970 - 1978 period when cooling water was being added to the tank.

Jansen et al. analyzed the heat-transfer characteristics of the tank installation, including the surrounding soil, and postulated a number of mechanisms by which hot spots could be created under the tank. Using temperature profiles measured in the radiation laterals 10 feet below the tank, they estimated that in dry soil, the leak volume could be 6,000 - 14,000 gallons, depending on the location of the leak relative to the lateral. In wet soil, which has higher thermal conductivity, the minimum hemispherical leak volume would be 18,000 gallons.

In the conclusions of their report, Jansen et al. estimate the leak to be 5,000 to 15,000 gallons, prior to the commencement of sluicing operations.

Allen approached the calculation of water evaporation by a series of computer simulations. The heat generated in the tank was first estimated by adjusting the assumed conditions until the computed results matched the temperature profile observed in the laterals under the tank. This model established the amount of heat removed from the tank through the air ventilation system. A second computer model was then used to calculate the evaporation rate for a range of air flow rates through the tank.

Allen starts with the assumption that only 2,365 ft^3 of sludge is in the tank, and that none of the sludge is under the bulged bottom of the tank liner. In the process of adjusting the computer model to match the temperature in the laterals, he postulated a second, smaller, and homogeneous region of heat generation directly beneath the tank, which seems to require the further assumption that substantial quantities of radionuclides have leaked from the tank. As discussed later in this report, no evidence of such sizable leaks has been found.

4.0 LEAK EVALUATION

This section presents a current evaluation of leakage from Tank 105-A during four phases of the tank's history, including waste storage and transfers, pump-down and sluicing, addition of cooling water, and current conditions.

4.1 Waste Storage and Transfers, 4/62 - 8/68

Tank 105-A was built in 1955 but was not used until May 1962, when it was made operational to support the PUREX cesium recovery program. From 1955 to 1962 the tank contained only a water heel ranging in depth to a maximum of 18 inches. In May of 1962, 330,000 gallons of supernate were added followed by a number of transfers of waste into and out of the tank. Heating of the tank was initiated in January 1963 by the addition of thermally hot tank farm condensate in preparation for receipt of PUREX self-boiling waste. After adding the self-boiling waste, the tank reached boiling temperature in early March. While not reported as a problem, it was noted from a review of operational data that unexplained tank level increases as large as 33,000 gallons (12 inches) started to occur as early as September 1963. This indicates that steam was probably forming under the tank liner and deforming it upward at this early date. In one case, following an unexplained rise in the tank level, the data indicated that a drop in level was associated with a temperature drop, further supporting the steam theory.

The first reported leakage problem occurred in November 1963 when low-intensity radiation was detected in one leak-detection lateral. Reference 3, which reports this incident in detail, indicates the lateral reading was approximately 0.05 R/h (later corrected to 0.75 R/h) compared to a tank internal reading of 40,000 R/h. The tank level had been raised from 260 inches to 280 inches four months earlier. This led to the assumption that the radiation reading in the lateral was due to a side wall leak, so the level was reduced to 260 inches. This action resulted in a slow reduction in radioactivity in the lateral, which led the operators to the conclusion that the leak was indeed in the side wall or was minor and had self-healed.

This conclusion and the fact that no further storage capacity was available resulted in a decision to maintain the tank at this level. The tank remained in a standby condition until enough water had boiled off to reach the maximum allowable salt concentration limit. At this point, waste was added to the tank to avoid exceeding allowable concentrations.

The tank was then gradually filled with further additions of waste while maintaining the allowable salt concentration and, by October 1964, the level had reached the suspected leak zone with no indication of further leakage. The tank was considered operational and was filled to capacity in December 1964. Tank operation appeared normal and there were no indications of a leak.

The next notable occurrence was a steam release on January 28, 1965. This steam release resulted in the venting of steam through a Tank 103-A riser over a period of approximately 30 minutes. This event created local contamination of soils and equipment around the tank. There was no immediate indication of tank leakage, but 39 days later, on March 8, increased radiation was detected in Lateral No. 3, which is 10 feet below the tank. The reading in this lateral had decayed to 50,000 c/m shortly after the November 1963 peak reading and remained constant until March 8, 1965 at which time the reading increased by a factor of 60 and remained constant (see footnote). Test wells were drilled adjacent to the tank and no indication of radioactive contamination was found. One of these wells was drilled to the level of the leak detection laterals and was terminated within 10 feet of the highest radiation reading in the lateral. From this information it was concluded that the leakage from the tank was small, as it had not spread horizontally.

While preparing to add an air sparger to the tank to enable mixing the tank contents, workmen encountered an obstruction approximately eight feet above the tank floor. This obstruction had been reported several months earlier, when difficulty was encountered during the use of a sludge probe (Ref. 3). This indicated that the tank floor may have bulged upward prior to the steam release. This indication is further supported by the unexplained increases in tank level observed as early as September 1963 when the tank was first brought

Note: Reference 37 questions the factor of 60.

up to boiling temperature. Investigations (Ref. 3) following the steam release established that the tank floor had bulged upward, creating a void space of approximately 80,000 gallons. After the tank was pumped down for sluicing in 1968, it was established that the liner had ruptured and that the area under the bulge contained a significant amount of sludge. Reference 10 provides full details on the condition of the liner.

Contingency plans and procedures were developed to remove the tank contents, and full sluicing capabilities were installed in the tank. It was then decided (Ref. 3) that the tank would not be emptied until it was scheduled for waste management processing, or until further deterioration was detected.

The tank remained in a static condition until April 1967, when liquid-level fluctuations began to occur. Studies and laboratory tests were performed and, as a result, it was decided that the fluctuations in liquid level were caused by the collapse and regeneration of a steam bubble below the bulged liner. This conclusion was supported by the observation that most of the steam bubble collapses coincided with the addition of cooling water to the tank. This led to the concern (Ref. 3) that a build up of sludge under the bulge would result in elevated temperatures and a potentially unsafe condition.

New areas of low-activity radiation were detected under the tank in mid-1967, indicating that further deterioration of the tank was occurring. Activity in the laterals was, for the most part, directly under the perimeter of the tank. This observation resulted in plans to initiate sluicing activities to remove tank contents. By August 1968, the tank level had been reduced to 35 inches by pumping and the sluicing activities had started.

The cumulative volume of leaks during the operational phase was estimated to be between 5,000 and 15,000 gallons; available data support this estimate. The early leaks appeared to be self-healing. The highest radiation reading 10 feet under the tank prior to March 1965 was 150,000 c/m (Ref. 3), which roughly translates to 75 mR/h (Ref. 37); this reading had decayed to 50,000 c/m by March 1965. The leak triggered by the steam release in January 1965 took 39 days to reach the lateral 10 feet under the tank; this indicates that the leak was small. A major leak should have been detected by significant elevation of temperature readings in the laterals just below the tank bottom. Reference 2 states that a leak of as little as 175 gallons of waste sludge could result in temperatures exceeding 1,500 °F at the soil/concrete interface. As temperature never exceeded 370 °F, the conclusion that very little sludge leaked out, if any, appears proper. Further support is the fact that the radiation peaks observed did not spread horizontally, as would be expected had the leak been large.

4.2 Pump Down and Sluicing, 8/68 - 11/70

Sluicing of Tank 105-A began on August 14, 1968 and was stopped on November 17, 1970, while substantial amounts of sludge remained in the tank. During this period the tank was periodically sprinkled with inhibited sulfuric acid, followed by neutralization, and then sluiced.

At the start of sluicing, Lateral No. 3 (see Figure 1-3) was indicating 200,000 c/m, which reflected a slow decay of radioactivity in this lateral since the 1965 steam release. The peak radioactivity levels in Lateral No. 3 remained constant when sluicing started, but there was an immediate large increase in activity in Lateral No. 2 and a coincident first-time indication of radioactivity in Lateral No. 1. Within three weeks of the start of sluicing, the activity in Lateral No. 1 was holding steady near 35,000 c/m and the activity in Lateral No. 2 was fairly constant near the 400,000 c/m reading. A repair of the activity-measuring instrument on October 29 corrected these readings to 20,000 c/m, 190,000 c/m and 120,000 c/m for Laterals No. 1, 2 and 3 respectively. The sluicing operation clearly caused increased leakage from the tank, probably by loosening and removing solid build-ups at the leak sites.

Although increases in radioactivity in the laterals are said to establish that leakage has occurred, they do not prove that more radionuclides have leaked from the tank. The leakage could be only water. It is well known that most radionuclides are more or less strongly absorbed by the alkaline soils of the Hanford area. A leakage of pure water (pH=7), following the path of an earlier alkaline leak, can mobilize adsorbed radionuclides due to pH change alone. The mobilized radionuclides, leaked from the tank months or years earlier, could cause observations of increased activity in the laterals. Whether the liquid leaking from the tank is neutral water or supernate cannot be determined from radiation measurements alone, once leakage of radionuclides has occurred.

The next significant change in lateral activity was in August 1970, when all laterals showed increased readings. The reading of Lateral No. 1 increased to 40,000 c/m and remained constant. Activity in Lateral No. 2 increased to about 375,000 c/m and fluctuated over a range of 80,000 c/m. Activity in Lateral No. 3 increased to about 960,000 c/m and varied over a range of 400,000 c/m. These fluctuations indicated that leaks were active and, because the readings remained high, the sluicing operation was aborted on November 17, 1970. Substantial quantities of sludge remained in the tank, and its heat generation made cooling water additions necessary to maintain safe temperatures.

The volume of leaks which occurred during the sluicing period cannot be estimated from a material balance due to the rapidly changing fluid additions and pump-down rates, but since the radiation zone under the tank remained confined to small areas and did not spread horizontally, it seems likely that large leaks did not occur. Leakage probably exceeded 5,000 - 15,000 gallons, but was less than two times that amount, based on the observations made in the laterals.

4.3 Temperature Stabilization of Residual Waste by Cooling Water Additions, 11/70 - 12/78

The third historical period of Tank 105-A started in November 1970 when the sluicing operation was completed, and continued until the last water addition was made to the tank on December 4, 1978. During this time, raw water was sprinkled into the tank or was otherwise added into the tank to control temperature rise resulting from radioactive decay of radioisotopes in the residual sludge. In this section of the report, one important question is addressed: Of the water that was added into the tank, how much evaporated and how much leaked into the soil under the tank.

