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87

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by

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July 1993

Abstract

This report is an analysis of data from a variety of sources on Hanford waste tank farm, 241-C. This farm consists of twelve 530 kgal and four 55 kgal waste tanks. The data sources used in the analysis include a comprehensive fill history, a variety of core analyses, temperature logs, and leak histories for the tanks on C-Farm. The report addresses safe storage issues on C-Farm, which include: 1) an organic layer in C-103; 2) heat generating high strontium-90 sludges in C-106 as well as C-107, C-104, and C-103; 3) the presence of substantial amounts of ferrocyanide sludge in C-109 and C-112; 4) leaks of tanks and transfer lines; and 5) the potential for criticality because of high inventory of fissionable isotopes.

The report concludes that: 1) the organic layer should be removed from tank C-103; 2) tank C-106 is now on the high heat watch list and should remain there. Tank C-105, though, should be removed from that list; 3) substantial amounts of ferrocyanide sludge remain only in two tanks, C-109 and C-112. Although C-108 and C-111 are both on the FeCN watch lists, most of their FeCN sludges have been removed. Furthermore, recent analytical results for C-112 sludge show peak energy contents of only 30 cal/g (dry wt.). This low energy content suggests that most of the ferrocyanide has decomposed and the removal of tank C-112 and indeed all C Farm tanks from the FeCN watch list is therefore recommended.

The report further concludes: 4) although there have been four different confirmed leaks on C-Farm, a fifth leak at C-110 has never been confirmed. For example, no dry well activity has ever been found around C-110. Furthermore, the level drop that was attributed to a leak from C-110 in 1969 was due to a measurement error. It is recommended, therefore, that C-110 be reevaluated as an assumed leaking tank. Finally, 5) even the most conservative interpretation of the data for plutonium inventories does not even come close to a criticality hazard for any of the measured tanks on C Farm, which are C-102, C-103, C-104, C-105, C-106, C-110, and C-112. Furthermore, none of the other waste tanks on C Farm are expected to have any greater hazard for criticality than the tanks already measured.

Introduction

All questions about safety, retrieval, and pretreatment of the High Level Waste (HLW) in Hanford waste tanks begin with a simple one—"What is in the tank?" Although several strategies have been developed in the past for defining tank wastes in terms of fill histories at Hanford, none has been completely satisfactory for describing the contents of individual tanks. This report is an attempt to build on all of these previous attempts and further incorporate even more of the information that is available about these waste tanks into a description about each of the waste tanks.

A previous report[1] (hereafter referred to as ABB-93) on C-Farm discussed many of the safe storage issues for C-103, which include a floating layer of organic TBP/NPH (tributyl phosphate and normal parafinic hydrocarbon) as well as a sludge layer of high strontium within the tank. The information in the present report is a more comprehensive look at all of the tanks on C Farm as well a the refinement of a strategy for defining the contents of all Hanford waste tanks, especially for tanks with incomplete or conflicting information.

Background

There have been a variety of different approaches for defining the nature of the waste tanks at Hanford. Basically, all of these approaches used historical fill records in combination with other information on composition of waste types. This is a brief description of the various approaches about which I am aware.

An effort to derive tank contents by Allen[2] compiled analytical data for 13 Redox tanks, 8 Purex sludge tanks, and 8 salt cake tanks in an attempt to define the nature of the sludges based on an average these tank's solids. Allen also compiled the types and amounts of chemicals that were actually used in the various processes at Hanford over the years, and derived ideal compositions for many different sludges. Unfortunately, many of the analytical results were incomplete or questionable, and no decent tank history was then available to really "define" any of the tanks that were used in the samples, and many of Allen's "Redox" sludges contained other solids as well, such as CWR and 1C. For example, Allen assumed that tank U-110 was an example of a Redox sludge, when in fact it contains primarily 1C sludge.[3]

Anderson compiled quarterly waste status summary reports into a single large report,[4] (hereafter referred to as "Anderson-90") which contained information about the total volumes of waste in each of the Hanford waste tanks, as well as some information about which types of waste were placed in which

[1]Agnew, S. F.; Baca, P.; Biehl, F. "Tank History Analysis: C-Farm and C-103," LAUR-93-1989, June 1993.
[2]Allen, G. K. "Estimated Inventories of Chemicals Added to Underground Waste Tanks, 1944 through 1977," ARH-CD-6108, March 1976.
[3]Brown, T. M. and Jensen L. "Tank Characterization Report for Single-Shell Tank 241-U-110," WHC-EP-0643, April 1993.
[4]Anderson, J. D. "A History of the 200 Area Tank Farms," WHC-MR-0132, June 1990.

tank. (This report was largely complete in 1979, but was not issued until 1990.) Basically, Anderson-90 contains the total waste and solids volumes from 1944 to 1980 for single and double shell tanks, as well as a rough breakdown of wastes as to types and volumes for many of the tanks. There was also an attempt to keep track of waste types, but the methodology was not consistently applied to describing all types of wastes and their origins. Moreover, waste names would change with time, and the systematics of the methodology also evolved.

Later, Jungfleisch[5] (hereafter referred to as Jungfleisch-84) developed an S2K (System 2000 K) database called TDF (Transaction Data File), which he used as input to a computer program called TRAC. This data base was a compilation of all tank transactions, which are the volume transfers from process plants or from other tanks, from 1944 to 1980. TDF was used as input to the TRAC (hereafter referred to as W-TRAC to differentiate it from other TRAC programs) program, along with fuel element composition and waste stream composition, and the result was a listing of tank contents by major chemicals and radio nuclides. This effort was the most comprehensive and complete that has ever been performed for the Hanford tanks, and this data largely forms the basis of what I report. Unfortunately, the input data was still riddled with numerous errors, the W-TRAC program had many bugs, and it was never optimized nor benchmarked, with the result that the tank inventories of radio nuclides and major chemicals are often in gross error.[6,7,8,9] One notable deficiency, for example, was the use of an earlier report by Murphy[10] to define the amounts of so-called "accounted" radio nuclides (Pu, U, Np) in single-shell tank wastes. The Murphy report dates to 1964, and therefore did not even address any wastes that came into SST's after that time. Most of C-Farm's sludges came after 1964.

There was another attempt[11] to categorize the contents of waste tanks by using tank history information and process knowledge. This report by Hill and Simpson developed a sorting model (SORWT) based on Anderson-90. They derived some 29 categories of tanks, and checked these categories against the analytical results of a set of 19 tanks. The strategy of this report is certainly valid, but the information base (i.e. Anderson-90) was not sufficiently complete to derive waste contents for all tanks, and there were tanks whose wastes were incorrectly identified. Furthermore, it was not clear from Hill and Simpson how

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[5]Jungfleisch, F. M. "Preliminary Estimation of Waste Tank Inventories in Hanford Tanks through 1980," SD-WM-TI-057, March 1984.

[6]Jungfleisch, F. M. "Hanford High-Level Defense Waste Characterization—A Status Report," RH-CD-1019, July 1980.

[7]Ryan, J. L.; Morgan, L. G. "Review of the Chemistry Assumptions and Limitations for TRAC," WHC-EP-0075, January 1985.

[8]Morgan, L. G.; Schulz, W. W.; Adams, M. R.; Owens, K. W. "Summary of Single-Shell Tank Waste Characterization—1985 to 1987," WHC-EP-0085, 1987.

[9]Kummerer, M.; Estey, S. D.; Piepho, M. G.; Powers, G. L. "Near-Term Safety Study of Interim Stabilization of Non-Watchlist Tanks," WHC-SD-WM-RPT-044, September 1992.

[10]Murphy, J. G. "Tank Farm Data," ARH-1994, July 1964.

[11]Hill, J. G.; Simpson, B. C. "Sort On Radioactive Waste Type Model: A Method to Sort Single-Shell Tanks into Charactistic Groups," WHC-EP-0449, August 1991.

much of an improvement these new tank groupings represented over what had been used in the past for predicting waste tank contents. I believe that this effort was severely hampered by the incomplete historical information in Anderson-90.

Yet another attempt to define waste tank contents was reported by Rouse, et al.[12] This report's estimates were based on a breakdown of wastes into four fundamental types: supernatant, sludge, salt cake and slurry. The amounts of these components within each of the tanks was taken without judgment from Hanlon,[13] and then each of the waste types was assigned a composition. The waste compositions evidently were derived from the IDB[14] (integrated data base), but a letter report[15] that was attached to the Hanford update[16] to IDB had different compositions, although the categories were similar. At any rate, using these compositions, Rouse, et al. simply calculated each tank's contents based on the Hanlon breakdown of each tank into the four waste types.

Unfortunately, Rouse, et al.'s approach can not describe each tank's contents and is only appropriate for deriving *averages* of all of the tanks. Furthermore, their waste type "supernatant" composition is suspect, since it does not even agree with the IDB values for "liquid". Rouse, et al. reported the supernatant as 1.6 g/cm^3 density and 12 M Na and the slurry as 1.3 g/cm^3 and 7 M Na. These waste descriptions need to be reviewed. Also, Rouse et al.'s waste type "sludge" is an average composition for all sludges. It does not distinguish between Purex sludge, which contained some 8 Ci/L of Sr-90, and cladding waste sludge, which has very little strontium. Therefore, the Rouse et al. representation of individual tanks is of dubious value and actually misleading in many cases.

General Approach

I have developed a strategy for defining the layers of sludge in the C-Farm tanks and comparing these definitions with other observations about the tanks. That is, with a prediction of a particular layer of Purex sludge in a tank, there should be consistent analytical and thermal measurements that reflect that inventory. In other words, to determine what is in the tank, start with what was put in the tank. Derive the amount of solids with each waste type and then check what was taken out of the tank. Were any solids lost? Then consider

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[12]Rouse, J. K.; McLaughlin, T. J.; Airhart, S. P.; Jensen, E. J.; Lindberg, S. L.; Robinson, D. D.; Cruse, J. M. "Underground Storage Tank Integrated Demonstration Participant Site Characteristic Summary," WHC-EP-0566, 1992.

[13]Hanlon, B. M. "Tank Farm Surveillance and Waste Status Report for March 1992," WHC-EP-0182-48, August 1992.

[14]ORNL document (no author), "Integrated Data Base for 1991: U. S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics," DOE/RW-0006, Rev. 7, 1991.

[15]McGuire, H. E. "Revision to 1983 Submission to the Integrated Data Base and Comments on the Draft Document," letter to W. R. Corman, July 19, 1983.

[16]Roecker, J .H. "Hanford High-Level Waste Update to the 1992 Integrated Data Base," 9201075B-R1, letter to S. N. Storch, March 31, 1992.

analytical information and determine whether the analytical data is consistent with the fill history.

Finally, with addition of high Sr sludge, the thermal history of the tank should reflect any high heat layers in the waste. Are there temperatures within the sludge layers that are consistent with the Sr sludge layer?

My intent is that not only will the information contained within this report be useful, but that the strategy that I developed and used for C-Farm will be applicable to the remaining tanks as well. Thus, other issues with regards to the waste tanks, such as safety, characterization, retrieval and pretreatment might likewise become much better defined.

This report uses information[17] that is available on the fill history of C Farm on the Hanford reservation to define what is in these waste tanks. Basically, the strategy is divided into three parts. When primary waste (primary designates a direct addition of waste from a process plant) is added to a tank, the solids within the waste settle and form a layer on top of any previous layers within the tank. There is a given amount of solids in nearly every waste stream at Hanford, and the sedimentation of these solids normally occurs in the first tank (primary receiver) that receives that waste. This will be shown in greater detail later in the report.

In a manner very similar to that of Hanlon or Rouse, I define four primary waste forms for Hanford: sludge, salt cake, salt slurry, and other liquid, which generally follow Hanford terminology as much as possible. I will then use these primary forms as a foundation for a secondary characterization this will predict specific inventories for each tank. Within these major waste forms, only sludge and other liquid exist on C-Farm, and sludge is by far the dominant C-Farm constituent. Hanlon reports 2,146 kgal (1 kgal = 1,000 gal.) of total waste for C Farm, comprising 1,977 kgal sludge and 169 kgal supernatant. I will use the terminology "other liquid" instead of supernatant in my report, since supernatant has been used to describe, among other things, the liquid portion of salt slurry. I wish to keep "salt slurry" and interstitial liquids distinct from "other liquid" among the major waste types.

Likewise, I will use the terminology "salt slurry" to represent either double shell slurry, double shell slurry feed, or any salt cake that has shown significant and unexplained level fluctuations over the past five years. Since salt slurry exists in single-shell tanks as well as double-shell tanks (there are many SST's with DSSF as well as any salt cake tank with level fluctuations, both waste types I define as salt slurry) the name is a misnomer. Furthermore, within my definition, many salt cake wastes in SST's are actually salt slurries. However, since there are no salt slurries in C Farm, redefining salt cake will not be an issue for C Farm.

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[17]Jungfleisch, F. M. "Supplementary Information for the Preliminary Estimation of Waste Tank Inventories in Hanford Tanks through 1980," SD-WM-TI-058, June 1983.

Sludge is the sediment from primary waste additions and generally consists of metal oxides, hydroxides, carbonates, silicates, phosphates, sulfates, and other insoluble species. The major components are $Al(OH)_3$, $NaAlO_2$, $FeO(OH)$, Na_2SiO_3, $Cr(OH)_3$, Na_2SO_4, Na_3PO_4, $Na_2NiFe(CN)_6$, Na_2ZrO_3 and Na_2CO_3. Note that some of these species are fairly soluble and therefore exist in solution as well as in the sediments. However, by far the largest inventory of these components exist as sediment. For example, even though sodium carbonate is fairly soluble, it is often precipitated since it is usually in excess of its solubility limit at the level of sodium in the wastes.

Liquids that exist as distinct layers over sludge layers I define as "other liquid" (or OLAF for "Other Liquid And Floats"). Note that these other liquids may be very different from the interstitial liquid that exists within the sludge voids, since the other liquid includes any liquids that have been added to the tank and not just the liquid supernatant that remains after primary waste sedimentation. OLAF's consist of a wide range of concentrations of the primary components mentioned above, but all in solution. Other liquids also includes floating organic layers and floating material such as "crusts". One important OLAF in C Farm is the floating organic layer in C-103, and the histories of organic layers in C-102 and C-104.

All wastes in Hanford tanks can be defined in terms of layers of these major components, and in C Farm, all the tank wastes can be defined in terms of layers of sludge and OLAF. The strategy that I will use in this report largely reflects this major breakdown of wastes. That is, the first step in defining the contents of a waste tank is to trace the accumulation of sludge due to primary waste additions. The sludges that accumulate from primary waste additions tend to have very characteristic per cent volume of the total waste, and this fact facilitates tracking the accumulation of those sludges.

The next stage is to attempt to reconcile the sometimes sparse solids record with the history of waste amounts and to derive any inadvertent solids transfers out of the tank or from another tank, i.e. solids transfers entrained within liquid flows or dissolved by incoming liquid during waste addition and removal. I will show that CWP waste is particularly prone to inadvertent entrainment and/or dissolution, and 1C waste, which is actually 50% cladding waste, shows similar behavior. The aluminum content of CWP produces very high porosity sediments, and any $Al(OH)_3$ in the precipitate will be very susceptible to redissolution by caustic supernatants, forming the very soluble aluminate ion, $Al(OH)_4^-$. When I determine that there has been appreciable removal of CWP solids, I will not distinguish between entrainment and dissolution, and will assume that either or some combination of both processes has actually moved the CWP solids.

The other category for C-Farm consists of other liquids, which exist only in C-103, C-106, and C-109. There are two separate liquid phases in C-103, an aqueous layer and a floating organic layer of TBP/NPH. Therefore, the composition of the wastes in C-Farm largely reduces to a definition of the sludge histories of these tanks.

Approach for C Farm

An accurate solids history for each tank in C Farm defines the sediment in terms of historical layers of waste types. If one then applies some knowledge of sludge compositions, this information on layering allows one to derive a representation of the composition of the entire tank's sediments. Thus, there are two critical steps for predicting C Farm sediment compositions. First, deriving the sludge history in term of layers of waste types, and second, assigning a chemical composition for each sludge waste layer. These compositions are stated in a variety of sources, including Anderson-90, Allen, Jungfleisch, and Hill, and will be derived in another report.

I will first describe the solids histories for each of the C Farm tanks and derive a best estimate of the solids layering. These solids layers are designated by the nomenclature that has been used at Hanford for a number of years, such as R for Redox high level waste and P for Purex high level waste. These terms are described in the Appendix. Note that I am using these terms to describe the solids associated with these major waste types.

There will be an uncertainty associated with each layer thickness that derives from several sources. First, the solids measurement itself may be in error. Second, the amount of solids that derived from any waste was undoubtedly variable and not strictly the same for every batch. Third, solids can be inhomogeneously distributed because of heaping or cratering of the solids layers. Heaping occurs under waste inlets because of solids that de-entrain from the liquid flow and therefore do not distribute evenly around the tank. Craters form during waste removal as a result of solids entraining in the liquid flow around pump inlets. For example, there was a report[18] of substantial entrainment of TFeCN (in-tank or in-farm ferrocyanide scavenging sludge) in C-112 that produced a large variation in FeCN layer thickness in one side of the tank as compared with the other. I have ignored any such variations in my analysis, and have used only the solids volume reports for each tank. I assume, then, that my analysis represents the average value of solids in each tank, and that there are undoubtedly inhomogeneities in the layers of solids. Note that solids volume measurements are often based not only on actual level measurements, but also on other data, such as in-tank photographs of surface irregularities.[19]

Solids level measurements are normally performed in risers at the outer edge of 530 kgal tanks (risers 1, 2 or 8, Fig. 1). Because of a 12" dish in the tank, the solids level will touch the bottom of each tank at the point that there is still 12.5 kgal in the tank. Therefore, a the tank volume is (2.75 x height in inches) + 12.5 = volume of tank in kgal (one inch is only 2.75 kgal of tank volume above the dish). This has several implications. First, any volume less that 12.5 kgal reported for a tank is suspect, including zero volume. Most "zero" volumes for these tanks must be considered nominal unless they are otherwise

[18]Simpson, B. C.; Borsheim, G. L.; Jensen, L. "Tank Characterization Data Report: Tank 241-C-112," WHC-EP-0640, April 1993.

[19]Boyles, V. C. "Single-Shell Tank Stabilization Record," WHC-SD-RE-TI-178, Rev.3, July 1992.

corroborated. In particular, during sluicing operations, a zero volume is often reported for the tank contents even though a doughnut heel[20] was nearly always present following sluicing. These doughnut heels were a result of the reluctance of operators to direct a sluice nozzle at the walls of the tanks. Any volumes less than 12.5 kgal for dished tanks are estimates based on some other measurement or simply a nominal value.

Finally, cores removed from waste tanks are usually removed from risers along the outside edge of the tank, for example, risers 1, 2, or 8 in Fig. 1. These same risers are very near the waste fill and removal points. Typically risers 6 or 9 are removal or pump points, while risers 2 or 3 are fill points. The FeCN tanks C-108, 9, 11, and 12 used a reversed configuration starting in 1956, and riser 2 has a floating suction pump installed and riser 6 was the waste entry point. That configuration has been used ever since for these four tanks. In any event, the cores often sample waste that has been disturbed by mounding or cratering phenomena and these cores are not necessarily representative of the average waste layers within the whole tank. A detailed comparison of the core data with my layer predictions will be in a following report.

History of C-Farm

C-Farm was completed in 1945 and put into service shortly thereafter. C-Farm tanks were meant to provide waste storage for the $BiPO_4$ process, which was the first process used for plutonium purification. This process ran in B-Plant from 1945-1952 and T-Plant until 1956 and produced three waste types. The first type was metal waste (MW), which contained 90% of the fission products, 1% of the plutonium, and virtually all of the uranium of the burnt fuel. MW was meant to be later recovered and reprocessed to extract the uranium for reuse.

First cycle (1C) waste contained the remaining 10% fission products and was mixed with decladding waste. (In Purex and Redox, decladding wastes (CWP or CWR) were kept segregated from high level wastes.) Second Cycle (2C) waste was the result of the second plutonium purification cycle, and this waste was very low in fission products, although it contained a large residue of $BiPO_4$. Finally, there was the transformation of the crude plutonium product into metal with a LaF process, which produced waste called 224-F or LaF.

The first major campaign for C-Farm involved disposal of 3,180 kgal of MW and 3,180 kgal of 1C and 2C wastes. C-101,2,3 and C-104,5,6 were each used as three tank cascades and were filled with MW from 1946-47. C-107,8,9 and C-110,111,112 were also each used as three tank cascades that filled during the same period with 1C and 2C wastes. The 2C wastes were very low activity and the supernatant from these wastes was normally cribbed (sent to the ground) once the solids had settled. However, very little 2C waste was added to C-Farm, and so what 2C was added, was commingled with 1C. Therefore, no cribbing of 2C supernatant occurred on C-Farm.

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[20]See photographs of sluiced tanks.

Riser Diagram C-106

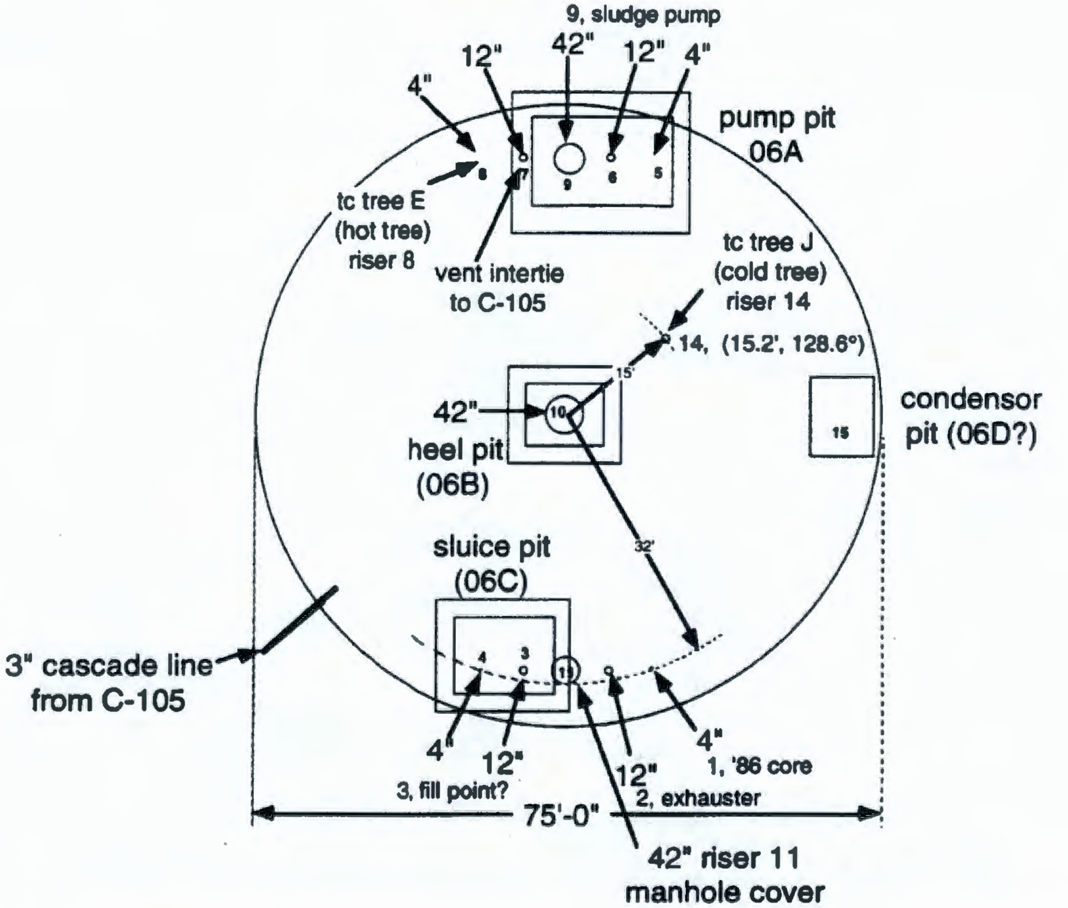

Fig. 1. Riser diagram for 241-C-106. Largely typical of C-Farm, but not all risers or pits are the same on all tanks.

The 1C supernatants from C-107,8,9,10,11,12 were then concentrated in 242-B evaporator in 1952. The next major campaign for C-Farm involved recovering the six tanks of MW (C-101 through C-106) and reprocessing them through the U-Plant or Uranium Recovery Plant. Three pits were constructed at each of C-101 through C-106 as shown in Fig. 2. These pits were designated the pump, slurry, and heel pits and were designed to facilitate the removal of liquid and sluicing of solids that were to be removed from these tanks. Tanks C-107 through C-112, on the other hand, were never meant to be recovered and therefore had no such pits built over them. This recovery operation was detailed in the UR Plant manual.[21]

[21] no author, "Uranium Recovery Plant Technical Manual," HW-19140, November 1951.

The uranium recovery campaign created two gallons of waste for every gallon of MW processed and so a scavenging operation involving precipitation of cesium with a $NiFe(CN)_6^{2-}$ was undertaken. This operation was performed in the CR vault and involved the tanks C-108, C-109, C-111, and C-112 for settling and storing the FeCN sludge.

The third major campaign for C-Farm was the cesium/strontium recovery operation. This campaign involved the use of C-105 and C-106 as supernatant feed tanks for cesium recovery and strontium sludge washing. Cesium and strontium recovery were performed in B-Plant and involved a solvent extraction process for strontium, neptunium, and rare earths and an ion-exchange process for cesium. It was during this campaign that high strontium sludges were inadvertently placed into C-106 and C-105, as well as intentionally distributed into C-103, C-104, and C-107.

The waste from B-Plant processing was of two primary types, B (high-level) and BL (low-level) wastes. B waste was the high level waste that was processed as a result of Purex and BL was the low level waste stream from those same processes. Of B and BL sludges, only BL or B-Plant low-level waste is present on C-Farm. The other type of wastes associated with the cesium/strontium recovery were CSR, SRR, and AR-002. CSR and SRR were wastes generated by the extraction of cesium from supernatants (CSR) and the extraction of strontium from sludges (SRR). These supernatants were those recovered from wastes throughout Hanford, but the sludges were recovered only from A-101,2,3,4,5,6 (1,285 kgal, '68-2 to '78-2) and AX-101,2,3 (188 kgal from '75-3 to '77-3), as well as AX-104 (55 kgal in '77 and '78).

The supernatants (22,926 kgal from '67-3 to '80-4) were largely routed through C-105, but also through BX-104 (5,143 kgal), C-110 (73 kgal) and AX-101 (259 kgal). The wastes that derived from these operations, however, were routed to tanks outside of C Farm.

The AR-002 solids (so-called strontium terminal solids or SRS solids) came from solids washing in cell AR-002 in AR Vault. These solids were washed in preparation for their dissolution in nitric acid and for being fed into the strontium recovery process, with the supernatant that derived from these washings recycled to C-106 and eventually into the cesium recovery through C-105. However, there was a problem with solids settling and about 93 kgal of solids were inadvertently transferred[22] to C-106 from AR-002 along with supernatant, and then 24 kgal of that amount that was in C-106 was inadvertently transferred to C-103 from C-106 as well. The solids that were being washed in AR-002 in 1970 came from A-106, which was a primary waste receiver for Purex from '60-4 to '63-1. A-106 also received OWW from '63-4 to

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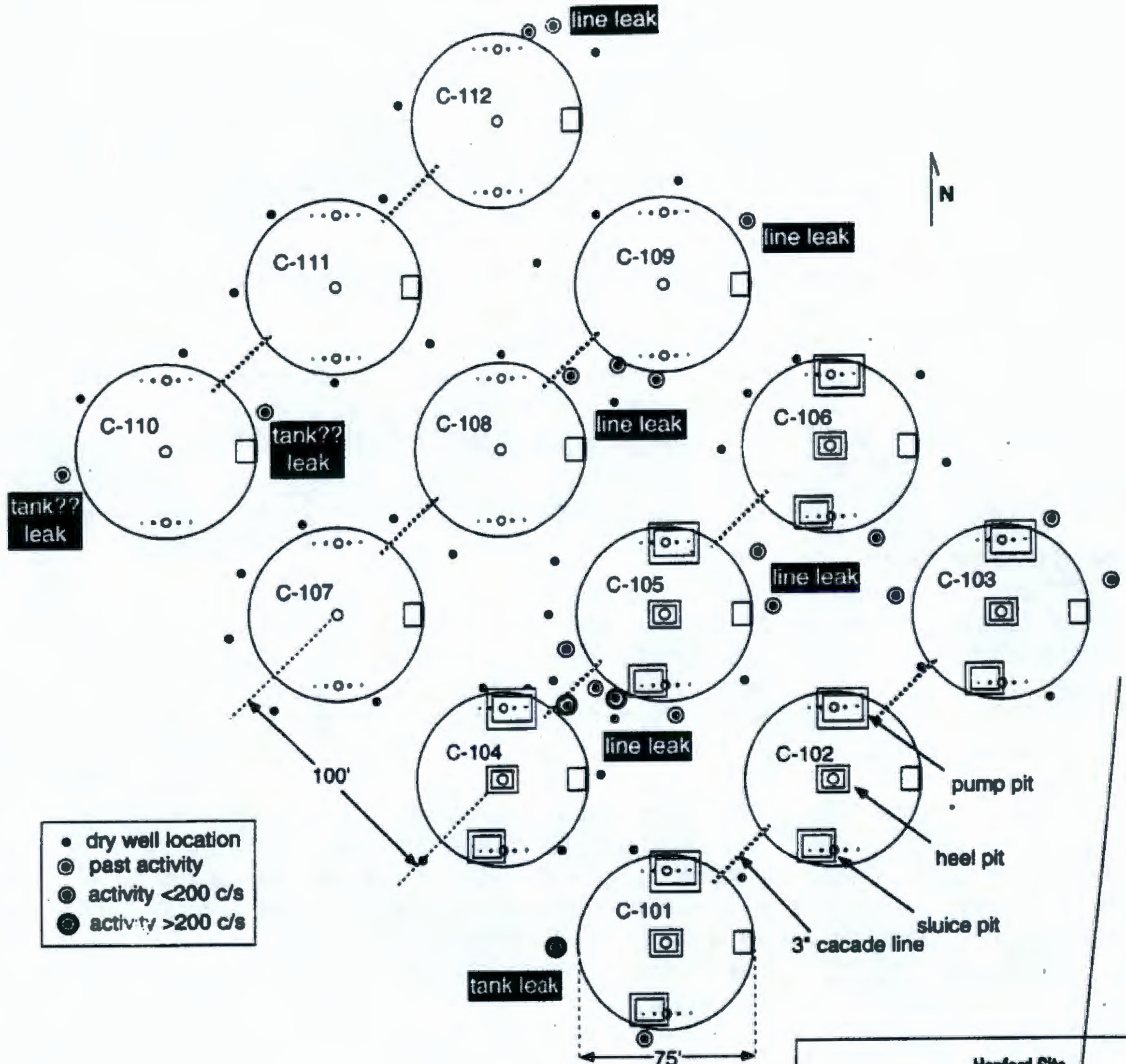
[22]Babad, H. "An Overview of Progress Made Toward Resolving Priority One Safety Issues," WHC-EP-0606, December 1992.