The question was approached by examining the heat balance in the tank. An estimate of the amount of water added to the tank was obtained from the original operators' data sheets. The amount of heat generated in the tank was estimated from observations made in Reference 10 of sludge volumes, and isotopic analysis of the sludge was taken from Reference 3. After allowing for heat losses by conduction into the soil, and losses due to heating the ventilation air as it was drawn through the tank, the remainder of the heat generated was available to evaporate water.

4.3.1 Cooling Water Added

A measure of the amount of water added to the tank was obtained from three principal sources:

(1) Monthly Boiloff Rates Book for the period ending 3/31/72.
(2) Tank Farm Daily Status Reports for 11/1/73 through 12/4/78.
(3) Tank Farm Liquid Level Readings for 1/1/76 through 12/4/78.

The Daily Status Reports and the Tank Farm Liquid Level Readings are original data recorded by the operators at the time. They are the most reliable data now available, but with one reservation: although water additions are usually recorded in both documents, they are occasionally omitted from one or the other. These records should be examined together, whenever possible, to obtain the most accurate information. Except for the single day, 10/31/71, log sheets prior to 11/1/73 have not been found.

The Monthly Boiloff Rates Book is the only source of recorded data found for the period 2/1/71 through 3/31/72. No data were found for water additions from the stopping of sluicing on 11/17/70 to the start of the Boiloff Rates Book on 2/1/71. For the period 4/1/72 through 10/31/73, data were found only for June 1973 (Ref. 23); these data appear far too low by comparison with earlier and later water addition rates.

Extracting data from the operators' records is not simply a matter of copying numbers, but is instead a problem of interpretation, of deciding what the entry actually means. Some example entries requiring interpretation are as follows:

(1) "Water added" but no volume stated.

(2) "500 gallons water added" referring to something done and recorded on a previous day.

(3) "Increase in tank level", but no record of water added.

(4) "Water added", but the level did not rise. This is not unusual for small additions of water, as the precision of level readings is about +/- 1/4-inch at best. It could also be that the level was read before the water was added.

(5) Days missing from the records. As only a few days' data were missing, no adjustments were made to compensate for missing days' data.

Water additions to Tank 105-A are summarized in Table I on the following page. The data extracted from the log sheets and used to develop Table I are presented in Appendix 8.2, as are the calculations of average water addition rates and the heat required to evaporate all the water. The water additions preceded by the word "say" in Appendix 8.2 have been inferred from the context, as the amount of water added was not recorded.

TABLE I.
WATER ADDED TO TANK 105-A
BETWEEN NOVEMBER 1970 AND DECEMBER 4, 1978

TIME PERIOD	AVERAGE RATE WATER ADDED GALLONS/DAY	SOURCE OF DATA
11/1970 to 1/31/71	----	None Found
2/1/71 to 3/31/72	290	Boiloff Book (Ref.1)
4/1/72 to 10/31/73	----	None Found
11/1/73 to 12/31/74	242[(1)]	Daily Status Reports
1975	221[(1)]	Tank Farm Status Report (Box 58071, Archives)
1976	159	Tank Farm Status Report and Liquid Level Readings (Box 58073, Archives)
1977	141	Tank Farm Status Report and Liquid Level Readings (Box 61285, Archives)
1/1/78 to 12/4/78	121	Tank Farm Status Report and Liquid Level Readings (Box 68653, Archives)

<u>NOTES</u>: (1) Water introduced by flushing circulators is assumed to be 180 gallons per occurrence during these time periods.

A significant amount of water was added to the tank through flushing the circulators, which is required to maintain them in operating condition and thereby ensure continuous operation (Ref. 25). The amount of water so added was not recorded by the operators; only a notation that this event had occurred. This was done daily in February 1971, and an amount of 180 gallons per day is included in the water additions recorded in the Boiloff Book (Ref. 1). A flushing rate of 15 gpm for three minutes for each of four circulators equates to 180 gallons, per a notation in the book. Although the flushing was said to have been stopped in early 1971, the Tank Farm 241-A Status Reports show that circulators were flushed frequently until the end of August 1975. A water addition of 180 gallons/occurrence was assumed for the period of 11/1/73 through 8/31/75.

In all the documentation examined, no evidence was found of significant water intrusions from sources not recorded in the operator's log sheets. Water was routinely added through the sprinkler head and the volume faithfully recorded, except for the few occasions noted in Appendix 8.2. Circulators were flushed and so noted in the log sheets. On a few other occasions, when for some reason the sprinkler could not be used, water was introduced to the tank via another path; in all cases, the volume of water added appears to have been recorded in the log sheets.

Where data are not available, and where interpretation is required, thinking and engineering judgment have been strongly influenced by standard operating procedures and other instructions (Refs. 24, 25, 26, and 27). From these water addition data, and heat release considerations, a total water addition of approximately 610,000 gallons is inferred. See Section 4.3.5.

4.3.2 Heat Generated

The amount of heat generated in Tank 105-A at any time is the product of two factors: 1) the specific rate of heat generation per cubic foot of residual solids, and 2) the volume of solids remaining in the tank. All available earlier documents on the subject have been reviewed. These are listed in the References, Section 7.0.

For this heat balance analysis the first factor was calculated from available analyses of sludge samples, plus heat generation rate and decay calculations. For the second factor the estimates of Woodward-Clyde (Ref. 10), which were developed from stereoscopic photographs of the tank's interior and other measurements, were accepted. Substantial uncertainties are present in both factors, as will be discussed later in this section.

Three samples of the sludge were taken from different locations in the tank and analyzed in January 1972 (Ref. 4). The necessary calculations were made to determine heat generation rates during the 1971-1978 period. Using the same terminology as the reference document, these are identified as curves *one-a, one-c, and two-b* on the Specific Heat Generation Rates curves on the following page. The average of these analyses is also plotted as curve *ave-72*. Note that the heat generation rates for these samples vary by a factor of 3.6. In reporting these analytical results, the authors of Ref. 4 point out two anomalies in the data: The duplicate analyses are in good agreement for the non-radioactive constituents, but vary substantially for the radioactive species; and the particle densities reported for the "dry" solids were substantially less than those reported for other sludges, and appear to be in error.

An earlier sample of the sludge was analyzed in 1965 (Ref. 3). Similar calculations were made from this analysis, resulting in curve *sixty-five* of the Specific Heat Generation Rates curves. This curve falls within the range of the three 1972 analyses, and is lower than the average of those analyses by a factor of 1.5.

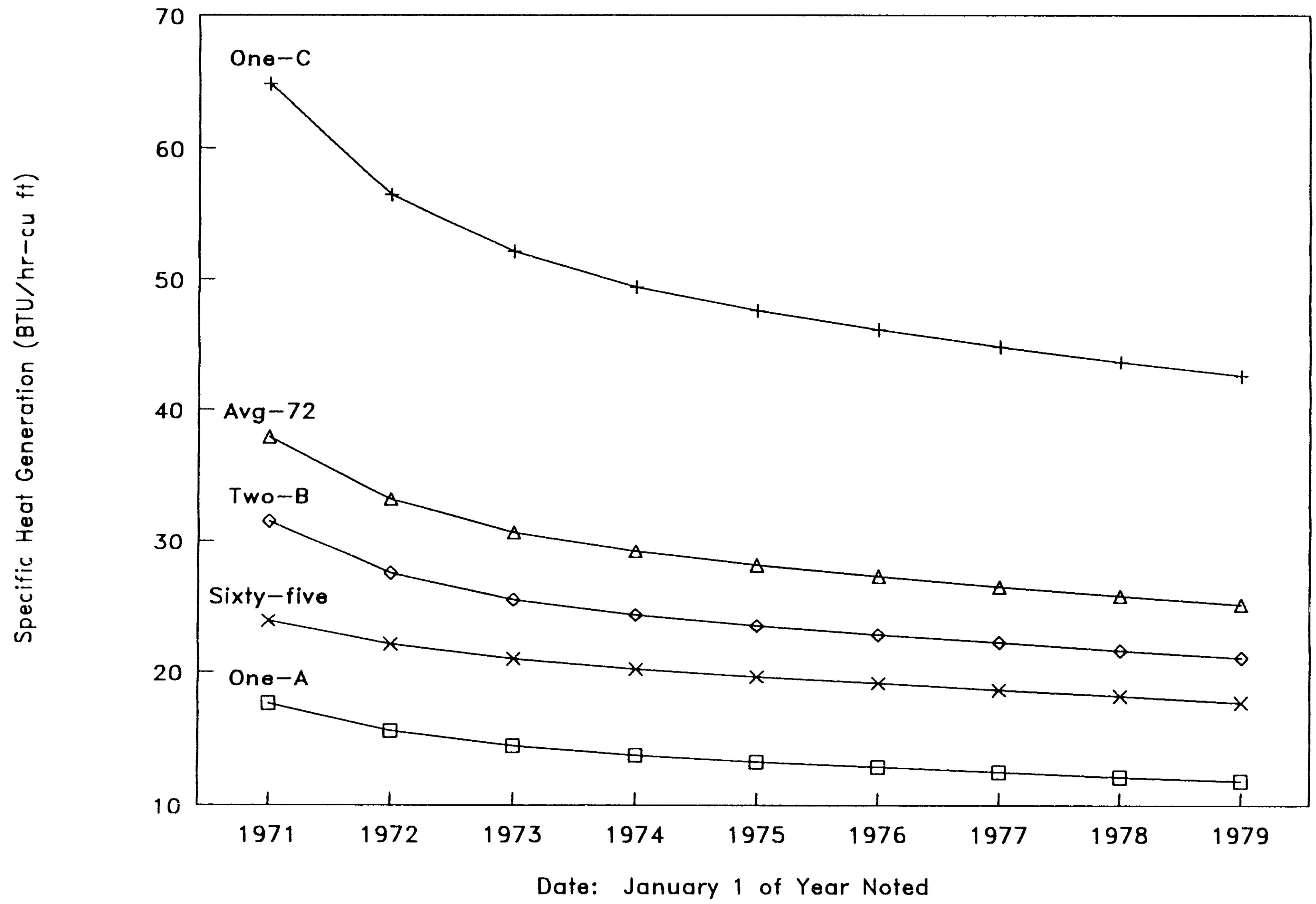


Figure 4-1. Specific Heat Generation Rates Based on Analyses of Tank 241-A-105 Sludge

Earlier documentation contains references to a calorimetric determination of heat generation and to a 1978 isotopic analysis, but neither of these nor confirmation that they exist have been found.

The 1965 analysis has been adopted as the basis for heat release calculations. It is lower than the average of the 1972 analyses, and more conservative so far as calculations of cooling water leakage are concerned. The data are taken from Reference 3 and are presented in Appendix 8.4.