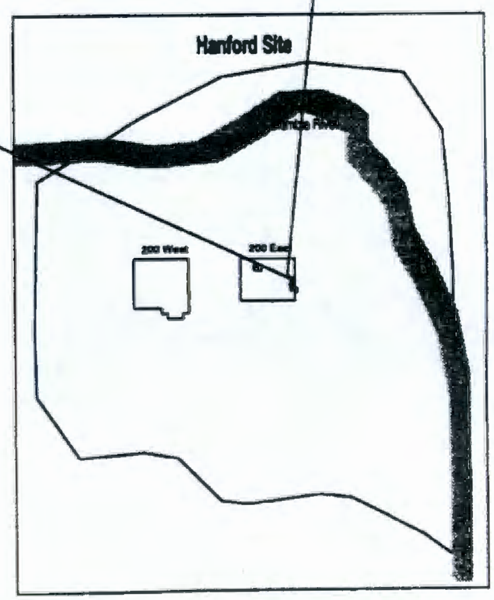


Fig. 2. Layout of 241-C Farm on Hanford Site.

'68-2, but very little solids derived from OWW waste. However, A-106 did show an unusually large solids accumulation, 8.1 vol%, for its Purex waste additions, as opposed to to the more typical 2.2 vol%, as shown in App. 1. In anay event, some 156 kgal of solids were sluiced from A-106 between '69-4 to '71-1, and evidently the washed solids did not properly settle in AR-002 and were largely transferred to C-106.

Although the above three major campaigns largely describe the wastes that were placed into C-Farm, there were other uses for C-Farm tanks. For example, C-102 acted as a CWP receiver (11,803 kgal for '60-3 to '69-4) and an OWW receiver (1,833 kgal for '68-2 to '69-1). C-104 was a CWP receiver (1,118 kgal for '56-1 to '57-2 and 4,351 kgal for '69-4 to '72-3) and an OWW receiver (5,163 kgal for '69-4 to '72-4). In fact, many tanks on C Farm were used as either CWP or OWW receivers.

Safe Storage Issues in C-Farm

There are several safe storage issues for C-Farm. First, the noxious vapor emissions, which are largely attributed[1] to the organic layer that is now in C-103, have been a hazard for workers on C Farm for many years. The nature of the organic layer and the vapor in the dome space has also been reported,[23,24] and there is a report[25] on the continued safe storage of the organic layer in C-103 as well.

A second safe storage issue is the heat loads due to the presence of high strontium sludges in several C-Farm tanks. There is a layer of high strontium sludge in C-106 that I estimate to be 69 kgal (C-106 is a high-heat watch list tank), although other estimates vary widely. Other high Sr-90 sludge layers according to my analysis are 24 kgal in C-103, 12 kgal in C-104, 17 kgal in C-105, and 29 kgal in C-107. These "strontium" sludges have varying concentrations of strontium, but all derive from Purex high level waste (P waste). P waste was produced in the Purex plant and placed largely in A and AX farms, although some was placed directly into C-Farm tanks. This "P" waste had a nominal 2.2 vol% settled solids (see App. 1), and these solids contained virtually all of the strontium-90 from the original fuel elements (as well as all the Pu). Strontium in Purex waste should be about 9.0 Ci/L based on the flowsheet,[26] which suggests a strontium in the sludge of 409 Ci/L with a 2.2 vol% sludge. My calculations, however, suggest that the strontium was only about 0.3 Ci/L in Purex waste, which is derived from the largest strontium

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[23]Strachan, D. M.; Schulz, W. W.; Reynolds, D. A. "Hanford Site Organic Waste Tanks: History, Waste Properties, and Scientific Issues," PNL-8473, January 1993.

[24]Huckaby, J. L. "An Engineering Assessment of the Aerosol and Vapor Flammability in 241-C-103," WHC-SD-WM-ER-181, December 1992.

[25]Babad, H.; Crippen, M. D.; Turner, D. A.; Berber, M. A. "Resolving the Safety Issue for Radioactive Waste Tanks with High Organic Carbon," WHC-SA-1671-FP, February 1993.

[26]Fission yields for Cs and Sr are 6.2 and 5.8 %, respectively, and there is ~0.9 mol Pu produced per mol fissions. A 0.24 g/L Pu in Purex HA feed means 2.6 g Pu processed per L Purex neutralized waste, or 0.011 mol Pu processed per liter waste. This would be 0.011 / 0.9 = 0.012 mol fissions per liter waste. This predicts 7.4e-4 mol/L Cs and 7.0 e-4 mol/L Sr in waste, which is 8.9 and 9.0 Ci/L, using 1.19e4 and 1.28e4 Ci/mol, for Cs and Sr, respectively.

concentration that I have seen reported which was 14 Ci/L, which agrees with Sr concentration in the layers in C-103 and C-106. I do not understand why there is a factor of 18 difference between these numbers.

In any event, if I assume the original strontium sludge was 14 Ci/L, it will have decayed to its present level of 6-8 Ci/L, as shown in Fig. 3.

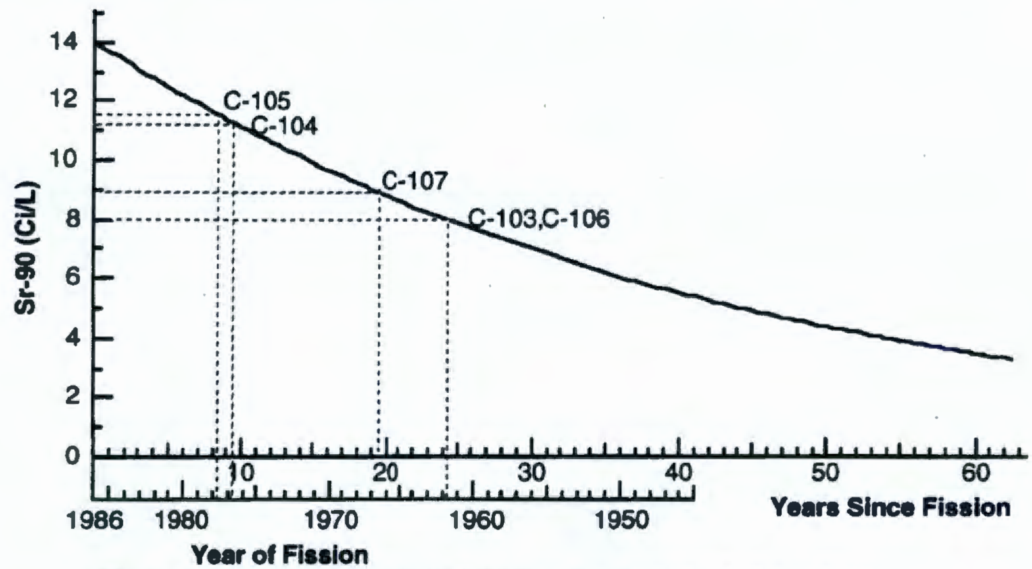

Fig. 3. Change in Sr-90 concentrations versus years since fission in Purex sludge that begins at 14 Ci/L. Referenced to 1986.

Therefore, the solids of Purex high level waste sludge have a very large amount of strontium-90 and therefore a large radiolytic heat source. Using 0.023 and 0.016 Btu/hr/Ci Sr-90 and Cs-137 respectively, the calculated heat loads due to strontium and cesium are shown in Table 1.

Upon a suggestion from Ralph Crowe of WHC, I have included in my tabulation not only the peak waste temperature, which is the standard reported tank temperature, but also the *average* dome space temperature. This average dome space temperature is the average over seasonal changes for the last two years of recorded temperature data. Crowe has found[27] that as long as the heat losses for the tanks to the ground and air are the same, the average dome space temperature is proportional to the total heat generation rate of the tank. That is,

$$\text{total heat generated} = C_1 \times (T_{dome} - T_{reservoir})$$

where C_1 is some constant depended on the thermal diffusivity of the soil and the ventilation rate of the dome space. $T_{reservoir}$ is the average temperature of the reservoir, which I assume to be the average atmospheric temperature of C Farm, or 57°F. If I fit the known data for tanks C-103, C-104, and C-105, I find

[27] Crowe, R.; Kummerer, M.; Posma, A. "Estimation of Heat Load using Average Vapor Space Temperatures," in preparation, 1993.

that C_1 = 326 Btu/hr./°F. This analysis depends on the heat loss of theses tanks, in particular the ventilation, being identical, i.e. all passive. The ventilation rate for C-106 is much higher, since it is being actively ventilated, and so its dome space temperature is correspondingly lower. Likewise, C-105 has a tie line to

Table 1a.
Estimates† of Sr-90 sludge in C farm.

	C-103	C-104	C-105	C-106	C-107
est. Sr. sldg. (kgal)	24	12	17	69	26
Sr-90 (Ci/L)	8.0	11.1	11.5	8.0	?? (est. 9.0)
peak wst. temp. °F	126	??**	110	170*	135
tc	1	??**	1	1	3
avg. dome space temp °F	108	90	74	80* (est. 188 with no vent.)	112
total MCi Sr-90 (1986)	0.73	0.49	0.74	2.1	?? (est. 0.87)
total MCi Cs-137 (1986)	0.03	0.042	0.13	0.35	
total Btu/hr†† (1993)	17,300	10,100	16,250	45,800	(est. 17,900)

†All sample values given as analysed in 1986 and are not decayed to 1993. See references for various analyses. Temperatures were those provided by Hanlon.
**Higher temperatures occur when ventilation is off for C-106. Estimated dome space temperature was calculated using T_{dome} = 0.00307 x heat load + 57.*
***Temperatures have been recorded for C-104 in the range 160 to 290°F, but the measurements were labeled no good. In fact, the temperature measurements went bad shortly after the supernatant evaporated from C-104 in 1980.*
††Calculated using 0.023 and 0.016 Btu/hr./Ci for SrYZr-90 and CsBa-137, respectively. These values were further adjusted (decayed) to 1993 by multiplying by 0.85. Estimated values were derived using Btu/hr. = 326x (T_{dome} - 57°F). See text for details.

the C-106 ventilation, and its temperature is some thirty degrees lower than that predicted by this fit (see Fig. 4).

Using this expression, I estimate that the average dome space temperature for C-106 in the absence of ventilation would be 188°F. Likewise, I can estimate the heat loads of all the other tanks on C Farm, which I have shown in Table 1b, for which I have average dome space temperatures.

A third issue is the presence of varying amounts of ferrocyanide in C-108, C-109, C-111, and C-112. I estimate the amounts of ferrocyanide remaining in each of these tanks as 2, 44, 7, and 67 kgal of FeCN sludge, respectively (see

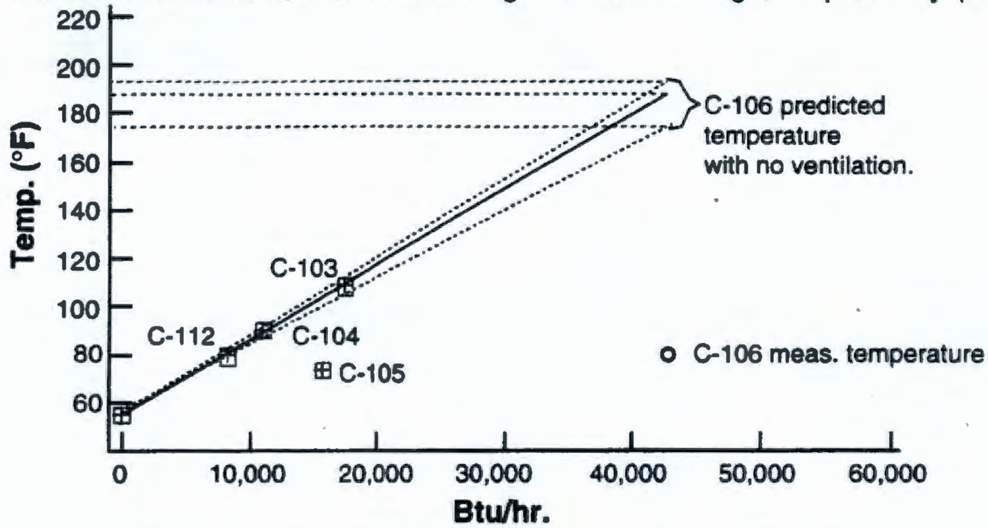

Fig. 4. *Fit of average dome space temperature versus heat load. Heat load is decayed from 1986 to 1993 by 15%.*

individual section for each tank). For C-109 and C-112, these values agree well with those of a previous report.[28] For C-108 and C-111, though, I have found much lower FeCN sludge amounts. Tanks C-108 and C-111 lost nearly all of their original FeCN sludge because of solids entrainment and/or dissolution during waste removals following the ferrocyanide campaign. In any event, a rather detailed core and analytical report[29] for C-112 has shown very little energy content with the FeCN sludge in C-112, even though this is the tank with the largest amount of FeCN sludge, as well as the highest concentration. The largest energy content was only 8.5 cal/g (30-40 cal/g extrapolated to dry material), while concern only begins for materials that are 100 cal/g or greater. Therefore, I find that there is no reactive hazard with ferrocyanide sludge on C-Farm.

The leak histories of C-Farm tanks are summarized in Welty,[30] with some other information in a report[31] that discusses the stabilization of C Farm tanks. In Welty, C-101 and C-111 are both listed as suspected leakers, while C-110 is listed as questionable integrity. However, only C-101 has shown appreciable dry well contamination, while C-110 has shown only nominal activity in two dry wells (02 and 09) and C-111 has shown no dry well activity at all. (In fact, the evidence suggests that C-111 has not actually leaked, as argued below.) I will

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[28]Borsheim, G. L. and Simpson, R. C. "An Assessment of the Inventories of the Ferrocyanide Watchlist Tanks," WHC-SD-WM-ER-133, October 1991.

[29]Simpson, B. C.; Borsheim, G. L.; Jensen, L. "Tank Characterization Data Report: Tank 241-C-112," WHC-EP-0640, April 1993.

[30]Welty, R. K. "Waste Storage Tank Status and Leak Detection Criteria," SD-WM-TI-356, Vols. 1 & 2, Sept. 1988.

[31]ibid Boyles 1992.

further argue that the proximity of the dry well activity around C-110 and the fill history of C-110 both suggest that its leak is also due to cascade line leaking.

Table 1b.
Average dome space and peak waste temperatures.