The volume of sludge in the tank has been reported several times (References 5, 9, 10, 11, and 14). Woodward-Clyde (Ref. 10) approached the estimate directly by photographic observation of the tank interior, using stereo photos and other physical measurements of the tank and its contents to prepare topographic maps of the bottom contours of the tank. They estimated the amount of sludge remaining in the tank, and prepared profiles to illustrate the conditions assumed in making the estimate. Commenting on the results of their study, the authors state that "...they are subjective and are based on judgments as well as hard data."

Everly and Bath (Ref. 11) estimated the sludge in the tank through a computer simulation to match a given temperature profile in the temperature laterals under the tank. A key factor in their calculations was a specific heat generation rate of 29.47 Btu/hr-ft^3, which appears to have come from the 1972 sludge analyses (Ref. 6). Everly and Bath do not comment on the computer program they used; it is not clear whether it can be used to estimate sludge quantities which are not in direct contact with the bottom of the tank. The Woodward-Clyde report suggests that sizable amounts of sludge may be in such positions.

Woodward-Clyde concluded that sludge remaining in the tank was in three positions:

(1) between the bulged and ruptured liner and the wall of the tank: 1,000-1,200 ft^3

(2) on top of the liner: 1,300-1,600 ft^3, and

(3) under the bulged liner: choose A: 2,000-2,500 ft^3

or B: 4,000 ft^3

For estimating the heat generation in the tank this report uses numbers at the low end of the Woodward-Clyde estimates. It uses the sum of the smallest volumes shown above, or 4,300 ft^3, as the estimated sludge volume. This is again conservative, for purposes of estimating cooling water leakage.

4.3.3 Heat Transfer by Ventilation

One approach to estimating the heat release in the tank is to measure the ventilation air flow, its temperatures into and out of the tank, and the relative humidities into and out of the tank, from which the increase in enthalpy is a straightforward calculation. Campbell (Ref. 14) took this approach and calculated a heat release of 60,000 +/- 40,000 Btu/hr.

For this report, water evaporation and dry air heating are handled as separate items in the enthalpy calculations. This is an equally valid approach, and for this report it is more practical. Water additions can be measured directly and, theoretically at least, with excellent accuracy. Air heating is handled as a reduction in the heat available for evaporation, and if this is small, large uncertainties can be accepted without affecting the validity of the conclusions.

Air flow through the tank was not metered during this period. Kaser and Veneziano (Ref. 8) estimate the flow at 150-660 ft^3/min, "...with the most likely value being in the lower end of that range." Their upper-level estimate of 660 ft^3/min is based on the assumption that the air flow from each tank is equal. The lower estimate takes into account the actual operating conditions in the plant in June 1976, recognizing that the tanks in A, AX, AY and AZ farms all operate at different levels of negative pressure. This report accepts Kaser and Veneziano's comment that the most likely value is at the lower end of the range, and uses 150 ft^3/min for estimating heat losses to tank ventilation.

Using a tank outlet air temperature of 115 °F and an inlet air temperature of 48 °F (both from Ref. 22), the temperature rise is 67 °F as the air passes through the tank. Heat absorbed by the 150 ft^3/min of inlet air is estimated at 11,900 Btu/hr. This heat is not available to evaporate water.

4.3.4 Other Heat Losses

Other heat losses will, like the loss to dry air, reduce the amount of heat available to evaporate water. One such loss is the loss by conduction - upward through the dome, and downward through the tank bottom.

Jansen (Ref. 2), in 1965, estimated heat losses by conduction to be 16,700 Btu/hr through the ground surface and 2,140 Btu/hr downward to the water table, assuming dry soil. His calculations were for a tank full of liquid and sludge, at a temperature of 226 °F near the dome and near 230 °F at the tank bottom. His temperature at the surface of the soil above the dome is 70 °F, and his temperature at the water table, 201 feet below the surface, is also 70 °F.

For the 1971-1978 time period, the tank bottom temperature may be assumed to be 230 °F, but the vapor space temperature will be close to 115 °F (Ref. 22). Adjusting approximately for these changed conditions, the following heat losses by conduction are estimated:

Downward to the water table:			2,140 Btu/hr
Upward through the ground surface:	$\frac{(16{,}700)(115-70)}{(226-70)}$	=	4,820 Btu/hr
			6,960 Btu/hr

This heat also is not available to evaporate water. Total heat losses, therefore, are approximately 18,900 Btu/hr.

4.3.5 Heat Discussion

The amount of water added to Tank 105-A during this period is known, and the amount of heat required to evaporate all this water can be calculated. The rate at which heat was generated in the tank by radioactive decay is known, and allowances can be made for known heat losses; the remaining heat was available for the evaporation of water. From a comparison of these heat balance items, it may be judged whether leakage from the tank was essentially nil, modest, or excessive in amount.

Heat available for evaporating water, after allowing for air heating and conduction losses, was as follows:

TABLE II. HEAT GENERATED IN TANK 105-A AND AVAILABLE FOR EVAPORATION

DATE	SPECIFIC HEAT GENERATION Btu/hr-ft^3	TOTAL HEAT GENERATION Btu/hr	HEAT AVAILABLE FOR EVAPORATION Btu/hr
1-1-71	23.9	102,600	83,700
1-1-72	22.1	94,900	76,000
1-1-73	21.0	90,200	71,300
1-1-74	20.2	86,900	68,000
1-1-75	19.6	84,300	65,400
1-1-76	19.1	82,000	63,100
1-1-77	18.6	79,900	61,000
1-1-78	18.1	77,900	59,000
1-1-79	17.7	75,900	57,000

The above information is shown on the following page in a graph showing three plots: 1) a bar chart showing how much heat would be required to evaporate all the water added to Tank 105-A, 2) a curve showing heat available for evaporation, based on the 1965 sludge

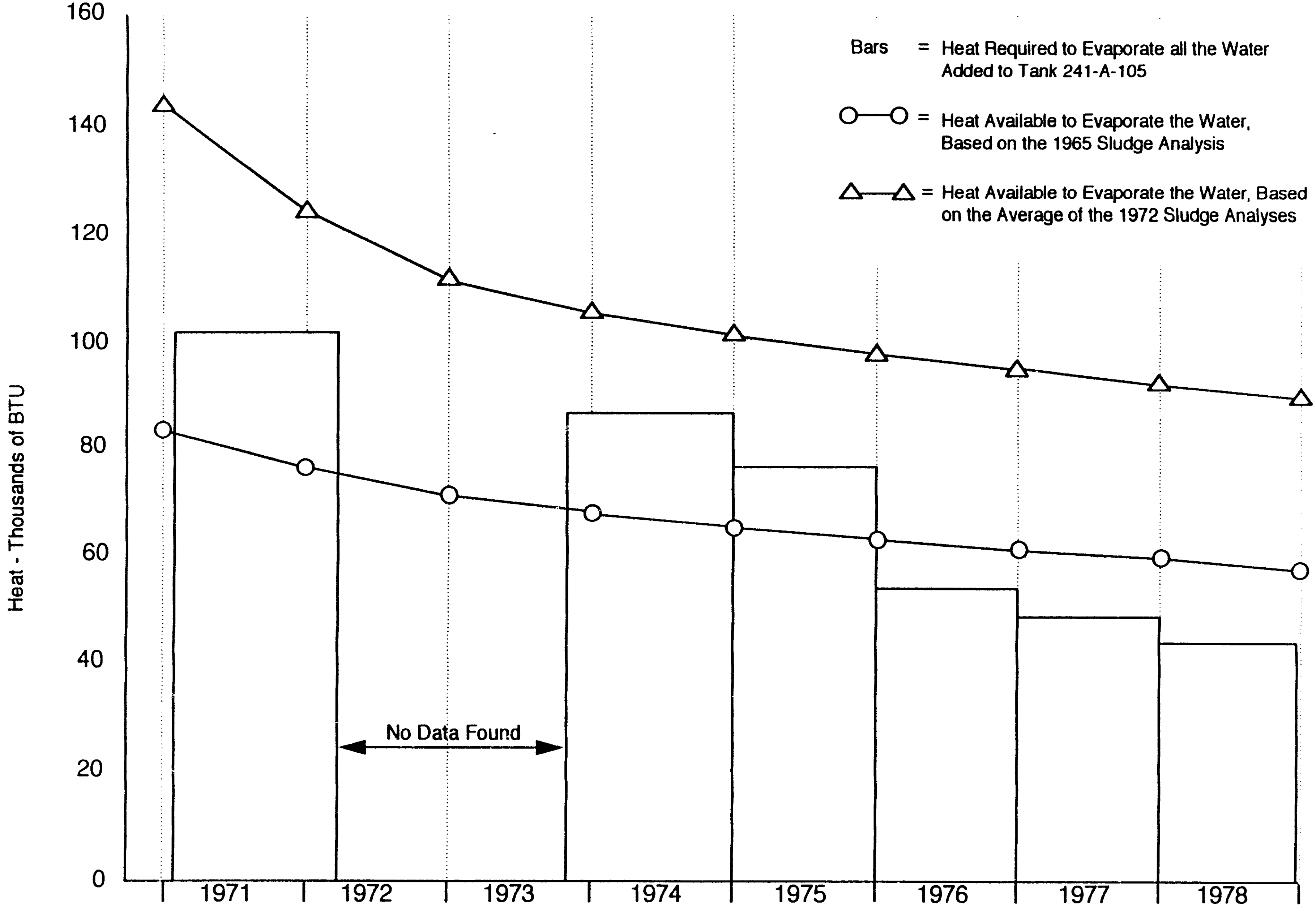


Figure 4-2. Heat Required to Evaporate Water vs. Heat Available to Evaporate Water in Tank 241-A-105

analysis, from the above table, and 3) a second curve showing heat available for evaporation, based on the average of the three 1972 analyses.

From this heat balance plot and other knowledge of the history of the tank, two significant observations are made: 1) The heat available in the tank was approximately that required to evaporate all the water added. During the period 4/1/72 through 10/31/73, for which no data were found, the operating procedures were identical to those used during earlier and later periods (Ref. 24, 28). That is, the tank level was held essentially constant and only enough water was added to do so. It is reasonable to assume that water additions during the period of missing data would fall in line with the other periods. On this assumption, total water additions to the tank are estimated at approximately 610,000 gallons. 2) If a fair line were drawn through the tops of the bars denoting heat required, it would have a slope steeper than that of the heat available curve. No explanation is available for the different slopes, but this could happen if the 1965 sludge analysis failed to report significant amounts of short-lived radionuclides. Exploring this possibility, it appears that this may indeed be the case. The 1972 analyses, for example, report the presence of Sb-125 and Eu-154 (Ref. 4). Jungfleisch (Ref. 15) suggests that a number of other radionuclides may be present in significant amounts.

From other operating data found in the archives it is known that some leakage occurred during 1975, as increased activity was detected in the radiation laterals under the tank at that time. No basis for estimating the volume of these leaks has been found, but all indications are that the leakage was small.

4.4 End of Water Additions to Current Date, 12/78 to date

A review of temperature readings and radiation readings for Tank 105-A confirmed that the radioactivity has decayed substantially and that temperature readings are constant. As an example, the peak count in any of the three radiation laterals, since late 1985, has been 268 c/s in Lateral No. 1, 2,000 c/s in Lateral No. 2, and 7,000 c/s in Lateral No. 3. The peak readings are still centered in the previous leak locations and have shown very little variance for the past six years.

On June 12, 1990, there was a one-day peak reading of 23,070 c/s, which, when checked the next day, had changed to 433 c/s. It is suspected that this was caused by a radioactive gas build-up in the lateral or other spurious reason and was not an indication of leak activity.

The highest temperature reading below the tank in April 1991 was 220 °F and temperatures were fairly consistent across the tank bottom. Dry well radiation readings, taken from early 1991 records, indicate that all of these readings have decayed to or near background.

Air cooling of the residual sludge in the tank is continuing and periodic radiation and temperature readings are being taken in the tank, in the laterals below the tank, and in the drywells surrounding the tank.

Psychrometric survey data taken since January 1979 suggest that substantial amounts of water continue to evaporate from Tank 105-A. The cumulative amount evaporated between January 1979 and December 1990 would be about 40 feet of water, if these data are to be believed. This is clearly unlikely, unless water additions to the tank have been resumed, as the tank level at the beginning of the period was less than eighteen inches.

Ebasco has not explored the reason for this apparent anomaly, as it is beyond the scope of this sub-task. Three avenues of exploration should be considered:

1. The methods used, while fully adequate for tank monitoring, may not be of sufficient accuracy for water-loss calculations.

2. The data were all obtained on the day shift; 24-hour monitoring may reveal a reversal of equilibrium conditions in the tank.

3. Perhaps soil moisture is being drawn into the tank and contributing to the humidity measured in the exhaust air. A pressure gradient exists for such a flow, and a possible chimney effect should not be overlooked.

4.5 Leakage of Radionuclides

The number of curies of radioactivity accumulated under Tank 105-A because of leakage from the tank has been estimated. From the earlier observations of the self-plugging nature of the leaks, it appears likely that little if any of the solid sludge materials escaped from the tank. The basis for the estimate is the supernate analysis obtained on May 1, 1965 (Ref. 3), and presented in Appendix 8.4, with appropriate decay calculations applied to arrive at a 1/1/91 analysis. These analyses are as follows:

TABLE III. ANALYSIS OF SUPERNATE

Component	Analysis May 1, 1965 Curies/gal	Decayed to Jan. 1, 1991 Curies/gal
Sr - 90	0.034	0.018
Ce - 144	<0.019	$<2.4 \times 10^{-12}$
Cs - 137	30.7	16.9
Ru - 106	<0.076	$<1.4 \times 10^{-9}$
ZrNb - 95	<0.019	0

During the operational phase the fluid leaked is assumed to be supernate. During the sluicing phase the fluid leaked could have ranged from water at one extreme, to supernate at the other. This gives a basis for estimating the range of curies that may have leaked during these periods.

After the sluicing had been completed and cooling water was being added, the situation is not so clear. The amount of leakage is unknown and cannot be estimated, but is thought to be small. The sludge remaining in the tank has been leached with sulfuric acid and with large amounts of water; most likely, the solids remaining are essentially insoluble in water with a radioisotope content that is only a small fraction of that in the original supernate. Leakage during this period is probably water.

Based on the above considerations and the range of leakage estimated in this report, from 85,000 to 760,000 curies have accumulated under Tank 105-A. Of this, about 99.9% is from Cs-137, and 0.1% from Sr-90. Other constituents reported in the 1965 analysis of supernate have decayed away to insignificance.

5.0 CONCERNS REGARDING REMEDIATION

Although the amount of material leaking from Tank 105-A was probably relatively small, the depth of penetration into the soil under the tank cannot be determined from existing data. From 1) the observed radiation peaks, 2) the fact that these peaks are directly under the tank walls, 3) the limited horizontal spreading of the radioactive areas, and 4) the known characteristics of the soil, it is likely that the leaks followed narrow paths downward. The depth of penetration, and therefore the magnitude of the remediation problem, can best be determined by a program of core drilling at an angle under the tank.

Another unknown that will enter into plans for remediation is the amount of sludge remaining in the tank, in particular the unseen sludge under the bulge in the liner. The Woodward-Clyde report estimates this unseen amount at 2,000 - 4,000 ft^3 If it becomes necessary to know this amount more accurately, some direct method of measurement would be preferred over any indirect method.

Although the Allen report (Ref. 51) and this work differ by up to 244,000 gallons in the amount of water leaked during the sprinkling phase, they represent a considerable narrowing of the 5,000 to 960,000 gallons estimated by earlier investigators. In that sense, they may be said to be roughly in agreement. The major value of these reports, however, is any guidance they may provide for remediation planning. As applied to that problem they are in complete agreement: core drilling under the tank is advisable, to define the limits of contamination.

6.0 CONCLUSIONS

From the analysis of data from Tank 105-A, the following conclusions regarding leakage from the tank can be drawn:

(1) The extent of leakage during the operational phase (prior to 8/68) was estimated at that time to be between 5,000 and 15,000 gallons. This earlier estimate was reasonable.

(2) During the sluicing phase (8/68 - 11/70), leakage exceeded 5,000 to 15,000 gallons, but probably did not exceed twice that amount. Insufficient data are available to be more precise. Estimated leakage during this phase is therefore 5,000 to 30,000 gallons.

(3) While cooling water was being added to the tank (11/70 - 12/78), the procedures followed by the operators of the tank farm were intended to control temperatures, while minimizing the amount of leakage into the soil under the tank. They effectively achieved these goals.

(4) Between 2/1/71 and 12/4/78, approximately 610,000 gallons of cooling water were added to Tank 105-A. Most, and perhaps nearly all, of this water was evaporated.

(5) Radionuclides escaping into the soil under the tank cannot be estimated directly because of many uncertainties. Based on a range of total leakage from 10,000 to 45,000 gallons, assumed compositions, and decayed to 1/1/91, radioactivity under the tank is expected to be in the range of 85,000 - 760,000 curies. Of this, 99.9% is from Cs-137, 0.1% from Sr-90.

7.0 REFERENCES AND COMMENTS

1. **Monthly Boiloff Rates, June 1965 to March 1972,** ARHCO internal memos with calculation sheets attached. These show boiloff rates while the tank was full, and after sluicing had been completed. In many months the boiloff was calculated, but not reported in the memo. Basic assumption in all cases is that all water put into the tank was evaporated, after allowing for net level change during the month.

2. **12/22/65 (approx.), Report by G. Jansen, Jr., et al., Techniques for Calculating Tank Temperatures and Soil Temperatures Near Leaks - Application to PUREX Waste Tank 105-A, BNWL-CC-376.** This study applies to a condition in which Tank 105-A is full of liquid and sludge, boiling, and uniformly hot as a result. It contains the following information which is germane.

   The volume of the leak from Tank 105-A is estimated at 5,000 to 15,000 gallons. In dry soil, about 16,700 Btu/hr is lost upward to the ground surface and about 2,140 Btu/hr downward to the water table. For wet soil these increase to 66,100 and 9,300 Btu/hr respectively; the temperature distribution remains unchanged.

   Air flowing at 100 ft^3/min could remove 23,000 Btu/hr. (NOTE: Exit air at 230 °F.)

   ^{95}Zr-Nb and ^{144}Ce are present only in the sludge in alkaline tanks and in solution in acid tanks.

3. **10/31/67, Report by S.J. Beard, et al., PUREX TK-105-A Waste Storage Tank Liner Instability and Its Implications on Waste Containment and Control, ARH-78.** See pg. 18 of this reference for 5/1/65 analysis of separated sludge taken from Tank 105-A. Heat release calculated from this analysis falls within the range of the samples taken on 1/1/72.

4. **1/12/72, Letter, W.W. Schulz/C.W. Hobbick to C.J. Francis/C.M. Walker,** **Composition and Density of the 105-A Solids.** Reports the analyses of two dry solids and one slurry sample, taken from different locations in Tank 105-A. The letter notes that the analyses of inert ingredients are in good agreement for the three samples, but that there is substantial difference in the radioactive elements. This anomaly is not explained.

NOTE: Heat release calculations for the analyses vary from 15.5 to 56.4 Btu/hr-ft^3. The arithmetic mean is 33.15 Btu/hr-ft^3. Samples were analyzed in early January, 1972.

5. **7/31/74, Report by W.P. Metz,** **Action Plan for Stabilizing Tank 241-A-105,** **ARH-CD-135.** States that as much as 2,005 ft^3 of sludge may be under the bulged liner. Further states that radiolytic heat generation rate has been determined both by isotopic and calorimetric analysis, and that the two methods agree at 34-42 Btu/hr-ft^3.

The report also states (pg. 4) that 2,000 gallons/week of water are required to hold an 18-inch level in the tank, leading to the conclusion that 1) heat release is about 100,000 Btu/hr or that 2) the tank leaks. However, routine leak detection monitoring has not detected leaks.

NOTE: We have been unable to find a calorimetric determination of heat generation rate. Water addition data from other sources indicates that water addition rate at this time was about 1700 gallons/week. Our calculations from chemical analyses give an average heat release for the three samples of 33.15 Btu/hr-ft^3 in January 1972. Decayed to 1974, we calculate 29.15 Btu/hr-ft^3.

6. **2/12/76, Letter, S.S. Koegler to R.E. Felt, <u>A and AX Tank Sludge Heat Generation Rates</u>.** Cites the average heat generation rate of three sludge samples from Tank 105-A, based on content of ^{90}Sr and ^{137}Cs only, at 3.94 Btu/hr-gal. Notes that the samples varied by a factor of 3, and that the samples were obtained in 1972.

> NOTE: $(7.48)(3.94) = 29.47$ Btu/hr-ft^3. This is the source of the heat release number used in later studies.