	C-101	C-102	C-108	C-109	C-110	C-111	C-112
avg. dome space temp. °F	90	94	72	76	67	75	80
peak wst. temp. °F	110	96	77	82	??	86	89
pred. total Btu/hr	10,800	12,100	4,900	6,200	3,300	5,900	7,500
total MCi Sr-90		not meas.					0.18
total MCi Cs-137		0.024					0.22
calc. 1993 total Btu/hr		>386 (Sr not meas.)					7,660

In addition to leaks from tanks themselves, there are reports of three separate transfer line leaks that resulted in surface and dry well contamination. They are a cascade line leak between C-104 and C-105, between C-108 and C-109, and a spill from a transfer line from C-112 to the 252-C diversion box. Activity in dry well 01 for C-112 is 11,000 c/s and is attributed to this spill.

Finally, for the important issue of criticality, there are no indications of concentrations of fissionable isotopes that are even close to hazardous on C Farm. The criticality level of a Pu solution in an infinite volume of pure water is 247 µCi/g, but the presence of neutron poisons and neutron leakage will increase that number significantly in actual waste tanks.[32] In any event, the largest concentration measured for any C Farm tank was 10.4 µCi/g for C-103, suggesting a very large safety margin for C-Farm as far as a criticality hazard is concerned.

The common criticality control[33] in Hanford waste process streams has been 2 g/L Pu-239/240, which is a concentration of 120 µCi/g. Once again, none of the analyses on C Farm are even close to this value. There is, however, another criticality specification of 50 kg *total* Pu-239/240 in any waste

[32] Krohn, B. J.; Perry, R. T. "Criticality Calculations for Tank SY-102", memo to Harold Sullivan, Feb. 10, 1993, N-12-93-066.

[33] (a) Bratzel, D. R. "Iron Chemistry in Plutonium Finishing Plant Waste," 65453-84-355, letter to D. M. Tulberg, Nov. 19, 1984. (b) Jones, B. L. "Iron Chemistry Analysis in Tank 102-SY," letter to L. M. Sasaki, 13314-88-034, Mar. 9, 1988.

tank at Hanford. My estimates for C-102, C-104, and C-106 all exceed this limit, and measured plutonium indicates these three tanks (and possibly C-103 if greater solids volumes are used, see below) exceed this limit as well. However,

Table 2.
Estimates of Plutonium Inventories for C Farm.

	meas. Pu kg †	calc. Pu kg. ††	TRAC Pu kg. †††	Vol. CWP kgal	Vol. P kgal	Vol. 1C kgal	Assign unk. layer	Solids Vol. kgal	meas. µCi/g †	dens. g/cc
C-101		8.9	1.7	35				88		1.5
C-102	91.5	84.9	33.3	369				423	2.54	1.35
C-103*	45.1	29.7	5.0	35	58		33 to P	62 (95)	8.6	1.34
C-104	67.6	63.2	11.7	145	97		85 to P	295	3.0	1.21
C-105	12.5	29.4	16.7	83	17			150	0.85	1.55
C-106	55.1	63.7	5.0	28	140		71 BL to P	197	3.1	1.43
C-107		16.3	5.0		26	249		275		1.5
C-108		0.3	1.5			19		66		1.5
C-109		0.2	.02	8		10		62		1.5
C-110	3.3	3.3	1.7			187		187	0.18	1.54
C-111		7.2	1.2			20		57		1.5
C-112	1.6	5.4	1.0	21				104	0.16	1.52

	µCi/g	Assumed Pu extraction efficiency for...	
CWP	2.7	99.95%	dissolution
P	4.5	99.90%	Purex
1C	0.18		

†Values reported in references for these tanks. Corrections to four report values by K. D. Fowler, ECN #164203, 164204, 164205, 164206, Sept. 27, 1991.

††Calculated using plutonium concentrations shown below table for CWP, P, and 1C wastes. Unknown solids in tanks C-103 and C-104 are assumed to be P waste for this calculation, and BL waste is set to that of P waste for C-106. These estimates assume no plutonium in UR or TFeCN layers.

†††TRAC values derived from 03/12/85 output.

*Average of values of two core composites, which were 10.4 and 6.8 µCi/g, and using the reported 62 kgal for solids volume . Note that each of the two cores had different solids levels than the official level, see text for details, and therefore an unaccounted 33 kgal of solids.

none of these tanks are anywhere close to a critical concentration of plutonium, and therefore do not constitute a criticality hazard.

There is also some inventory of another fissionable radionuclide, U-233, in the TH/THL (thoria wastes) solids that accumulated in C-102 and C-104. At the present time, I am unable to estimate these inventories because I lack a good estimate or measurement for U-233 in this waste type.

C-101

Tank C-101 received 1,590 kgal of MW from '46-1 to '46-4, which cascaded to C-102 and C-103, as shown in Fig 5. This MW was sluiced in 1952, and then C-101 received 1,066 kgal of UR waste from '53-2 to '53-4 and 660 kgal of CWP from '60-1 to '62-2. None of the other waste additions involved appreciable solids, and therefore these primary waste addition describe the solids layering quite well.

Table 3.
Estimates of Solids for C-101.

date	q	meas. solids	solids gain/loss	pred. layer	layer type	primary waste volume	comments
1952	1		0	0	MW	1,590	sluiced
1953	4		53	53	UR	1,066	
1958	1	98			meas.		ignore
1962	2		53		CWP	660	
1963	2	109	3		unk.		unk. gain
1983	3	88	-21	35	CWP		unk. loss

Based on this analysis, the bottom layer of C-101 is 53 kgal of UR sludge and the top layer is 35 kgal of CWP.

Tank C-101 had a liquid level decrease in Dec. '69 and was then pumped to a minimum heel. In 1970, activity was found in dry wells (09 read 11,690 c/s at 29' in '86-2 and 06 had 106 c/s at 38' in '86-2). C-101 was P-10/salt well pumped up till '79-2, and declared stabilized in 1984.

C-102

Tank C-102 received 1,060 kgal MW as cascade from C-101 from '46-2 to '47-4, and further cascaded 530 to C-103 (see Fig. 6). Following sluicing in 1952, C-102 received 230 kgal UR by cascade from C-101, and 267 kgal of CWP by cascade from C-101, these additions of which had few if any solids. A direct addition of UR (552 kgal '53-3 to '54-1) should have contributed solids, as shown in Table 4.

Most of the solids in C-102 came from direct CWP additions (11,803 kgal from '60-1 to '69-4, although an addition of 443 kgal thoria waste in '66-2 added a predicted 26 kgal solids in the middle of the CWP layers. I have attributed 5.8 vol% solids to the thoria waste.

The unknown gain of solids in '65-2 is likely a measurement error. Such errors would occur if, for example, the solids measurement is made near a crater in the solids layer, resulting in an anomalously low reading. We therefore assume that this unknown source is simply unaccounted CWP sludge.

The history of C-102 is somewhat complex, and therefore its layers will be correspondingly uncertain. The layering in C-102 is 28 kgal UR, 210 kgal CWP/Al, 26 kgal TH, and 144 kgal CWP/Al, and 15 kgal CWP/Zr. I have

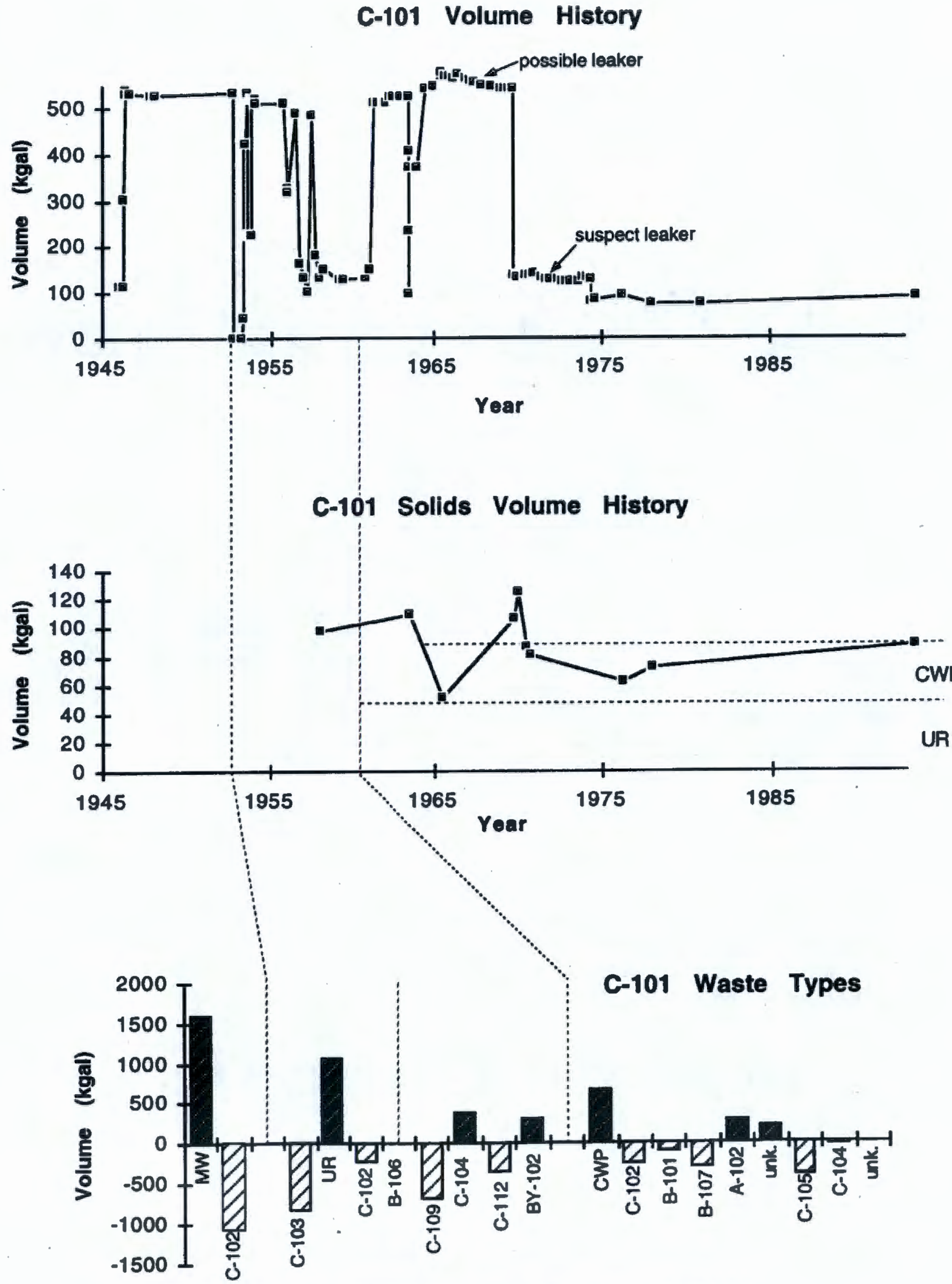

Fig. 5. Total volume, solids volume, and waste type histories for C-101.

assumed that the last unaccounted 78 kgal CWP was always present in the tank, and represented 63 kgal of the CWP/Al and 15 kgal CWP/Zr. The 102 kgal of CWP/Zr solids that were transferred out of C-102 presumably occurred with transfers to BX-103 (from 1968q2 to 1969q4, 4,333 kgal were relayed through C-102 to BX-103) and the final transfer to C-103 in '75q4, where 33 kgal were moved to C-103. Subsequent analysis will show if there indeed was any CWP/Zr moved to these tanks.

Table 4.
Estimates of Solids for C-102.

year	q	meas. solids	solids gain/loss	pred. layer	layer type	primary waste volume	comments
1952	1		0	0	MW	1,060	sluiced
1954	1		28	28	UR	552	
1958	1	98			meas.		ignore
1964	4		103		CWP/Al	4,135	2.5 vol%
1965	2		99		CWP/Al	1,220	8.1 vol%
1965	2	238	8	210	CWP/Al		unk. gain
1966	2		26	26	TH	443	5.8 vol%
1966	3		144		CWP/Al	1,783	8.1 vol%
1969	1				NPH/TBP	1,833	36 kgal organic
1969	4		117		CWP/Zr	4,665	2.5 vol%
1969	4	345	-180	81	CWP/Al		unk. loss
1976	1	62			meas.		ignore
??			63	63	CWP/Al		unaccounted?
??			15	15	CWP/Zr		unaccounted?
1982	2	423			meas		

An organic layer was noted in C-102 in 1969 and reported[34] to be 36 kgal. This organic layer was subsequently transferred[35] to C-103 in a P-10 pumping of C-102 in 1975. There is a recorded transfer of 111 kgal in '75-4, but the level change in C-102 indicated that only 25 kgal was transferred, with another 8 kgal in '78-3, for a total of 33 kgal. Presumably, this combined 33 kgal transfer was largely the organic layer, and would have left 3 kgal in C-102. P-10 salt well pumping was completed in '78-3, and C-102 was declared sound/deactivated.

A core was removed from C-102 in 1986 and analyzed in two separate

[34]Anderson, T. D. "Organics in 102-C Tank," letter to W. L. Godfrey, October 2, 1969.
[35]Carothers, K. G. "Tank 103-C Transaction History—Post January 1976," letter to D. A. Dodd, 13331-88-600, September 22, 1988.