Calculations by Frank Young (Ebasco), which take into account all the radioactive species reported, give a heat generation rate of 33.15 Btu/hr-ft^3 for early 1972, higher than the rate reported by Koegler.

7. **12/19/77, Letter, J.H. Roecker to O.J. Elgert, <u>Program Plan for Stabilization of Tank 105-A</u>, 9606R-2.** Contains the following statements in an attachment:

Heat loss to ground from tank at 140 °F = 16,000 Btu/hr.
Heat loss due to water evaporation and ventilation = 17,200 Btu/hr approx.
Heat losses for tank at 180 °F at 500 SCFM and 60% RH = 240,000 Btu/hr.

This attachment is not referred to in the body of the letter. The attachment refers to reference (c), while the letter has only references (a) and (b).

> NOTE: We conclude that this attachment is misplaced and does not pertain to Tank 105-A.

8. **1/23/78, Report by J.D. Kaser and T.B. Veneziano, <u>Tank 105-A Stabilization Progress Report</u>, RHO-CD-255.** Contains the following statement on page 31:

> Over the past year, water has been added at an average rate of 1,000 gallons per week. If all of this water is evaporated by

radioactive decay heat, the corresponding heat generation rate would be about 50,000 Btu/hr.

NOTE: This may be the source of the 1,000 gal/wk, 50,000 Btu/hr figures cited frequently in later documents. To check: water addition from liquid level readings is 141 gal/d, or 987 gal/wk.

$$(141)(8.35)(1/24)(1,000) = 49,100 \text{ Btu/hr}$$

The report also notes that the tank ventilation rate is about 150 ft^3/min. This, plus heat loss to the ground, would consume at least part of the excess heat from radioactive decay.

9. **2/1/78, Letter, Roecker to Elgert, <u>Decision to Measure Hydrogen Concentration in Tank 105-A Before Performing Drying Tests,</u> 9606-R3**. Contains the statement "...Woodward-Clyde Consultants have estimated that there may be 2,800 ft^3 of sludge under the liner."

NOTE: This appears to be preliminary information, which was expanded by Woodward-Clyde in their formal report.

10. **3/24/78, Report by Woodward-Clyde Consultants, <u>An Estimate of Bottom Topography, Volume and Other Conditions in Tank 105-A, Hanford, Washington</u>**. The volume of sludge between the bulged and ripped liner and the wall of the tank is 1,000-1,200 ft^3. The volume of sludge on the liner was calculated to be 1,563 ft^3 (1,300-1,600 ft^3).

Two estimates are made for the volume of sludge under the liner: 1) 2,000-2,500 ft^3, and 2) 4,000 ft^3.

The report further states, on pages 14 and 15, that unseen sludge under the liner controls the temperatures observed in the laterals under the tank.

11. **8/10/78, Letter, Everly/Bath to Veneziano,** **Heat Transfer Study on Tank 105-A, 60414-78-051.** Based on data from Tank Farm Process Engineering, estimates 2,365 ft^3 of sludge in the tank. Heat generation rate of 29.47 Btu/hr-ft^3 was provided by Tank Farm Process Engineering. (2,365)(29.47) = 69,700 Btu/hr heat generated in 1978.

12. **11/21/78, Letter, Everly to Veneziano,** **Transient Heat Transfer Study on Tank 105-A, 60413-78-0132.** Based on the same data as the 8/10/78 study, finds that 1,195 SCFM of air is required to remove heat from Tank 105-A. Recommends that measures be taken to prevent short-circuiting of air flow in the tank.

13. **March 1980, Report by Robert J. Catlin,** **Assessment of the Surveillance Program of the High-Level Waste Storage Tanks at Hanford.** Table 20 on page 84 states an estimated heat generation rate of 60,000 +/- 30,000 Btu/hr, but provides no data or source for the figures. The table is referred to on pg. 64 of the report, but no further information given. The tank is said to contain 4,400 ft^3 of solids.

    Page 115 states: "Past unplanned releases to soil are not known; owing to the philosophy of using soil as a secondary containment, spills and other accidental releases within the tank farm boundaries were not recorded routinely until 1972."

    Appendix H states that the maximum leak undetectable by the dry well monitoring is 17,500 gallons; by the horizontal laterals, 5,000 gallons.

14. **October 1981, Report by G.D. Campbell,** **Heat Transfer Analysis for In situ Disposal of Nuclear Wastes in Single- and Double-Shell Underground Storage**

Tanks, **RHO-LD-171 Informal Report**. Used psychometric data to calculate a heat release of 60,000 +/- 40,000 Btu/hr in Tank 105-A. States that heat loss by conduction was estimated, but gives no figures. Sludge volume stated is 2,500 ft^3, no source given.

15. **March 1984, Report by F.M. Jungfleisch,** Preliminary Estimation of the Waste Inventories in Hanford Tanks Through 1980, **SD-WM-TI-057**. Reports a heat generation rate of 12,000 Btu/hr in Tank 105-A.

    NOTE: This is much lower than found in other sources.

16. **7/23/86, Rockwell Internal Letter, W.S. Lewis/A.T. Alstad to S.J. Joncus,** Replacement of Defective Thermocouples in Single-Wall Tanks, **65950-86-437.** States that Tank 105-A heat load is 18,000 Btu/hr "from attached graph", but no graph is attached.

    NOTE: This heat load is not supported by other documents.

17. **9/30/88,** Waste Storage Tank Status and Leak Detection Criteria, **by R.K. Welty, SD-WM-TI-356.** This states (pg. 10-05-13) a heat release of 38-42 Btu/hr-ft^3 for an 84,000 Btu/hr heat generation rate. Water required is 2,000 gal/wk which corresponds to 100,000 Btu/hr.

    NOTE: The information cited here appears to have been taken from an earlier report by Metz. See Ref. 5 above. This heat release is substantially higher than that found in other sources.

18. **4/20/89, Memo, R.D. Gibby to V.D. Maupin,** High Heat Single-Shell Tanks, **13316-89-0042.** Cites heat generation rates taken from the above sources and "decayed to 1989."

50,000 Btu/hr	Ref. 14
49,000 Btu/hr	Ref. 13
17,000 Btu/hr	Ref. 16
11,000 Btu/hr	Ref. 15
39,000 Btu/hr	Average of first three

Gibby eliminated the 11,000 Btu/hr figure from his average for two reasons: 1) the theoretical nature of Ref. 15 as compared to the empirical nature of the other sources, and 2) the heat release stated in Ref. 15 showed a significant statistical difference from the other values for Tank 105-A.

NOTE: Until support for the 17,000 Btu/hr figure can be found, we would eliminate this figure as well.

19. **3/28/90, Report, T.W. Fisher/W.W. Chen/R.B. Pan, Thermal Analysis of Single-Shell Tank A-105, WHC-SD-WM-DA-061 Rev.0.** Uses a heat rate of 50,000 Btu/hr taken from Gibby to Maupin memo dated 4/20/89, above.

NOTE: Why did Fisher et al. not use 49,000 or 17,000 or 39,000 Btu/hr, which were also reported by Gibby? To be conservative we presume. Fisher et al. used solid thermal conductivity of 0.25 Btu/hr-ft-°F. Lange's handbook gives 0.080 for dry soil, 0.23 for dry sand. Presumably, Fisher et al. assumed some level of water in the soil.

20. **10/9/90, Engineering Data Transmittal, M.D. Britton to R.E. Raymond, Heat Balance Calculations, WHC-CM-3-4.** Calculates an average heat release in Tank 105-A of 78,500 Btu/hr for the 1971-78 period while cooling water was being sprinkled into the tank. All is based on a specific heat release of 29.47 Btu/hr-ft^3, taken from Ref. 12 above, and used without considering radioactive decay from 1972 to 1978.

21. **3/7/91, Calculations by F.J. Young of Ebasco, Heat Generation from Sludge Analyses. Not issued.** Based on the three analyses reported in Ref. 4, one analysis in Ref. 3 and the table Radionuclide Specific Activity and Heat Generation, heat generation rates were calculated for four analyses decayed to 1972. Results:

1972	1[a]	15.52 Btu/hr-ft^3
	1[c]	56.41 Btu/hr-ft^3
	2[b]	27.53 Btu/hr-ft^3
	Avg.	33.16 Btu/hr-ft^3
1965		22.06 Btu/hr-ft^3

Counting ^{90}Sr and ^{137}Cs only, for the 1972 samples, average heat release is 29.62 Btu/hr-ft^3, which agrees closely with the 29.47 Btu/hr-ft^3 figure in Ref. 6.

22. **10/8/90, M.D. Britton calculations, 105-A Heat Balance, Evaporation, EDT #125702.** Calculations are based on the use of 1972 analytical data for a 1978 heat release calculation, without considering radioactive decay from 1972 to 1978. See Ref. 20.

23. **10/26/90, Letter, W.H. Hamilton, Jr. to R.E. Gerton, Single-Shell Tank 241-A-105 Leak Volume Estimate, 8901832B R2.** Good source of information and reference to documentation. Estimates cooling water leakage at 50,000 gal to 960,000 gal.

24. **4/26/71, ARHCO memo, C.M. Walker and G.C. Oberg to L.W. Roddy, Process Limits and Waste Disposal in A, AX, and AY Farm Tanks.** Instructs that for Tank 105-A, level is to be maintained between 28 and 31 inches, except as required for sluicing. Circulators 2 and 4 are to be set at 10 ft^3/min, 1 and 3 at 0 ft^3/min.

25. **7/8/64, Report by L.W. Roddy and B.V. Snow, <u>Operation of a Boiling-Waste Tank Farm</u>, HW-83215.** To ensure continuous agitation, the circulators are water-flushed daily and diluent-flushed every month.

26. **SOP 200.2.28, <u>In-Tank Sprinkling</u>.** States that water is sprinkled in 500-gallon batches, not to exceed 1,000 gallons per week.

27. **SOP TO-020-320, <u>In-Tank Sprinkling</u>, replaces SOP #200.2.28, released 11/2/78.** States that water is sprinkled 500 gallons at a time, not to exceed 1,000 gallons per week.

28. **9/30/76, Occurrence Report 76-124, <u>Maximum Liquid Level Limit Exceeded</u>.** States that the operating and specification limits specify an operating range of 18 to 20 inches.

29. **5/26/78, Occurrence Report 78-49, <u>Radiation Peak Increase in 105-A Lateral 14-05-03 Exceeding Increase Criteria</u>.** Cites water spill on 2-23-78 as a possible cause of increased activity observed in laterals under Tank 105-A.