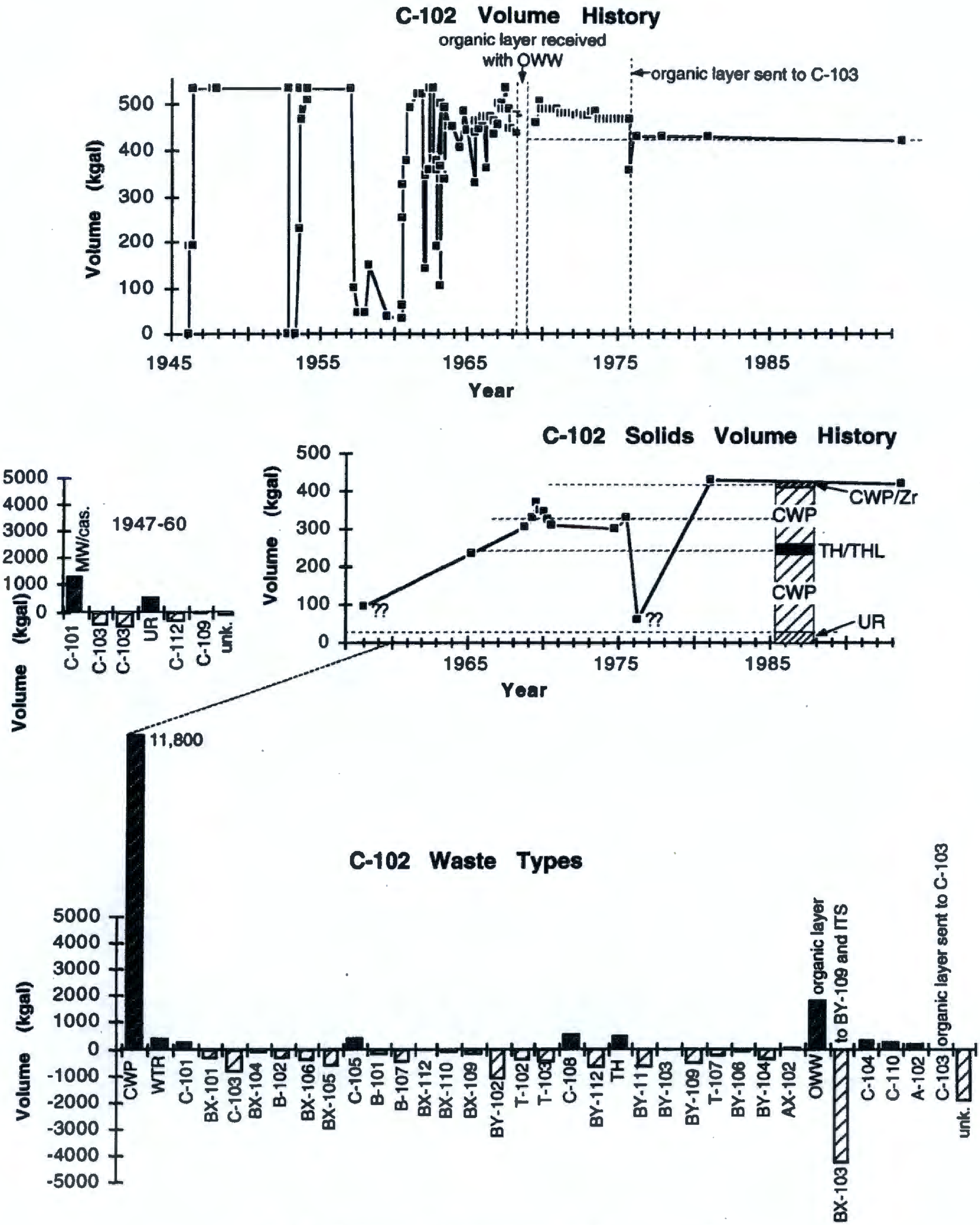

Fig. 6. Total volume, solids volume, and waste type for C-102.

reports.[36,37] These analyses are consistent with the CWP waste designation, (2 M Al, 3-4 M Na, low Fe, low Cr, and 0.5-1.0 M nitrate) and a more detailed comparison will be discussed in a later report. The Pu inventory based on this analysis would be 84.9 kg of Pu. This amount is consistent with the Purex flowsheet[38] for the dissolution, assuming a 99.95% plutonium dissolution efficiency for the decladding operation for Purex, and further assuming 8.1 vol% solids for CWP.

C-103

Tank C-103 received 530 kgal MW from '46-3 to '47-4 from C-102, and then was sluiced in 1952-53 (see Fig. 7). Then, C-103 received 167 kgal of cascaded UR from C-102, as well as 308 kgal UR waste from C-101, but these were supernatant transfers and no solids would have come from these transfers. The first solids accumulated with a CWP addition of 479 kgal from '60-2 to '60-4, as shown in the Table 5. Note that a previous report[1] suggested that this bottom heel might have had some MW remnant as well as CWP. However, the 8.1 vol% solids of the CWP additions have completely explained the solids observed within this tank, and now revises the estimate.

Table 5.
Estimates of Solids for C-103.

date	q	meas. solids	solids gain/loss	pred. layer	layer type	primary waste volume	comments
1952	1		0	0	MW	530	sluiced
1969	4		39		CWP	479	8.1 vol%
1967	3	35	- 4	35	CWP		unk. loss
1971	1		24	24	AR solids	425	from C-106
1971	1	92	33		meas.		unk. gain
1986	1		33		unk.		unaccounted solids in cores
1975	3				NPH/TBP	33	33 kgal organic from C-102
1990	3	62	-30		meas.		unk. loss

Tank C-103 has a bottom layer of 35 kgal of CWP, a second layer of 24 kgal high strontium solids (i.e. AR-002 solids from C-106), and a 33 kgal uncertain inventory (uncertain as to amount and type). Then, there is 133 kgal of supernatant (or 100 kgal less the unaccounted solids layer), of which I

[36]Weiss, R. L. "Data Transmittal Package for 241-C-102 Waste Tank Characterization," SD-RE-TI-209, January 1988.
[37]Thomas, D. L.; Hara, F. T.; Kaye, J. H.; Steele, R. T.; Stromatt, R. W.; Urie, M. W. "SST Sample Characterization Analysis of Archive Samples 102-C, 105-C, and 106-C," PNL-7258, February 1991.
[38]Swift, W. H.; Irish, E. R. "Purex Two-Cycle Flowsheet," HW-52389-declassified, Oct. 1, 1957.

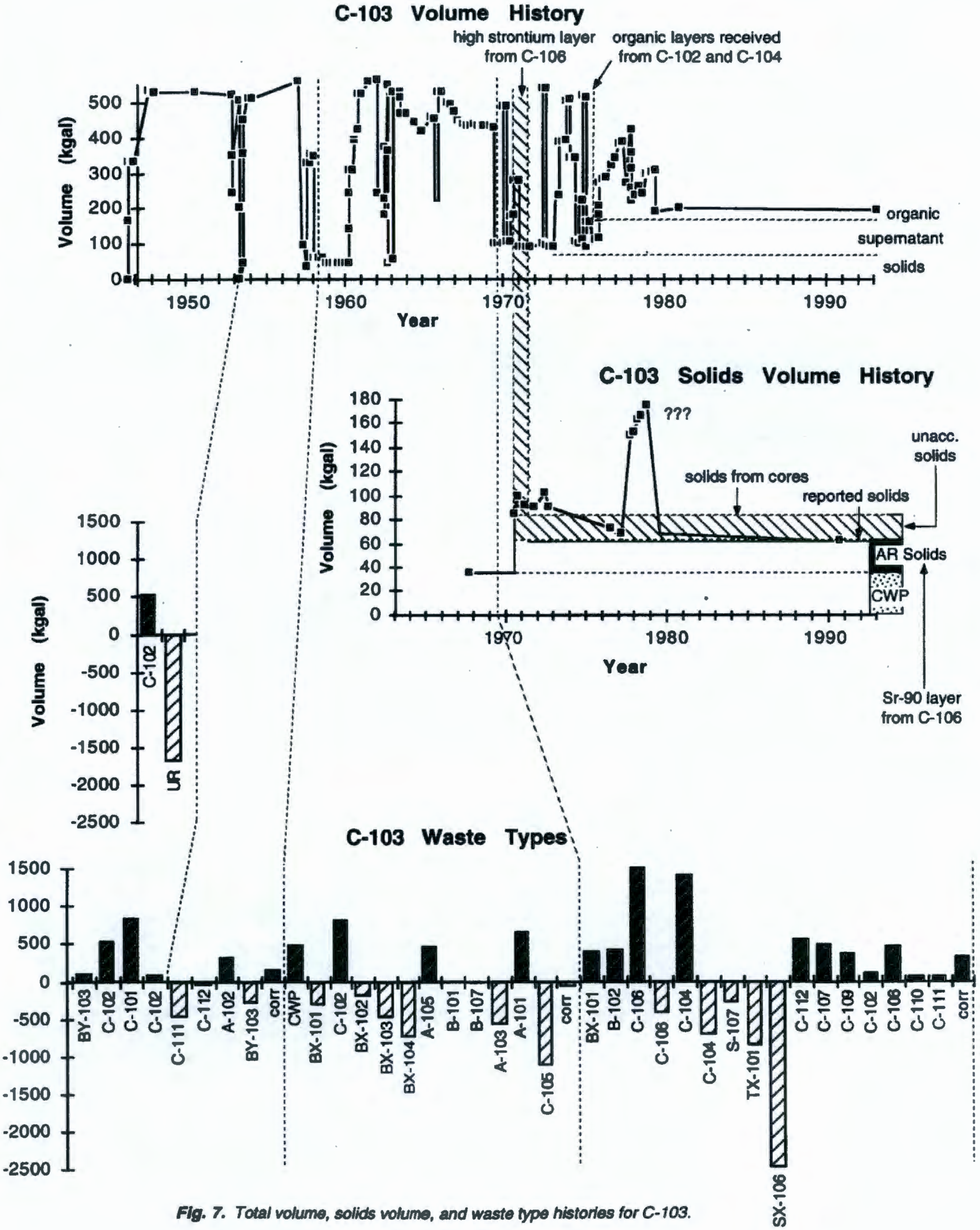

Fig. 7. Total volume, solids volume, and waste type histories for C-103.

attribute 100 (or 67) kgal to an aqueous liquid layer and 33 kgal to an organic layer, the organic layer having been transferred to C-103 from C-102 in '75-4 and '78-3. If the organic layer is the typical diluent plus TBP that is used in Purex, its composition would be 30% TBP and 70% NPH. However, I have been told that preliminary analysis suggests it is more like 70 % TBP and 30 % NPH. The results from the core only show 6 kgal organic (2" in the top segment) for one of the two cores, and no organic for the other core, so there may be as little as 6 kgal of organic remaining in C-103.

This description of solids layers assumes that the solids level measurements from '77-3 to '78-3 were not correct. These incorrect measurements were possibly due to mounding of the sludge under the riser that was used in the measurement, or perhaps floating solids. In any event, more recent solids levels are consistent with the historical solids layering. Such discrepancies do suggest that there are lateral solids inhomogeneities in C-103, as does the fact that neither of the solids levels derived from the two C-103 cores agree with the reported solids measurement for C-103. As a result, I believe that is some fraction of the 34 kgal unaccounted solids are actually still in C-103 (more detail shown below).

Tank C-103 has been used as the salt well receiver for C-Farm, and it is characterized as sound/deactivated. It was reported[39] that C-103 received 22 kgal of terminal solids during 1977, but I have no indication of a transfer from C-106 at this time. There is an unknown 148 kgal addition to C-103 in 1977 quarter 4 by Anderson-90, but no corresponding change in C-106 or C-105. During 1976 and 1977, C-103 was feed tank for the B-Plant evaporator, and Anderson-90 lists C-103 waste type as SRS (strontium recovery supernatant). However, I believe that C-103 actually received its AR solids in 1971 quarter 1, as shown in Table 5.

Some activity has been reported for dry wells 03 (147 c/s in '87-2 at 34') and 09 (131 c/s in '87-2 at 80'), but these levels are not high enough to be considered leaks.

The analytical data[40] indicate an average 3.1 and 0.14 Ci/L Sr and Cs, respectively, over the two core composites. If this activity were all in the 24 kgal layer, that would be 6.4 Ci/L Sr and 0.29 Ci/L Cs for a total inventory of 5.8e5 Ci Sr and 2.6e4 Ci Cs. The plutonium assay was reported as 6.5 and 10.4 µCi/g for the two solid composites of each of the cores, which suggests a Pu inventory of 45.1 kg Pu, whereas I estimate that there should be only 30.1 kg, based on the waste types, as shown in Table 2.

One problem with the C-103 core analyses is the fact that the solids volumes derived from core segment solids are greater than the measured solids level. In particular, the solids volumes from core #1, riser R-2 and core #2, riser R-8 were consistent with 87 and 103 kgal, respectively—both of which are much

[39]ibid Welty.

[40]Weiss, R. L. "Data Transmittal Package for 241-C-103 Waste Tank Characterization," SD-RE-TI-203, January 1988.

larger than the reported 62 kgal. Using these higher solids levels would increase the Cs/Sr inventories substantially, which is inconsistent with the dome space temperature noted above. However, I have taken the average solids levels of the two cores (95 kgal) and listed as unaccounted solids the difference between that measurement and the reported 62 kgal, or 33 kgal unaccounted, unknown solids.

I also do not understand why my plutonium estimate for C-103, 29.7 kg, is lower than that estimated from analytical results, 45.1 kg. This is especially perplexing since other waste tanks on C Farm have ostensibly similar waste types and my predictions match very well with the measurements for those tanks (C-102, C-104, and C-106) and my predictions are too high by a factor of four for C-105. However, there were unknown waste additions that occurred for C-103 in 1976-77, when Anderson-90 notes that C-103 was used as a Purex waste receiver and B-Plant evaporator feed, as well as in 1978, during SW RCR (Salt Well Receiver) evaporator feed operation. Perhaps these additions were responsible for the larger than expected plutonium inventory in C-103.

C-104

Tank C-104 received 1,590 kgal MW '46-4 to '47-4, which cascaded 1,060 kgal to C-105 (see Fig. 8). This tank was sluiced and became a CWP receiver in two separate campaigns, 1,118 kgal '56-1 to '57-2 and 4,351 kgal from '69-4 to '72-3, where the latter campaign involved CWP/Zr as well as CWP/Al. Most of the solids in C-104 came from these CWP additions. It also received 5,163 kgal OWW '69-4 to '72-4, for which there are no solids, and 912 kgal TH/THL from '70-3 to '70-4, with a solids content of 5.8 vol%. The fissile inventory of this tank is rated high because of the ^{233}U that was present in the TH/THL wastes, but the TH/THL additions were commingled with large amounts of CWP solids.

The only other solids came from P/PL wastes, which added 527 kgal from '70-4 to '76-2. Using standard value for P waste (2.2 vol%) results in the layering shown in Table 6.

One can see that there was an unknown loss of 52 kgal of CWP solids during '69-4 to '72-3. I attribute this loss to entrainment of the CWP solids similar to what occurred for C-102. That is, the large amount of CWP added reached a limit where the solids were passed on to other tanks, in this case BX-101 and BX-103. P/PL additions resulted in 12 kgal of solids, and there is an unknown gain of 85 kgal that evidently came from solids from one or more of the wastes that were transferred through C-104 from '72-4 to '76-2. These wastes originated from tanks U-107, C-111, C-101, A-101, A-102, C-106, and A-103.