30. **8/25/70, ARHCO Memo, C.M. Walker and W.C. Schmidt to L.W. Roddy, <u>Process Limits and Waste Disposal in A and AX Farm Tanks</u>.** Tank 105-A level to be maintained at 30-32 inches.

31. **6/2/70, ARHCO memo, C.M. Walker and W.C. Schmidt to L.W. Roddy, <u>Process Limits and Waste Disposal in A and AX Farm Tanks</u>.** Tank 105-A liquid level to be maintained at 28-31 inches, except as required for sluicing. Circulators 2 and 4 set at 10 ft^3/min, 1 and 3 at 0 ft^3/min.

32. **3/13/78, Letter, R.C. Routson and J.B. Sisson to E.H. Carbaugh,** Raw Water Leak in 241-A Tank Farm on February 23-24, 1978. Leak was from a broken pipe. Approximately 60,000 gallons infiltrated into the soil.

33. **2/23/78, Occurrence Report 78-24,** Release of Raw Water in 241-A Tank Farm. Rupture of M5a line released approximately 60,000 gal of water, causing a cave-in between Tank 102-A and Tank 105-A.

34. **1/3/90, WHC Internal Memo 13314-89-132, D.A. Reynolds to R.E. Raymond,** Temperature Rise in Laterals Under 241-A-105. Temperatures have increased due to shutdown of the portable exhauster in Spring 1989. Prompt repair of the exhauster is recommended.

35. **10/8/90, WHC Internal Memo, W.H. Hamilton Jr. to distribution,** October 5 Tank 105A Meeting. Contains comments contributing to recent history of Tank 105-A.

36. **4/30/91, Personal Communication, V.D. Maupin.** Penetration of the bulge in Tank 105-A was completed on October 7, 1978.

37. **8/5/77, Letter, J.H. Roecker to O.J. Elgert, re: Ref. 3 above, R77-99.** This questions certain data presented in Reference 3, but is not completely clear as to what the correct data should be.

38. **2/3/65 through 5/16/66, Meeting Minutes re:** Bumping of Tank 241-A-105, **various authors (Archives Box No. G 85617).** Good information on observations and investigations made at the time.

39. **1/30/74, Letter, M.C. Fraser and D.J. Larkin to H.P. Shaw, Radionuclide Inventories in Leaks from Transfer Lines and Tanks**. States that no data are available.

40. **December 1975, Final Environmental Statement, Waste Management Operations, Hanford Reservation, ERDA-1538**. This copy is not complete. Good general information on the site.

41. **June 1983, K.S. Murthy et al., Assessment of Single-Shell Tank Residual Liquid Issues at Hanford Site, Washington, PNL-4688 UC-70**. Estimated leakage from Tank 105-A is less than 5,000 gallons. States that Ru is not absorbed in the soil, but moves with the leaked water.

42. **10/9/84, Report by D.C. McCann and T.S. Vail, Waste Status Summary, September 1984, RHO-RE-SR-14 September 1984.** States that the estimated amount leaked from Tank 105-A is small.

43. **8/17/88, WHC Internal Memo, C.M. Walker to G.L. Dunford, Summary of Leaker or Questionable Integrity Tanks, 13331-88-460.** States that less than 5,000 gallons have leaked from Tank 105-A.

44. **5/17/89, Letter, R.J. Baumhardt to R.E. Gerton, Single-Shell Tank Leak Volumes, 8901832B R1**. Leakage previously reported from Tank 105-A is 5,000 gallons.

45. **June 1979, A.M. Tallman et al., Geology of the Separation Areas, Hanford Site, South-Central Washington, RHO-ST-23, Rockwell Hanford Operations, Richland, Washington**. Reports the general geology of the Separations Area and defines in detail the geologic environment of the local site (241-A Tank Farm).

46. **April 1976, W.H. Price, and K.R. Fecht, Geology of the 241-A Tank Farm, ARH-LD-127, Atlantic Richfield Hanford Company, Richland, Washington.** Reports the generalized geology underlying the 241-A Tank Farm.

47. **10/30/90, Electronic Mail Message, Rick Raymond to Distribution, Fact Sheet on Tank A-105 Temperatures.** Contains contributions to recent history of Tank 105-A.

48. **10/29/90, Electronic Mail Message, E.J. Campbell to R.E. Raymond, RTQ, Tank 105-A.** Describes current status of Tank 105-A.

49. **December 1981, Report by R.E. Isaacson and K.A. Gasper, A Scientific Basis for Establishing Dry Well-Monitoring Frequencies, RHO-ST-34.** Excellent report, describing behavior of subsurface plumes.

50. **4/12/78, Letter, R.C. Routson to S.P. Stalos, Changing Radiation Profiles in 105-A Lateral Dry Wells Since November 1977, and Letter to E.H. Carbaugh on Raw Water Leak in 241-A Tank Farm on February 23-24, 1978, 60110-78-003.** States that 5,000 gallons per month of water is being added to the tank, and suggests that as much as 570,000 gallons may have leaked to the soil. Recommends 1) a mass balance of the fate of the water entering the tank and 2) analysis of the sludge and a determination of the amount of radioactivity being leached.

51. **June 1991, Report by G.K. Allen, Tank 241-A-105 Evaporation Estimate 1970 through 1978, WHC-EP-0410.** Undergoing the approval process as this is written, this report postulates heat generation in 2,365 ft^3 of sludge in the tank, and further heat generation in the soil under the tank. For 150 ft^3/min air flow through the tank, estimated evaporation is 366,501 gallons.

8.0 APPENDICES

8.1 **History of Tank 105-A**

8.2 **Water Added to Tank 105-A from 11/01/73 through 12/04/78**

8.3 **Bibliography**

8.1 History of Tank 105-A

Operating Phase

1955	Tank 105-A was built and placed in reserve status, containing a six-inch water heel. (Ref. 3)
5/1962	Water depth has increased to 18 inches, due to addition of water to vapor seals. (Ref. 3)
5/1962	Pumped 330,000 gal. of supernate from Tank 103-A to Tank 105-A over a period of 20 days. Average rate 16,500 gal/day. Temperature increased from 46° to 56 °C. (Ref. 3)
7/27/62	Transferred 180,000 gal. from Tank 103-A. Temperature in Tank 105-A went up 8 °C. (Ref. 3)
7/27/62 to 12/12/62	Removed 63,000 gal. of supernate from Tank 105-A for cesium recovery in PUREX. (Ref. 3)
12/12/62	Pumped 252,000 gal. from Tank 101-A into Tank 105-A. Temperature in Tank 105-A went up 14 °C. (Ref. 3)
12/1962 or 1/1963	Blended Tank 105-A with the air-lift circulators. Transferred 490,000 gal. of supernate to Tank 103-C. Pumped remainder of Tank 105-A into Tank 101-A, leaving 10-inch heel in Tank 105-A. (Ref. 3)
1/1963	Started preparing Tank 105-A for full radiation level PUREX waste storage. Added 330,000 gal. of thermally hot tank farm condensate. Heated tank from 50 °C to 62 °C. (Ref. 3)
1/1963 to 3/5/63	Added full radiation level PUREX waste to bring tank up to boiling temperature. (Ref. 3)
3/5/63 to 11/19/63	Continued filling of Tank 105-A per routine, with no problems. (Ref. 3)
7/1963	Tank liquid level reached 280 inches. (Ref. 3)

9/25/63 and others	Observed unexplained changes in liquid level (Plotted data, Archives box 100429).
11/19/63	Tank 105-A about half-full. Radiation detected in one lateral, indicating a tank leak. A leak in the side wall was postulated as a possibility so the tank liquid level was reduced by self-concentration to 260 inches. A slow decline of the radiation intensity in the lateral indicated the leak had stopped either because of self-sealing or because the liquid level was below the leak point. (Ref. 3)
12/1963 to 9/1/64	Held tank level at 260 inches until the salt concentration operating limit was reached. Started increasing liquid level. (Ref. 3)
10/1964	Reached the postulated leak level, with no evidence of any new leakage. (Ref. 3)
12/1964	Tank 105-A is filled to capacity. (Ref. 3)
1/28/65	Sudden steam release occurred in Tank 105-A. Steam vented from riser on Tank 103-A for about 30 minutes. No wastes were added to Tank 105-A on this day except for tank farm condensate. Inspection confirmed damage to structure of tank and its internals. (Ref. 3)
3/1965	Intensity of radiation in the leak detection lateral has decayed by a factor of 3, to approx. 50,000 c/m. (Ref. 3)
3/8/65	Radiation in #3 lateral increased to about 195,000 c/m, then remained constant. No radiation increases were detected in the other laterals or the vertical wells. (Ref. 3, 37)
After 3/8/65	Three test wells were drilled along the side of the tank, directly over the lateral that indicated leakage. No radioactive contamination was detected in the soil removed from these wells, and maximum temperature in the test wells was 206 °F. These data indicated the leakage was small. (Ref. 3)
4/1965	Temperature of 325 °F found in Lateral #3, about 90 ft horizontally from the caisson. Temperature was monitored, and by June 1966 had dropped to about 220 °F, which was slightly warmer than Laterals #1 and #2. (Ref. 3, 37)

Late 1965 Conclusions reached: (Ref. 3)

1. Tank had ceased to leak
2. Leakage was small - no significant contamination of atmosphere or groundwater.
3. Tank liner was bulged upward, creating an 80,000-gal. void space under the liner.
4. It is unlikely that sludge is in the void.
5. Need to vent the bulged area.
6. The probability of sludge leaks into the soil is low.
7. Leakage of supernate would not cause high temperatures.
8. Dryout of the sludge might allow temperatures to go to 10,000 °F or higher.
9. Overheated sludge would produce NO_2 gas and fission products.
10. An atmospheric release would be more hazardous than a release to the soil, due to the sorption capacity of the soil.
11. Potential hazards will decrease as time passes, due to decay.