Thus, I predict the layering in C-104 is 45 kgal CWP/Al, 13 kgal CWP/Zr, 53 kgal TH/THL, 87 kgal of CWP/Al, 12 kgal P/PL, and 85 kgal of an unknown source. A portion of this unknown source may be unaccounted inventory of CWP, similar to C-102, or it might be BL solids transferred from C-106, or some

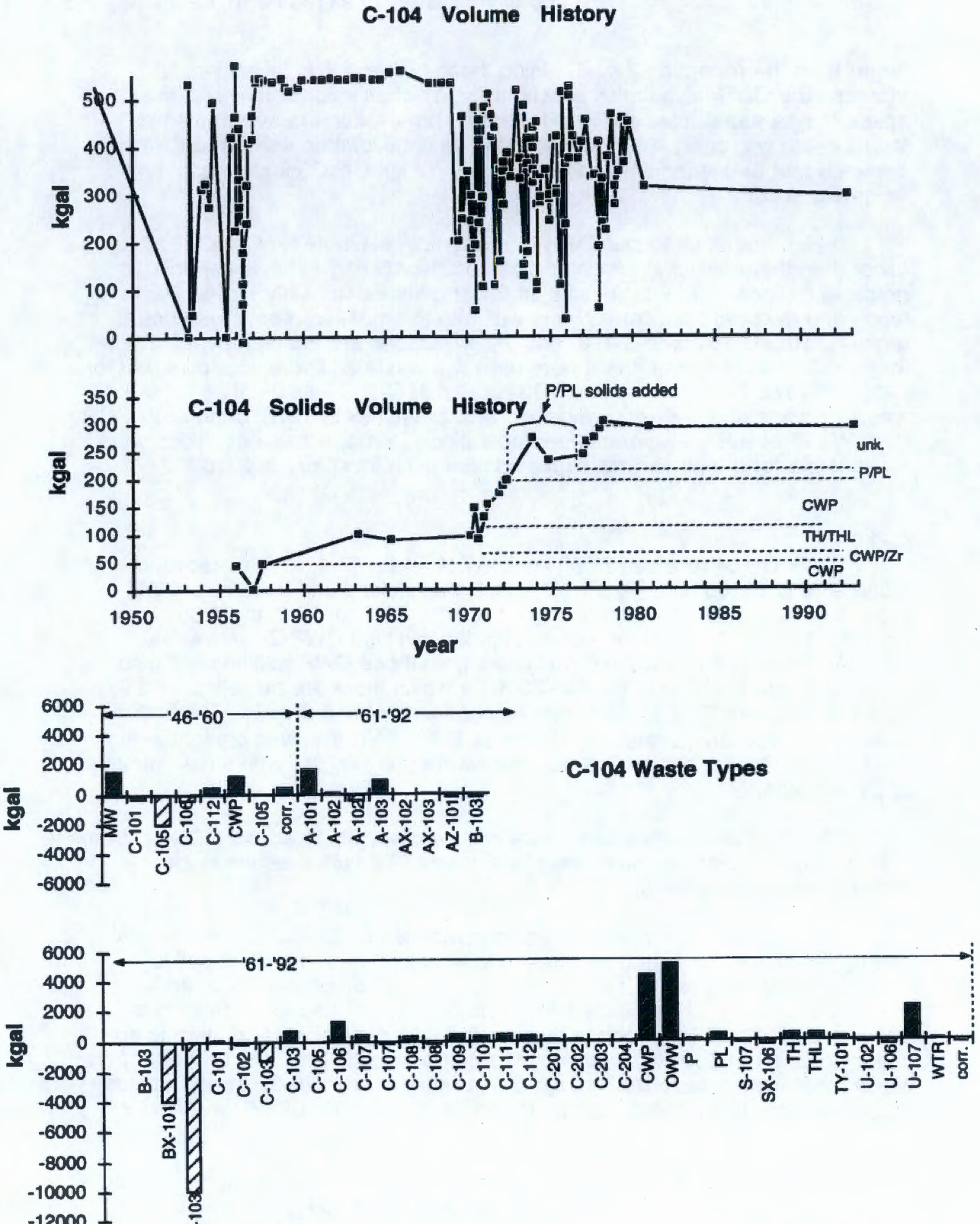

***Fig. 8.** Total volume, solids solume, and waste type histories for C-104.*

combination of the two sources. Tank C-104 received 1,321 kgal from C-106 from '75-3 to '76-2, which was BL waste "supernatant". Some solids could have

Table 6.
Estimates of Solids for C-104.

date	q	meas. solids	solids gain/loss	pred. layer	layer type	primary waste volume	comments
1952	2		0	0	MW	1,590	
1957	2		89		CWP	1,118	8.1 vol%
1957	3	45	-44	45	CWP		unk .loss
1970	1		13	13	CWP/Zr	535	2.5 vol%
1970	4		53	53	TH/THL	912	5.8 vol %
1972	3		95		CWP/Al	3,816	2.5 vol%
1972	2	198	- 8	87	CWP/Al		unk. loss
1976	2		12	12	P/PL	527	
1990	4	295	85	85	unk. gain		

been entrained in the transfers to C-104 from C-106. In fact, if only the solids that accumulated in C-106 are used, BL waste has a 2.5 vol% solids as compared to 2.2 vol% for Purex waste. For now, I must leave this layer as an unknown.

The solids content of TH or THL is very uncertain because of lack of information about the solids level changes in tanks that received these wastes (C-102 and C-104). I have adjusted the value to best fit the solids levels of these two tanks, a derived a value of 5.8 vol%. This must be used with caution, however, and is very uncertain because of the lack of data.

Substantial activity was measured in dry well 03 in '74-3, and the measurement in '87-1 was 27,467 c/s at 24'. This activity has been attributed to a overflow from spare inlets to C-105 in 1974, and not to a leak in C-104. Spare inlets are connections made into the tank wall at the same level and configuration as the cascade line. These spare inlets were supposed to have been sealed, but evidently were not sealed that well, since they did leak when the tank was overfilled.

It was reported[41] that 11 kgal of strontium solids were placed into C-104 during 1977. C-104 was noted in Anderson-90 as "Purex Waste Storage" at this time, and there were 86 kgal of unknown additions during 1977. However, the source of the strontium solids in C-104 is consistent with the recorded P/PL primary waste additions, which amounted to 527 kgal through '76-2. Some 12 kgal of solids (2.2 vol%) would have come from these additions from '70-4 to '76-2, and P waste solids are very high in strontium. The analysis shows[42] 0.45 Ci/L Sr for the core composite, which would be 11.0 Ci/L if all the Sr-90 came

[41] ibid Welty.
[42] Weiss, R. L. "Data Transmittal Package for 241-C-104 Waste Tank Characterization," SD-RE-TI-199, January 1988.

from the P/PL layer. Probably some of this Sr-90 came with the 85 kgal of unknown solids, since I expect more like ~7 Ci/L Sr-90 in strontium sludges (see Table 1). At any rate, this represents a total Sr inventory of 4.9e5 Ci, which is consistent with the heat load of the tank, as shown in Table 1.

I expect higher temperatures recorded for tc4 following the addition of the Sr sludge and even though I only have data back to 1974, tc4 and tc5 (at 156 and 222 kgal, respectively) are consistently higher in temperature than all the other thermocouples, which indicates that a heat source is concentrated in these upper waste layers for C-104.

Moreover, the evaporation rate of the waste in C-104 was very high, about 7 kgal/year, between 1980 and 1983. During this period, the level fell from 316 to 295 kgal.[43] The surface was reported[44] to be 75% dry in 1983 and dry and cracked in 1988. In 1982, the temperature history of C-104 shows very high readings for tc3, tc4, and tc5—as high as 350°F (177°C) for tc5 (288 kgal) in 1982, the time of which corresponds roughly with when the surface dried out. These measurements were flagged with a "temperature in question" statement, but not otherwise qualified. I predict that the strontium sludge layer would be around tc4, between tc3 and tc5, while the surface of the waste is between tc5 and tc6. The dome space temperature is 92°F, but no waste tc's have been reported since August 1988. At that time, tc1 and tc3 were reported at 154 and 89°F, respectively. The comments with these readings indicate that the thermocouples are out of service. The last full reading of the whole tree was in October 1985 where tc3 was 191°F and tc5 was 170°F. Once again, the hotter layer is exactly where I predict the Sr layer to be, suggesting that there may be a layer in this tank that is significantly hotter than the average tank temperature.

C-105

Tank C-105 received 1,062 MW as cascade from C-104 from '47-1 to '47-4, and passed 532 on to C-106 (see Fig. 9). Tank C-105 then received 546 kgal UR in '54-2 to '54-3, which forms the bottom 27 kgal of sludge in C-105, since it was sluiced in 1953. It then received 3,130 kgal of CWP from '57-3 to '60-2, which resulted in another 250 kgal of sludge and then some 32 kgal sludge from slurrying tanks A-103, AX-101, AX-102, and AX-103.

Evidently, 168 kgal of CWP was lost prior to '65-2, and an additional 22 kgal was lost in '68-1 to cesium recovery because the tank was drawn down to 84 kgal. (This last draw down is interpolated within a quarter by ordering the transactions so as to keep the tank from either underfilling or overfilling during a quarter.) Then, there was an unknown gain of 31 kgal from '69-1 to '85-2. Once again, there seems to be solids addition due to entrainment within supernatant transfers. During the period '67-3 to '80-4, a very large amount of supernatant was routed through C-105 on its way to cesium extraction in B-Plant. There were some 17,451 kgal of supernatant processed through B-Plant during this time.

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[43]ibid Hanlon.

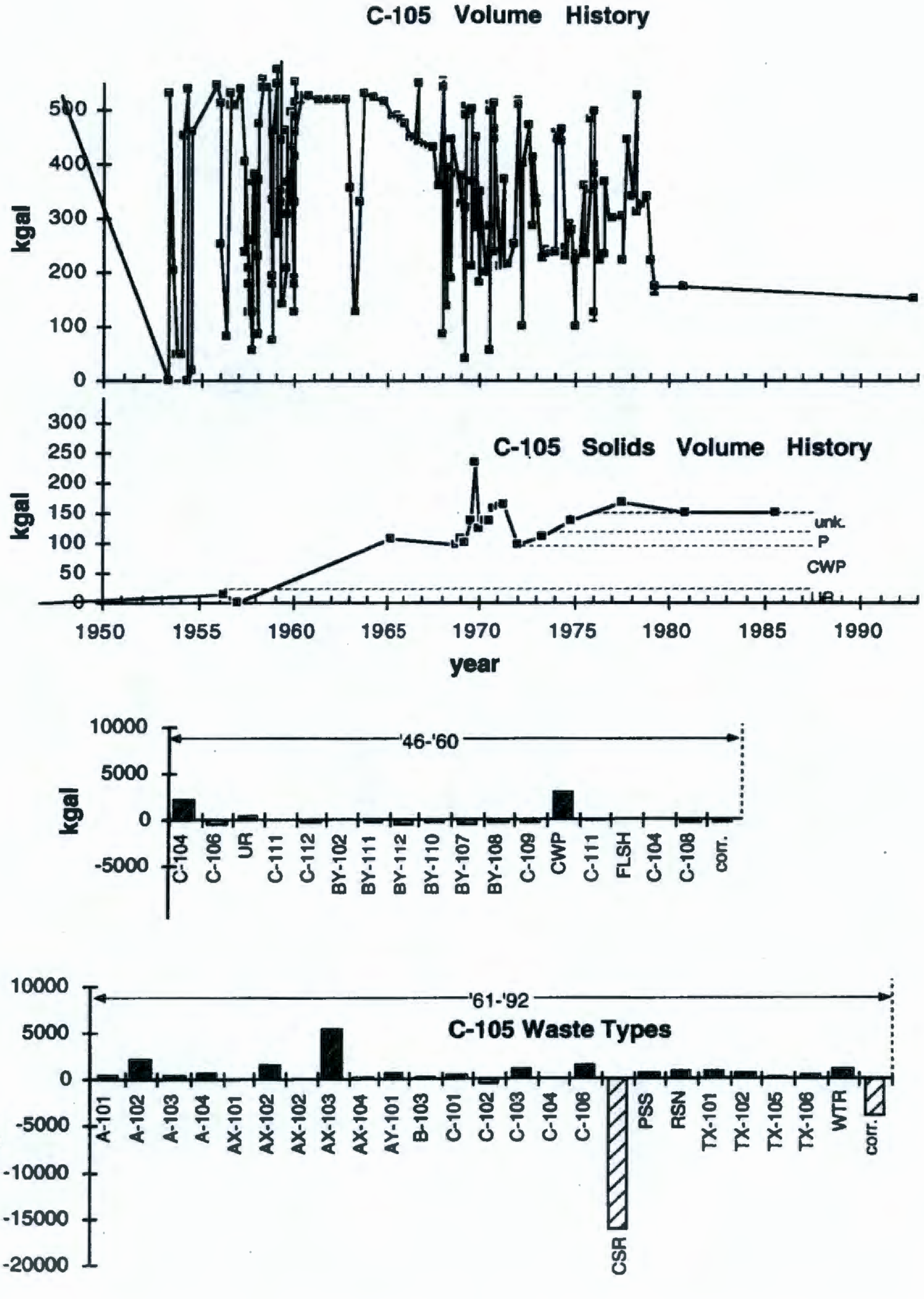

Fig. 9. Total volume, solids volume, and waste type histories for C-106.

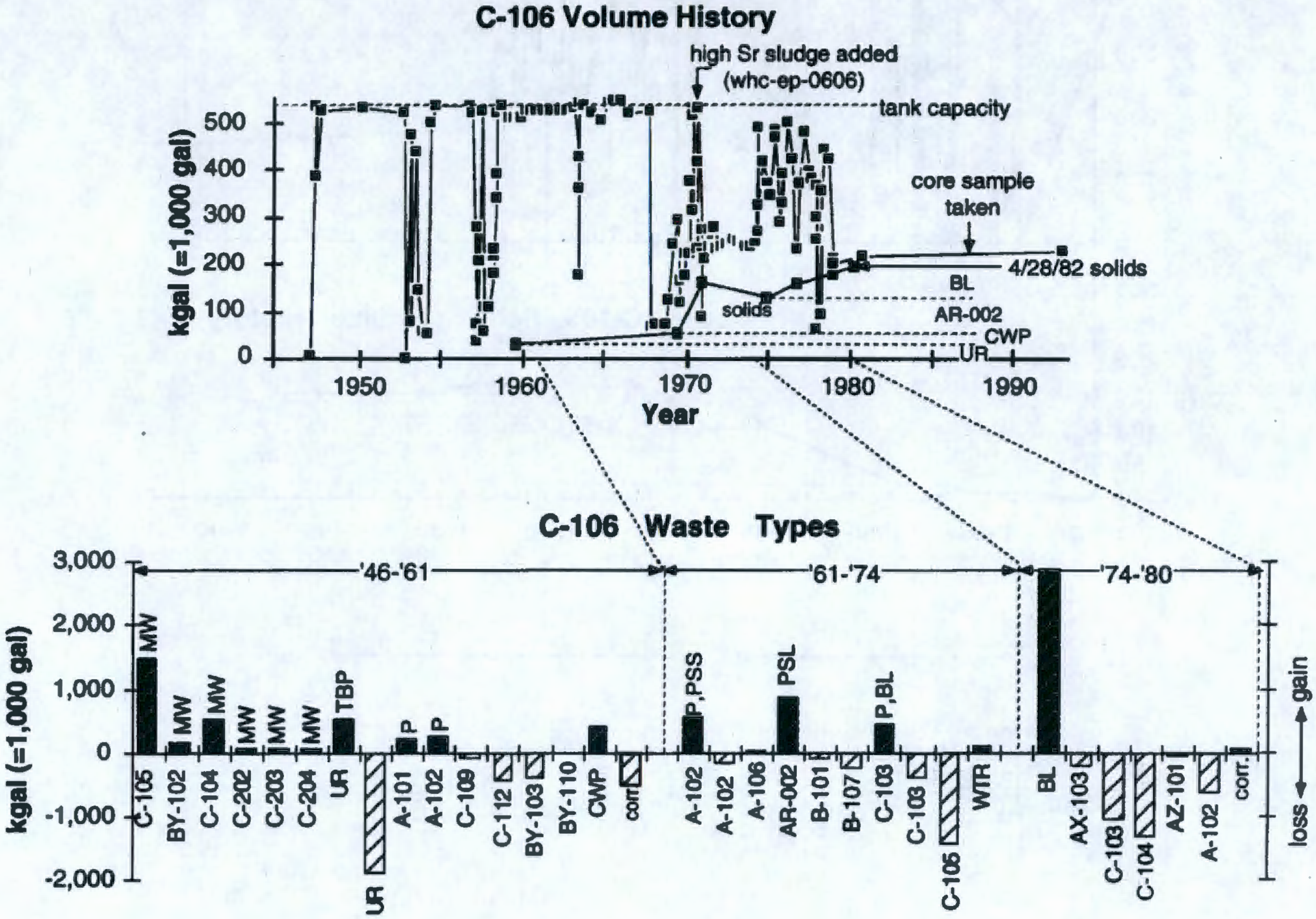

Fig. 9. Total volume, solids volume, and waste type histores for C-106.

Table 7.
Estimates of Solids for C-105.

date	q	meas. solids	solids gain/loss	pred. layer	layer type	primary waste volume	comments
1953	2		0	0	MW	1,060	
1954	3		27		UR	546	
1956	2	15	-12	15	UR		
1960	2	277	262		CWP	3,130	8.1 vol%
1965	2	109	-168		CWP		loss
1971	2	164	55		P		all lost
1972	1	98	-66	83	CWP		
1977	3		17	17	P	87	A-Farm Slurries
1977	3	167	52			4,740	other rec.
1985	2	150	-17	35	unk.		entrained?

The layering in C-105 would be 15 kgal UR, 83 kgal CWP, and 52 kgal P, where the 52 kgal P waste comprises both intentional and unintentional slurry transfer. Because of the large volumes associated with the CSR campaign, it is uncertain how much CWP waste was washed out of the tank. Once a layer of P solids was established, though, further CWP removal would not have occurred.

Activity was reported for dry well 02 in 1974 and was attributed to an overfill of C-105 and subsequent leakage from spare inlets and cascade line packings (same problem found in C-104 drywells.) C-105 was used as a staging tank for supernatant feed for cesium recovery in 1974, and therefore had large amounts of waste routed through it during that campaign.

A heat generation rate of 90,000 BTU/hr has been estimated[45] for C-105, but its temperature and fill history are inconsistent with such a large heat load. The peak temperature of C-105 is 110°F for tc1 and tc2, and the only heat producing material is the 17 kgal of P sludge that accumulated during the cesium recovery campaign, where C-105 was the feed tank for that process. This tank is ventilated through the 3" cascade line (~25' run) to tank C-106, and therefore I expect its temperature to be lower that predicted based on my heat load versus dome space temperature (see Fig. 4).

The analytical information[46] for the core composite of C-105 show Sr and Cs levels of 1.3 and 0.23 Ci/L, respectively. Thus this total heat load is actually comparable to that of C-103 and C-107. Another indication of the moderate heat load for C-105 comes from comparing peak waste temperatures as well as average dome space temperatures. The peak waste temperatures of C-103 are

[45]Walker, C. M. "History and Status of Tanks 241-C-105 and 241-C-106," ARH-CD-948, May 1977.
[46]Weiss, R. L. "Data Transmittal Package for 241-C-105 Waste Tank Characterization," SD-RE-TI-204, January 1988.

around 126°F for tc1 and tc2 as compared to 110°F for tc1 and tc2 for C-105, and the average dome space temperature is 108°F for C-103, while it is only 74°F for C-105. These measurements are consistent with the moderate heat load for C-105, as shown in Tables 1 and 2, and the fact that it is somewhat ventilated by connections to C-106.

The plutonium assay was reported as 0.85 μCi/g, which suggests a Pu inventory of 2,552 Ci or 12.5 kg. This is about a factor of two lower than I predict based on the layers of waste type shown in Table 7. I have no explanation for this difference.

C-106

Solids layering

Tank C-106 received 532 kgal of MW in '47-3 as cascade from C-105, was sluiced in 1953, and there is apparently little heel left from this operation (see Fig. 10). Thereupon, C-106 received 538 kgal UR in '54-3, 420 kgal CWP '58-2 to '60-2, 854 kgal from AR-002 '70-1 to '70-4, and 2,892 kgal BL from '74-3 to '76-1. The sludge accumulation should have been according to that shown in the Table 8.

Table 8. Estimates of Solids for C-106.

date	q	meas. solids	solids gain/loss	pred. layer	layer type	primary waste volume	comments
1953	2		0	0	MW/cas.	532	
1954	3		27	27	UR	538	
1957	4	29	2	2	meas.		gain from ??
1960	2		34		CWP	420	
??			- 6	28	CWP		loss to ??
1969	4	57			meas.		
1970	4		93		AR-002	854	
1971	1		-24	69	AR-002		loss to C-103
1976	2		71	71	BL	2892	2.5 vol%
1985	2	197			meas.		

The solids layering in C-106 would then be 29 kgal UR, 28 kgal CWP, 69 kgal AR-002 solids, 71 kgal BL, and 32 kgal of supernatant (which varies since water is added periodically to replace that lost by evaporation.

The only unrecorded loss of solids is the 24 kgal of AR-002 solids lost to C-103 in '71-1. These high strontium solids (termed AR-002) are actually P solids (sludge from Purex waste) that were being washed in AR-002, a tank in AR vault. The solids mostly originated from A-106, which was a primary receiver for P waste from '60-4 to '63-1, although A-106 accumulated solids from A-104 as well. Approximately 184 kgal of solids were sluiced from A-106

starting in Feb. 1970 through Jun. 1972, with 93 kgal of those solids ending up in C-106.

Radionuclide inventory estimate

Based on the solids layering and the core composite information,[47] the strontium concentration in the core composite is 2.8 Ci/L, which would be 8.0 Ci/L if it were all concentrated in the 69 kgal AR solids layer. A previous report by Walker[48] derives much larger inventories of Sr-90 in C-106. This author uses a sludge analysis[49] that is 18.8 Ci/L Sr-90, and a total sludge volume of 140 kgal, and states that the total Sr-90 is then 5-10 MCi. However, this author does not differentiate between BL and AR-002 sludges. The former has very little Sr-90, while the latter has Sr-90 on the order of 8.0 Ci/L. Thus, Walker derives a much larger total Sr-90 than I do, but I believe that his strontium concentrations were not representative of this waste type—Walker did not take into account the absence of Sr-90 in BL waste. My estimates for Sr-90 are tied to a tank core analysis as opposed to some grab sample, and are consistent with the waste type.

The reported dose readings on the core segments as they are brought to the surface are unusually high for the top two segments considering the low radio nuclide content expected for BL (B-Plant low-level) waste. These dose measurements are not consistent with low radio nuclide contents and I can't explain the discrepancy.

The plutonium concentration for C-106 from the core analysis was 3.1 µCi/g, which leads to an inventory of 55.1 kg. My estimation of the plutonium content of the tank is 63.7 kg, which is comparable to that estimated from the analysis.

Temperature anomaly in C-106

The inadvertent addition of high strontium sludge to C-106 in 1970 has been noted before in several reports.[50,51,52] Temperatures in excess of boiling occurred shortly after the addition of the high Sr sludge. In 1978, a second thermocouple tree was installed in riser 14 of C-106 (see Fig. 1) to help monitor the temperature of this tank. The temperature readings from thermocouples at the same level between the two trees agree within the dome space, but have never agreed within the waste, and there are differences on the order of 35-45°F between the tc2's of each tree. For example, in January 1993, tc1-r8 (thermocouple 1, riser 8) was 155°F, while tc1-r14 was 119°F. Likewise, the

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47Weiss, R. L. "Data Tranmittal Package for 241-C-106 Waste Tank Characterization," SD-RE-TI-205, January 1988.

48ibid Walker.

49Horton, J. E. "Analysis and Characterization of Sludge Sample form TK-106-C," letter to O. R. Rasmussen, Jan. 9, 1975.

50ibid Walker.

51*ibid* Babad, H. 1992

52Fulton, J.C. "Tank 241-C-106 Thermocouple Tree Data Comparisons," 9352648, letter to R. E. Gerton, April 1, 1993.

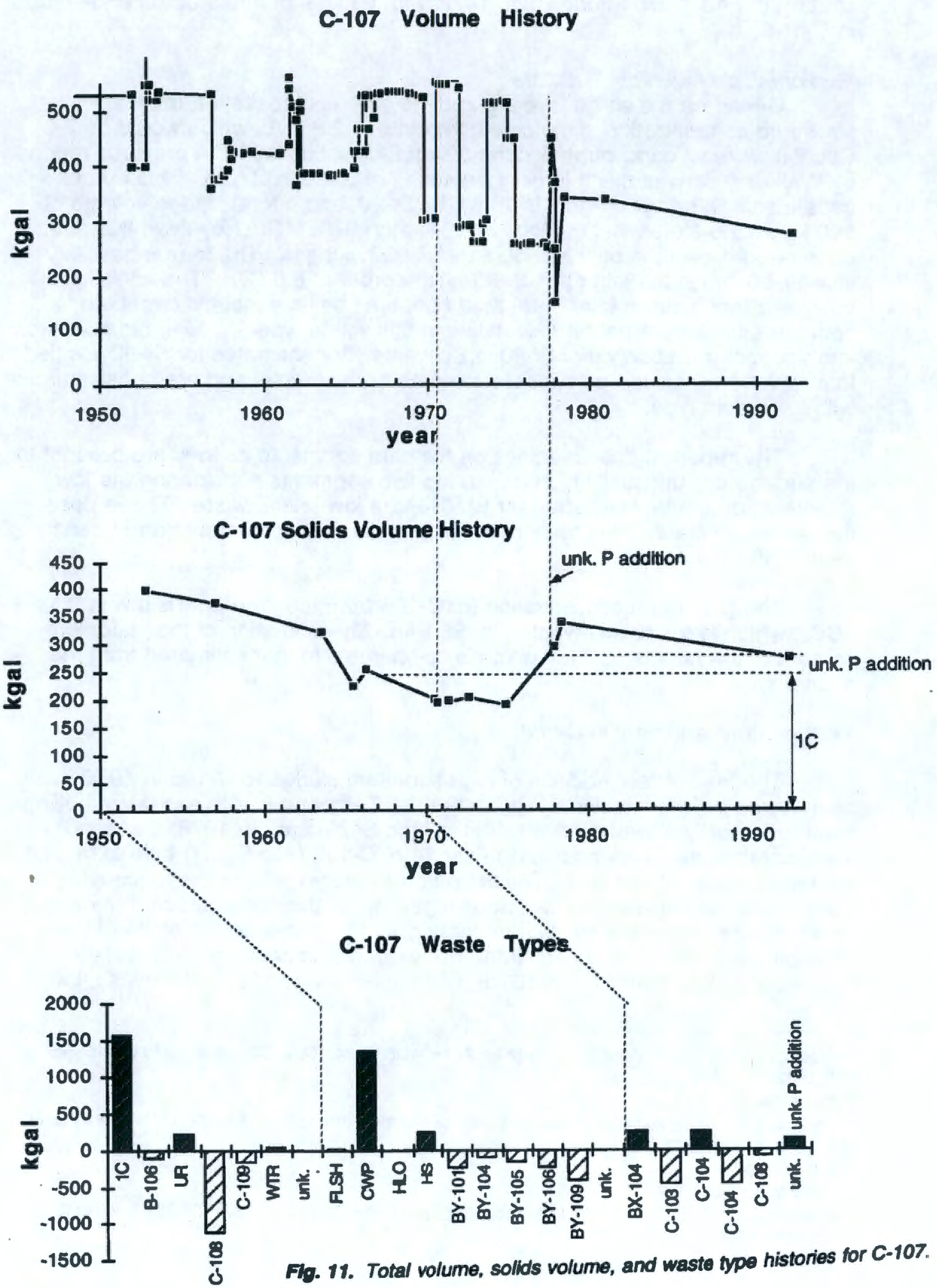

Fig. 11. Total volume, solids volume, and waste type histories for C-107.

tc2's were at 131 and 87°F, respectively. Riser 8 and Riser 14 are about 30' apart, and it seems counter-intuitive to have the higher temperature on the *outside* of the tank waste. In other words, I would expect the temperature near the tank outer wall to be lower at the same level as compared to the temperature of the waste near the center of the tank.

I suggest that this explanation for this anomaly is a chimney effect. That is, the riser-14 tree was likely inserted with a water lancing operation that effectively drilled a hole or chimney within the waste sludge. If this sludge chimney did not collapse following the insertion of the thermocouple tree, it would allow the free convection of liquid within that chimney and therefore the cooling of the waste around the tc tree. This localized convection would produce a cold spot that would not be representative of the temperature of the sludge. In all likelihood, then, the actual peak sludge temperatures at the center of the tank are actually higher than either thermocouple tree is now measuring.

An experiment to test this chimney hypothesis would be very simple and involve tamping the sludge around the tc tree in riser 14 in order to collapse the sludge around the tree. It is very important to have an accurate representation of the temperature of the sludge in C-106 and that will only be possible if the tc tree is packed into the sludge so as not to allow any free convection around the tc tree.

Another hypothesis that has been suggested is the presence of a "doughnut" of strontium sludge around the outer wall of the tank, concentrating the heat source near the wall.

C-107

Tank C-107 received 1C (first cycle decontamination) waste from the $BiPO_4$ process, which was a mixture of the actual waste from this cycle and the decladding waste (see Fig. 11). 1C waste had the highest solids fraction of any waste stream at Hanford, being on average 25 vol% solids.

Table 9.
Estimates of Solids for C-107.

date	q	meas. solids	solids gain/loss	pred. layer	layer type	primary waste volume	comments
1948	3		395		1C	1,588	24.9 vol%
??			4		unk. gain		
1952	3	399			meas.		
1953	3		11		UR	211	
1962	2		109		CWP	1,364	
1963	2	321	-198		meas.		loss to ??
??			-72	249	1C		unk. loss
1977	2	249			meas.		
1977	3		29		Sr solids		reported in Welty
1992	1	275	-3	26	Sr solids		unk. loss

Therefore, the waste is 249 kgal of 1C and 26 kgal of Sr solids (P sludge), see Table 9. There undoubtedly are some residual UR and CWP wastes between the Sr sludge and the 1C wastes, but indications are that most of the UR and CWP solids were washed out of C-107. Note that 148 kgal of 1C wastes have been moved from C-107. These high phosphate wastes will show up as precipitated solids in some other tank.

A report[53] of 29 kgal of high-Sr solids in August 1977 is not present in the fill history, although there is an unknown waste gain in C-107 in '77-3 of 201 kgal. Often, unrecorded waste additions occur during processing of large volumes of waste, and this unknown addition occurred during sluicing of AX-103 for Cs/Sr recovery. If this is the source of the unknown waste addition, its volume is consistent with an additional layer of 26 kgal of high Sr sludge on top of the 1C sludge, since I predict an additional 3 kgal unknown loss followed the 29 kgal addition.

To further substantiate the presence of a layer of Sr sludge in C-107, thermocouple tc3 is a higher temperature than either tc1 or tc2 for this tank, averaging 132°F versus 115°F for tc1 and 120 °F for tc2. This higher temperature in the upper layer of C-107 is consistent with the presence of a Sr sludge. The dome space is around 115°F, which is also consistent with a hot surface for this tank. In any event, there was a purported transfer of 219 kgal to C-103 in '78-1, but level change suggest that only 110 kgal was transferred, and probably all to C-103. Therefore, the missing 3 kgal solids probably was transferred to C-103 with the 110 kgal transfer during the stabilization of C-107.