11/1965 Full sluicing capability was in place. (Ref. 3)

Fall 1965 Decision made to maintain Tank 105-A in a static condition until scheduled for waste management processing, or until finding evidence of further tank deterioration. (Ref. 3)

4/1967 Cyclic liquid level variation began to occur. Level dropped 9-10 inches in minutes, stayed stable for 20 hours, returned to original level in about a day. (Ref. 3)

10/2/67 Low-level radiation detected in #2 leak detection lateral. Heat generation rate has decreased by a factor of 4 since the steam release event. Plans and preparations for sluicing are under way. (Ref. 3)

10/31/67 Hazards analysis shows that the risks of high waste temperatures are far greater than the risks of water going into the soil, even assuming gross leakage of wastes. (Ref. 3)

8/1968 Reduced liquid level from the operational level of 142 inches to 35 inches. (Ref. 8)

OPERATIONAL PHASE
TO AUGUST 13, 1968

Sluicing Phase

8/14/68	Sluicing of the sludge within the tank began. (Ref. 8)
11/6/69	Water level 31.5 inches. (Ref. 10)
6/2/70	Tank 105-A liquid level to be maintained at 30-32 inches, except as required for sluicing. (Ref. 31)
8/25/70	Tank 105-A liquid level to be maintained at 30-32 inches, except as required for sluicing. All liquid transfer routings have been removed from Tank 105-A; liquid level maintained through use of a Rainbird sprinkler. (Ref. 30)
9/9/70	Water level 24 inches. Sluicing is under way. (Ref. 10)
11/17/70	Sluicing of the tank was stopped. (Ref. 8)
11/25/70	Water level 26 inches. Much sludge has been removed since Sept. 9 photos. (Ref. 10)

Cooling Water Additions

11/1970 to 11/24/71	Liquid level was held between 34 and 38 inches. (Ref. 8)
2/1971 through 4/1971	Water addition to tank was 750 gallons per day. (Ref. 23)
2/1971	Added 180 gal/day circulator flush water. (Ref. 23)
4/26/71	Tank 105-A liquid level to be maintained at 28-31 inches, except as required for sluicing. Liquid level maintained through use of a Rainbird sprinkler. (Ref. 24)

5/1971 through 3/1972	Added 120 gal/day and stopped flushing the circulators. (Ref. 23)
11/24/71	Liquid level was allowed to decrease to 13.5 inches. (Ref. 8)
12/1971 and 1/1972	Liquid level was not recorded, but is assumed that the level was maintained around 13.5 inches. (Ref. 8)
1/27/72	Level was brought up to 19 inches. (Ref. 8)
1/1972 to 8/1973	Tank level was held at or near 16 inches. (Ref. 23)
1/27/72 to 9/13/73	Liquid level allowed to slowly drop to 15 inches. (Ref. 8)
4/1972 to 6/1973	Gaps in the data. Water additions inferred from the liquid level measurements. (Ref. 23)
9/1973 to 10/1973	Tank level was allowed to drop to 14.5 inches, and the rate of temperature rise increased. (Ref. 23)
10/26/73	Brought liquid level up to 18 inches. Maintained level by water additions at 17.25 to 18.5 inches until January 1978. (Ref. 8)
8/4/75	A flush valve was inadvertently left open and the level of the tank went up to 23.75 inches. No water was added to the tank again until September 11, 1975, when the level had again returned to 18 inches. (Ref. 8)
About 1/1976	Water is being added through an impulse sprinkler in Riser R-8. The water is added in 500 to 1,000 gallon increments approximately seven times each month. Over the past year, water has been added at an average rate of 1,000 gallons per week. If all this water is evaporated by radioactive decay heat, the corresponding heat generation rate would be about 50,000 Btu per hour. (Ref. 8)

10/7/76 Color photos difficult to interpret. Water level 17.5 inches. (Ref. 10)

12/1977 Woodward-Clyde completed stereo photography interpretation of the ruptured tank bottom. Events of the "bump" appear to have occurred in this sequence: (Ref. 10)

1) Steam pressure underneath buckled the tank floor upwards.

2) Steel of the wall was bent upward, and the edge of the liner was bent downward.

3) Then, the 90° floor-to-wall weld ripped.

2/23/78 Approximately 60,000 gallons of uncontaminated water was spilled to the ground in the 241-A tank farm and infiltrated into the soil. Scintillation probes which measure total gamma activity indicated that some radionuclide movement took place to the depth of the laterals adjacent to tanks 106-A and 103-A tank, thus indicating that the wetting front advanced to at least 60 feet below the ground surface. (Ref. 32)

Apparent cause of the 60,000 gallon water release was the rupture of the M5 a line about 30 feet southeast of the 501 Building. The water channeled from the site of rupture, along a pipe encasement, to the area of cave-in between Tanks 102-A and 105-A. (Ref. 33)

5/8/78 to 5/15/78 Radiation peak in lateral 14-05-03 increased from 8,600 counts per second to 18,000 counts per second on 5/15/78. Possible causes being investigated: 1) water being added to tank to control temperature, and 2) water spilled to the ground on 2/23/78 east of 241-A Tank Farm. (Ref. 29)

10/7/78 The bulged tank bottom was penetrated, using a chemical milling procedure, and the gas trapped beneath the bulge was sampled. (Ref. 36)

10/7/78 Tests for hydrogen gas beneath the bulged bottom were completed, and no hydrogen was found. (Ref. 23)

12/4/78 Last water addition to the tank. (Ref. 23)

Current Phase

3/1979	The tank is interim stabilized. (Ref. 35)
10/1985	The tank is interim isolated. (Ref. 35)
4/1/89	Shut P-17 exhauster down due to high HEPA inlet temperature. Highest temperature in #3 Lateral is 240 °F. (Ref. 47)
11/27/89	The hottest point under Tank 105-A has reached a temperature of 290 °F. (Ref. 34)
3/17/90	The exhauster was restarted. Temperature under Tank 105-A is 308 °F. (Ref. 48)
8/20/90	The exhauster was shut down. Temperature under the tank was 270 °F. (Ref. 48)
9/30/90	Restarted exhauster. (Ref. 47)

8.2 Water Added to Tank 105-A from 11/1/73 through 12/4/78

WATER ADDED TO TANK 105-A
FROM 11/1/73 THROUGH 12/31/74

Source: **Tank Farm - 241A Status Report (TRAC 0058, TRAC 0059)**
Status Report - 241A Tank Farm (TRAC 0059)

DATE	GALLONS SPRINKLED	CIRCULATORS FLUSHED	DATE	GALLONS SPRINKLED	CIRCULATORS FLUSHED
Nov. 1	500		Dec. 20	250	
2		X	21	250	X
4		X	24	250	X
5	500	X	25		X
6	500		26	250	X
7	500	X	27	500	
8	500		28	250	X
9	250	X	31	500	X
12	500	X	Jan. 2	250	X
13	500		3	250	
14	250	X	4	250	X
15	250		7	500	
16	250	X	8	400	
19	500	X	9	250	X
20	250		10	250	X
21	250	X	11	250	X
22	250		14	250	X
23	251	X	15	250	
27	250		16	250	X
28	240	X	17	250	
29	250		18	250	
30	250	X	21	250	
Dec. 1		X	22	250	
4	250		23	250	X
5	250	X	24	Say 250	
6	250		25	250	X
7	250	X	28	250	
10	500	X	29	250	
11	250		30	250	X
12	250	X	31	250	
13	250		Feb. 1	250	X
14		X	2		X
17	500	X	4	250	X
18	500		5	250	
19	250	X	6	250	X
Subtotal	**10491**	**21**	**Subtotal**	**9150**	**20**

WATER ADDED TO TANK 105-A
FROM 11/1/73 THROUGH 12/31/74 (Cont.)

DATE	GALLONS SPRINKLED	CIRCULATORS FLUSHED
Feb. 7	250	
8	250	
11	250	
12	250	X
13	250	
14	250	
15	250	
18	250	X
19	250	
20	250	
21	250	
22		X
25	250	X
26	250	
28	250	
Mar. 1	250	X
3		X
4	250	
5	250	X
6	250	
8	250	
11	250	
12	250	
13	250	
14	360	X
18	300	
19	250	
20	250	
21	250	X
22	350	X
23		X
25	250	
26	250	
27	250	
28	250	X
29	250	
30		X
31		X
Apr. 1	350	
2	250	
Apr. 3	250	
4	250	
5	250	X
Subtotal	**9860**	**15**

DATE	GALLONS SPRINKLED	CIRCULATORS FLUSHED
Apr. 6	150	
7	250	
8	250	X
9	250	X
10	250	X
11		X
15	250	X
17	400	
19	250	
22	250	X
23	500	
24	250	X
26	250	X
29	500	X
30	250	
May 1	250	X
2	250	
3	250	X
6	250	X
7		X
8	250	X
9	250	
10	250	X
11		X
13	250	X
14	250	
15	250	X
16	250	
17	250	X
18		X
19		X
20	250	X
21	250	
22	250	X
23	250	
24	500	X
27	250	X
29	250	X
30	250	
31	250	X
Jun. 1		X
2		X
3	240	X
Subtotal	**9790**	**30**

WATER ADDED TO TANK 105-A
FROM 11/1/73 THROUGH 12/31/74 (Cont.)

DATE	GALLONS SPRINKLED	CIRCULATORS FLUSHED
June 4	250	
5	250	X
6	250	
7	250	X
10	250	X
11	250	
12	250	X
13	250	
14	250	X
17	250	X
19		X
20	250	
21		X
23	241	
24	500	X
28	250	X
July 2		X
3		X
5		X
9	550	X
10	500	
11	250	
12	250	X
15	250	X
16	250	
17	250	X
18	250	
19	250	X
22	250	
23	250	
24	250	X
25	500	
26		X
29	500	X
30	250	
31	250	X
Aug. 1	500	
2		X
5		X
7	250	X
9		X
12	500	X
13	250	
Subtotal	10291	27

DATE	GALLONS SPRINKLED	CIRCULATORS FLUSHED
Aug. 14	500	X
16	250	X
19	250	X
21	250	X
22	240	
23	240	X
26	500	X
27	240	
28	240	X
30	500	X
Sept. 2	500	
4	240	X
5	240	
6	Say 240	X
9	480	X
10	480	
11	500	X
13	250	X
16	250	X
17	500	
18		X
19	240	
20	500	X
24	250	
25		X
26	250	
27	250	X
30	500	X
Oct. 1	240	
2	1500	X
3		X
4		X
7		X
8	240	X
9	1500	
11		X
14		X
16	250	X
18	240	X
21	250	X
22	240	
23	500	X
25	240	X
Subtotal	14080	31

WATER ADDED TO TANK 105-A
FROM 11/1/73 THROUGH 12/31/74 (Cont.)

DATE	GALLONS SPRINKLED	CIRCULATORS FLUSHED	DATE	GALLONS SPRINKLED	CIRCULATORS FLUSHED
Oct. 28	240	X	Dec. 2		X
29	240		3	240	
30	240	X	4		X
31	240		6		X
Nov. 1		X	9	240	X
4	240	X	11	240	X
5	350		12	240	
6		X	13	240	X
8	240	X	15	250	
11	240		16	240	X
12	240		17	240	
13	240	X	18	240	X
14	240		19	240	
15	260		20		X
18	240	X	22	500	
19	500		23	240	X
20		X	25	240	
21	240		26	240	
22	Say 240	X	27		X
23		X	30	720	X
24		X	31	Say 240	
25		X			
27		X			
28		X			
Subtotal	**4230**	**15**	**Subtotal**	**4590**	**12**

Average rate for the time period $= \dfrac{72482 + (180)(171)}{(61 + 365)}$

$= 242$ gal/day

Heat required to evaporate $= \dfrac{(242)(8.35)(1000)}{(24)}$

$= 84{,}200$ Btu/hr

WATER ADDED TO TANK 105A
FROM 1/1/75 THROUGH 12/31/75

Source: Status Report 241-A Tank Farm (Archives Box No. 58071)

DATE	GALLONS SPRINKLED	CIRCULATORS FLUSHED	DATE	GALLONS SPRINKLED	CIRCULATORS FLUSHED
Jan. 1	240		Feb. 25	240	
3		X	26		X
4	Say 250		27	480	
6	480	X	28		X
8		X	Mar. 3	525	X
9	480		4	250	
10		X	5		X
13	670	X	6	1030	
15	250	X	7		X
16	240		10		X
17	240	X	12	644	X
18		X	14	565	X
20	480	X	17		X
21	240		18	756	
22		X	19		X
23	240		21	941	X
24	240	X	24		X
27	480	X	25	500	
28	240		26		X
29		X	28	880	X
30	480		31	250	X
31		X	Apr. 1	240	
Feb. 3	480	X	2	240	X
4	240		3	240	
5		X	4	240	X
6	480		7	500	X
7	Say 1750	X	8	750	
10		X	9		X
12		X	11	500	X
14		X	14	500	X
18	240		16	400	X
19	240	X	18		X
20	240		21	500	X
21	480	X	22	500	
24	240	X	23		X
Subtotal	**9640**	**23**	**Subtotal**	**11671**	**25**

WATER ADDED TO TANK 105A
FROM 1/1/75 THROUGH 12/31/75 (Cont.)

DATE	GALLONS SPRINKLED	CIRCULATORS FLUSHED
Apr. 24	500	
25		X
28	700	X
30	300	X
May 2	600	X
5	500	X
7		X
9		X
12	500	X
14		X
15	500	
16		X
19		X
20	500	
21	500	X
23		X
28	500	X
30		X
June 2	589	
4	710	X
6	536	X
9	550	X
10		X
11		X
12		X
13	500	X
16	500	
18	500	
20	500	X
23		X
25		X
30		X
Jul. 2	500	
7	500	X
9	500	X
13		X
14	500	X
16		X
18	500	X
21	250	X
22	250	
23		X
24	525	
Subtotal	**13010**	**34**

DATE	GALLONS SPRINKLED	CIRCULATORS FLUSHED
Jul. 28	600	X
30		X
Aug. 1	450	X
4		X
6	6000	X
8		X
25		X
26		X
27		X
28		X
Sept. 8	565	
12	700	
15	500	
17	500	
19	357	
22	782	
24	500	
29	600	
Oct. 1	600	
3	300	
6	500	
10	800	
15	700	
16	800	
17	800	
22	500	
24	800	
27	500	
29	500	
31	500	
Nov. 4	500	
7	690	
10	380	
11	150	
13	350	
16	250	
17	750	
20	900	
24	550	
25	500	
Dec. 2	700	
5	700	
9	707	
Subtotal	**29781**	**10**

WATER ADDED TO TANK 105A
FROM 1/1/75 THROUGH 12/31/75 (Cont.)

DATE	GALLONS SPRINKLED	CIRCULATORS FLUSHED
Dec. 11	700	
15	700	
18	750	
23	650	
26	350	
29	650	
Subtotal	**3800**	**0**

Average rate for 1975 $= \frac{64102 + (180)(92)}{365}$

$= 221$ gal/day

Heat required to evaporate $= \frac{(221)(8.35)(1000)}{(24)}$

$= 76{,}900$ Btu/hr

WATER ADDED TO TANK 105-A
FROM 1/1/76 THROUGH 12/31/76

Source: Status Report-241A - Tank Farm and
Tank Farm Liquid Level Readings (Archives Box No. 58073)

DATE	GALLONS SPRINKLED	DATE	GALLONS SPRINKLED	DATE	GALLONS SPRINKLED
Jan. 2	1000	May 15	240	Jul. 9	240
7	600	17	240	12	240
9	500	18	240	13	1000
13	500	21	241	14	240
16	750	22	266	15	240
19	600	23	251	16	240
23	800	24	244	17	240
27	600	25	240	19	240
30	650	27	240	20	240
Feb. 4	625	28	240	21	240
6	725	31	240	22	240
13	900	Jun. 2	240	23	240
20	500	3	240	25	240
23	535	4	240	26	240
27	500	7	240	27	249
Mar. 1	800	8	240	28	240
5	500	9	240	29	240
12	500	10	240	30	240
15	600	11	240	Aug. 1	240
22	750	14	240	2	250
26	700	15	240	3	240
29	800	17	240	4	240
Apr. 2	800	18	240	5	400
7	800	21	240	6	240
9	415	22	240	11	500
14	240	23	240	12	510
16	244	24	240	30	800
28	240	25	240	Sep. 2	850
May 4	Say 500	28	240	6	300
6	250	29	1000	7	800
7	250	30	240	10	500
8	253	Jul. 1	240	14	2000
10	250	2	240	29	736
11	250	7	240	Oct. 6	100
12	250	8	240	11	500
Subtotal	**19177**	**Subtotal**	**9202**	**Subtotal**	**14295**

WATER ADDED TO TANK 105A
FROM 1/1/76 THROUGH 12/31/76 (Cont.)

DATE	GALLONS SPRINKLED	DATE	GALLONS SPRINKLED
Oct. 12	500	Nov. 28	500
13	500	29	Say 250
15	500	Dec. 3	500
19	500	7	500
22	500	9	500
24	500	10	500
27	1000	13	500
Nov. 1	1350	14	500
2	1000	15	500
14	250	23	500
16	500	24	500
18	500	27	400
20	500	29	850
25	500	31	250
Subtotal	**8600**	**Subtotal**	**6750**

Average rate for 1976 $= \frac{58024}{366}$

$= 159$ gal/day

Heat required to evaporate $= \frac{(159)(8.35)(1000)}{(24)}$

$= 55{,}300$ Btu/hr.

WATER ADDED TO TANK 105-A
FROM 1/1/77 THROUGH 12/31/77

Source: **Status Report - 241A Tank Farm and Tank Farm Liquid Level Readings (Archives Box No. 61285)**

DATE	GALLONS ADDED	DATE	GALLONS ADDED	DATE	GALLONS ADDED
Jan. 8	500	Jun. 21	500	Oct. 30	500
14	500	27	500	Nov. 2	500
15	500	29	300	5	1000
21	500	Jul. 1	500	10	500
25	500	2	500	15	500
27	1000	8	500	18	500
Feb. 7	1000	9	420	25	Say 500
13	500	13	500	30	600
19	1000	16	500	Dec. 4	500
25	1000	19	Say 500	7	450
Mar. 3	1000	24	500	12	Say 750
10	500	29	1000	19	750
13	808	Aug. 5	Say 1000	25	500
19	1000	9	500	30	668
27	Say 500	13	417		
Apr. 4	500	18	Say 750		
6	500	20	700		
9	500	23	Say 500		
12	500	Sept. 1	Say 250		
16	1000	2	500		
21	500	6	508		
24	600	9	500		
27	Say 500	12	500		
May 2	504	15	Say 500		
6	600	20	500		
9	Say 1000	21	500		
14	500	24	500		
17	750	27	500		
22	Say 1000	Oct. 5	500		
29	1000	6	500		
30	1000	9	Say 1000		
June 9	500	17	999		
10	500	23	500		
13	500	25	500		
20	500	28	500		
Subtotal	**23762**	**Subtotal**	**19344**	**Subtotal**	**8218**

Average rate for 1977 $= \frac{51324}{365}$

$= 141$ gal/day

Heat required to evaporate $= \frac{(141)(8.35)(1000)}{(24)}$

$= 48{,}900$ Btu/hr

WATER ADDED TO TANK 105-A
FROM 1/1/78 TO 12/4/78

Source: **Status Report - 241A Tank Farm, and Tank Farm Liquid Level Readings (Archives Box No.68653)**

DATE	GALLONS SPRINKLED
Jan. 3	500
5	Say 500
13	500
17	500
22	500
26	500
31	500
Feb. 6	1000
7	500
18	500
20	500
26	625
Mar. 4	500
6	946
9	910
24	Say 500
26	400
29	400
31	998
Apr. 6	Say 500
10	500
11	500
18	500
22	1000
29	952
May 4	500
7	500
11	500
27	516
June 2	500
7	500
11	500
16	Say 1500
20	500
27	437
Jul. 2	Say 1500
5	500
9	500
15	Say 500
Subtotal	**24184**

DATE	GALLONS SPRINKLED
Jul. 18	500
26	585
28	500
Aug. 1	593
6	500
12	805
16	516
23	500
24	500
25	113
26	502
30	300
Sept. 3	602
7	Say 500
11	495
13	474
19	513
21	741
22	400
30	500
Oct. 8	503
10	516
16	500
21	500
25	481
31	500
Nov. 3	516
7	537
16	600
21	500
25	538
29	559
Dec. 4	410
Subtotal	16799

WATER ADDED TO TANK 105-A
FROM 1/1/78 TO 12/4/78 (Con't.)

Average rate for the time period $= \frac{40983}{338}$

$= 121$ gal/day

Heat required to evaporate $= \frac{(121)(8.35)(1000)}{(24)}$

$= 42,100$ Btu/hr

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8.4 Sludge and Supernate Analyses

TK-105-A SLURRY COMPOSITION [(1)]
CURIES/LITER

	Separated Sludge [(2)]	Supernate
Sr-90	33	0.009
Cs-137	6.5	8.1
Ce-144	216	<0.005
Ru-106	68	<0.02
ZrNb-95	220	<0.005

(1) On May 1, 1965, sample taken of slurry above settled sludge.
(2) Centrifuged sample 14 volume percent sludge.

The above data are from Reference 3.

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