The temperature history of C-107 clearly shows a jump in tc3 and tc4 from 1977 to 1979. These thermocouples went from about 84°F to 130-140°F over this period. Clearly there was some very high heat generating sludge added during this time, suggesting that this report of sludge added is indeed correct. Furthermore, C-107 shows the very unusual characteristic of having a dome space that is as warm as the bottom of the tank. The dome space is around 112°F, and as is tc1, while tc3 is 125-130°F. There is a heat generating layer a surface of the waste in C-107 and the temperature evidence is consistent with the presence of a high Sr-90 sludge layer.

I have calculated the heat load of C-107 based on its average dome space temperature to be 17,900 Btu/hr., which would suggest a strontium concentration of 9.0 Ci/L for the predicted 26 kgal of Sr sludge (see Table 1.).

C-108

Tank C-108 received 1,058 kgal of 1C by cascade from C-107 '47-4 to '48-3, where most of the solids ended up in C-107 (see Fig. 12), although some solids did end up in C-108. Subsequently, 902 kgal of UR were added from '53-1 to '53-2, followed by TFeCN waste. This waste was produced by scavenging with sodium nickel ferrocyanide, and was performed in the field, so-

[53] ibid Welty.

called in-tank or in-farm processing. The addition was actually performed in CR vault, and C-108, 109, 111, and 112 were all used in this campaign.

Table 10.
Estimates of Solids for C-108.

date	q	meas. solids	solids gain/loss	pred. layer	layer type	primary waste volume	comments
1948	3		19	19	1C	1,058	
1952	3	34?			meas.		
1953	2		45	45	UR	902	
1957	4		15		TFeCN	1,034	
1957	4	79			meas.		
1961	2		40		CWP	502	
1969	4		-53	2	TFeCN		loss to C-102?
1984	1	66			meas.		unk. loss

There is a complicated layering associated with C-108, although straightforward in its analysis, as shown in Table 10. There are 19 kgal 1C, 45 kgal UR, 2 kgal of TFeCN solids. The 19 kgal 1C is derived simply by the difference in expected solids between UR and TFeCN. Note that most of the FeCN layer has been removed in a 375 kgal transfer to C-102 in '69-4, where C-108 was drawn down to 138 kgal total volume. In fact, C-102 did show a solids increase around 1970. Thus I predict that not only are all of the CWP solids moved, also most of the FeCN solids were moved as well. There should be very little FeCN sludge left in this tank.

Dry well 02 showed activity starting in 1974, but this was ascribed to a lateral movement of an existing plume. It is now reading 420 c/s at 75' depth.

C-109

Tank C-109 received 530 kgal 1C cascade from C-108 '48-2 to '48-3, which should have had no solids, but 10 kgal of solids were reported in '48-3 (see Fig. 13). Note that 10 kgal is below the 12.5 kgal measurement limit because of the dish in the tank. Then, received 2,954 kgal FeCN scavenging, which contributed some 51 kgal of FeCN solids. Then, there is an unknown solids source.

The layering for C-109 is 10 kgal 1C, 44 kgal TFeCN, 8 kgal of an unknown type (see Table 11), and 4 kgal of supernatant. The 41 kgal gain of unknown solids between '57-2 and '70-3 were probably due to the fact that a particular scavenging batch taken from C-110 resulted in a solids loss from C-110. That loss was 15 kgal of UR solids, but would only explain a part of the 41 kgal unknown gain that occurred.

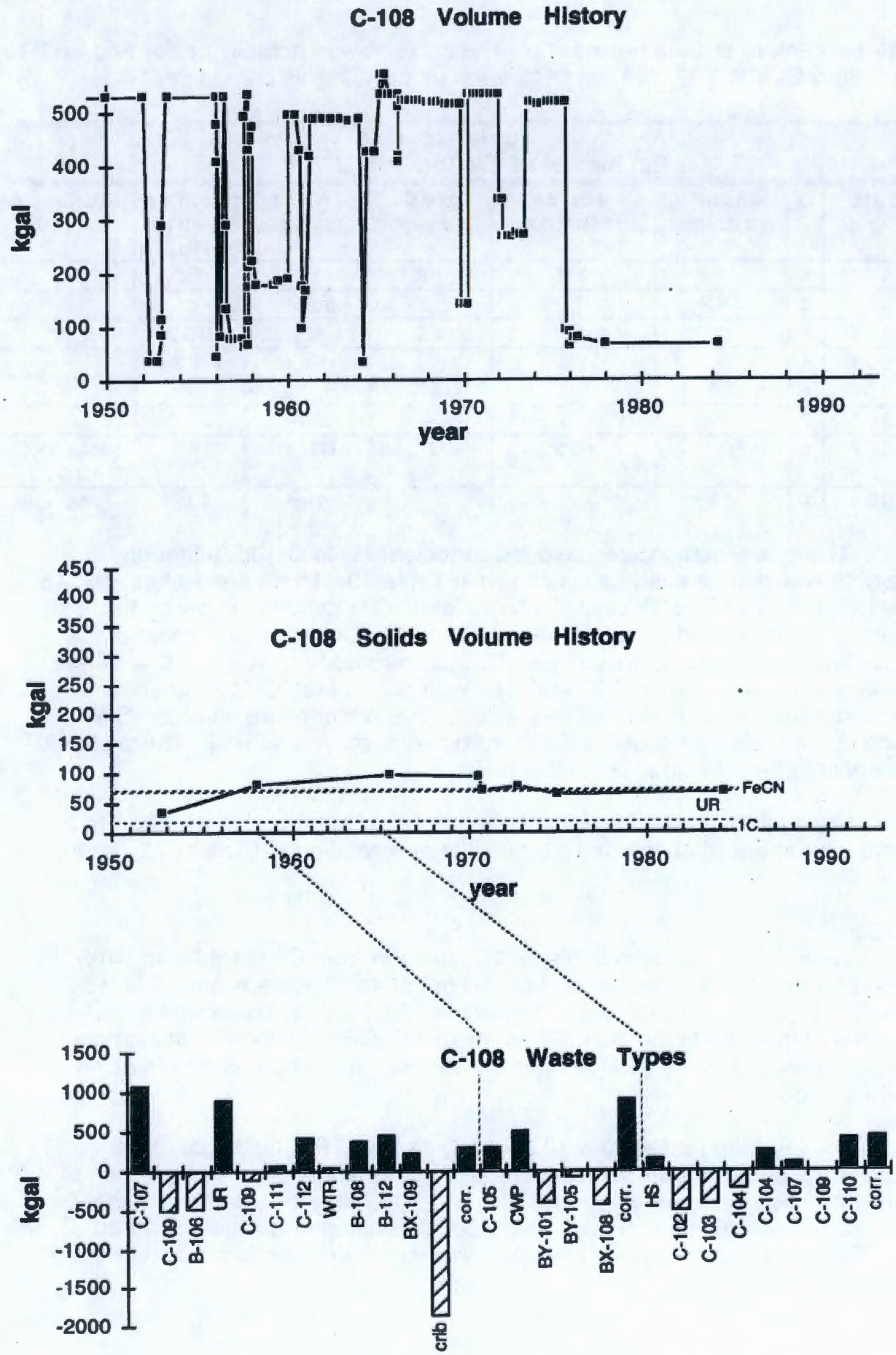

Fig. 12. Total volume, solids volume, and waste type histories for C-108.

Table 11.
Estimates of Solids for C-109.

date	q	meas. solids	solids gain/loss	pred. layer	layer type	primary waste volume	comments
1948	3		10	10	1C	530	
1952	2	10			meas.		
1956	1		44	44	TFeCN	2,954	
1957	2	51	-3		meas.		unk. loss
1970	3	95	41		meas.		unk. gain
1984	1	62	-33	8	unk. layer		1C from C-110?

The 41 kgal unknown gain was followed by a 29 kgal unknown loss. Obviously, if these solids were entrained inadvertently on input, they would likewise be entrained in liquid removal, especially P-10 salt well liquid removal. Nevertheless, the FeCN layer should be relatively undisturbed. Indications are that the precipitated solids from these batches comprised some 85 kgal solids or 2.9 vol% of the 2,954 kgal feed. This is roughly twice the precipitated solids of other in tank FeCN scavenging, and if true, suggests that the FeCN would have been diluted by this same factor of two as compared with other batches.

Dry well 06 showed increasing activity in 1982, and another well, 07, was drilled. Activity was attributed to migration of an existing plume.

C-110

This tank is another 1C primary receiver, and therefore will have a solids content much like C-107 (see Fig. 14). Because of this high solids level, the tank was never used for scavenging and never received FeCN solids. There was some UR waste added to this tank, and there was a loss of some 1C, as is typical of 1C solids.

The initial loss of 1C solids probably occurred in '52-3, where a draw down of the total tank volume to 231 kgal occurred. Thus, any solids above this level would necessarily have been moved to B-106 with this 299 kgal transfer. Unfortunately, no solids measurements were performed on B-106 at this time, so confirmation of this will need to wait for a full analysis on B farm. The UR solids were probably likewise transferred to C-109 in '56-1 with a 272 kgal transfer for a scavenging run. Thus, they would be mixed with the FeCN sludge layer in C-109.

The layering in C-110 should be 187 kgal 1C with some residual UR solids on the top, as shown in Table 12. The last 59 kgal loss of solids occurred

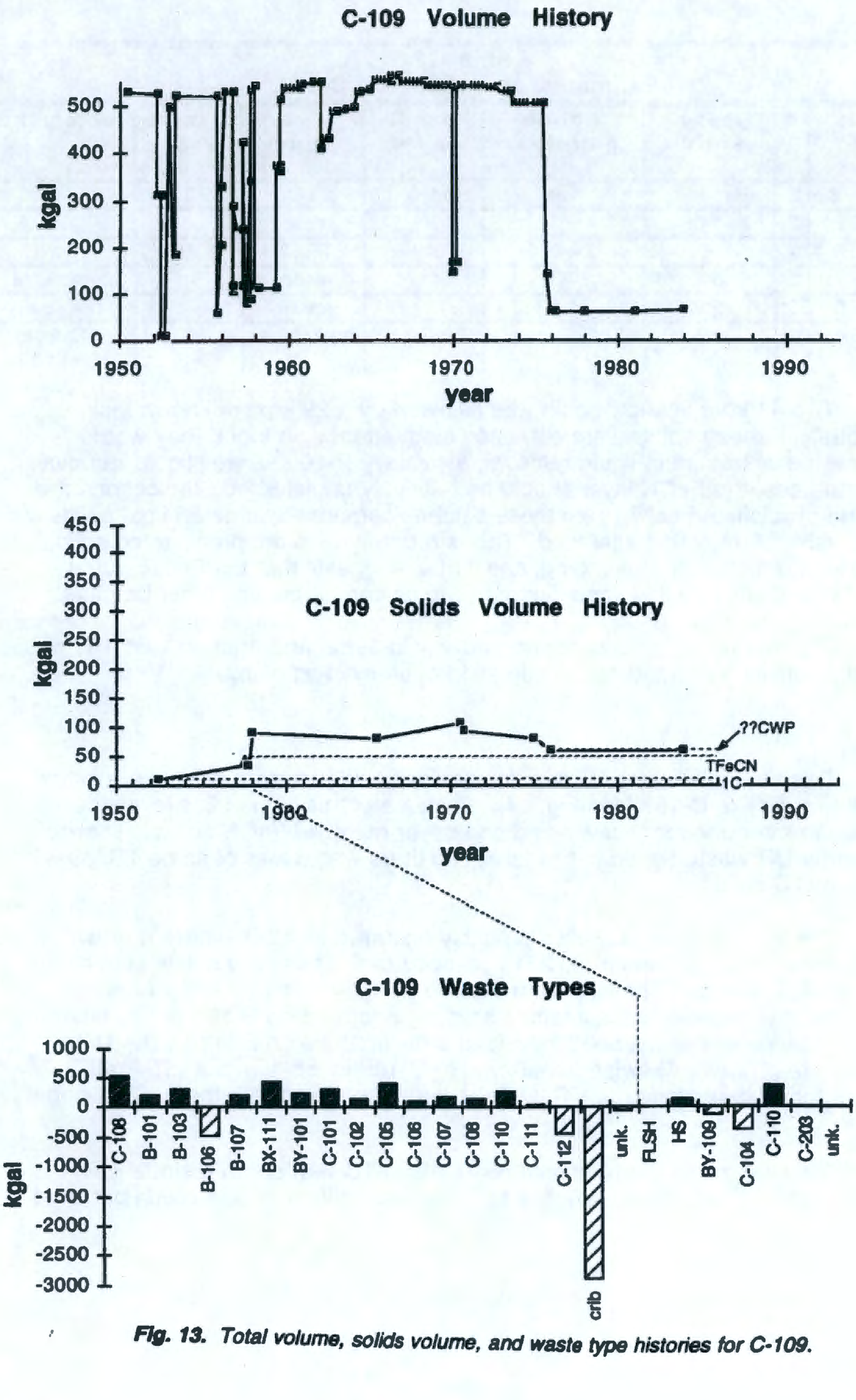

Fig. 13. Total volume, solids volume, and waste type histories for C-109.

Table 12.
Estimates of Solids for C-110.

date	q	meas. solids	solids gain/loss	pred. layer	layer type	primary waste volume	comments
1947	2		218		1C	1,589	13.7 vol%
1952	2	231	-14		meas.		unk. loss
1953	2		15		UR	307	all lost
1992	1		-59	187	1C		unk. loss
1992	1	187			meas.		

during stabilization, and the first 50 kgal solids would have been sent to C-112 (109 kgal '75-3) and C-103 (66 kgal '76-1 to '76-2). That latest pumping action started in Nov. 91 and resulted in 18.5 kgal volume loss, including 9 kgal solids, by Mar. 92 when the solids where last measured. This last stabilization would have been sent to the DST's as salt-well liquid, and AN-101 was the salt-well liquid receiver at that time.

This tank was of questionable integrity since activity appeared in wells 02 and 09. This activity was 72 c/s in 1975 for 02 and 241 c/s in 1975 for 09. Note that background is 50 c/s. C-110 was P-10 salt well pumped in 1979, but showed a steady increase in level from then until July 1986 that was 2.9" or 8 kgal. At this point, the tank level was 200 kgal. It was determined that the level increase was due to intrusions (of rainwater?) into the tank. This liquid was removed in 1991.

Preliminary data[54] on C-110 shows data on Pu of 0.15-0.18 μCi/g Pu for the core composite samples. This would amount to an inventory of 3.3 kg Pu.

C-111

Tank C-111 received 1C cascade of 1,059 kgal from '46-3 to '47-1, but most of the 1C solids remained in C-110 (see Fig. 15). Tank C-111 received 990 kgal UR from '52-4 to '53-2, and then became a receiver for scavenged waste (FeCN). It received 2,732 kgal of FeCN waste, followed by 347 kgal CWP waste from '57-1 to '60-4. C-111 also received 228 HS (hot semi works) waste, which derived from a pilot plant operation of the strontium recovery process. There are indications that this waste did have a very high in strontium concentration, since measured values of strontium in C-112 surface layers are very high.

The early history of the solids is complicated by the presence of two FeCN runs on top of the UR solids, and then followed by CWP addition. Evidently, about 24 kgal of CWP and UR solids were lost to BY-111 with a 363 kgal transfer in '57-2. But the bottom line is that, similar to C-107, most of the FeCN sludge that was in C-111 is now gone.

[54]Hill, J. H., preliminary data on C-110, March 1993.

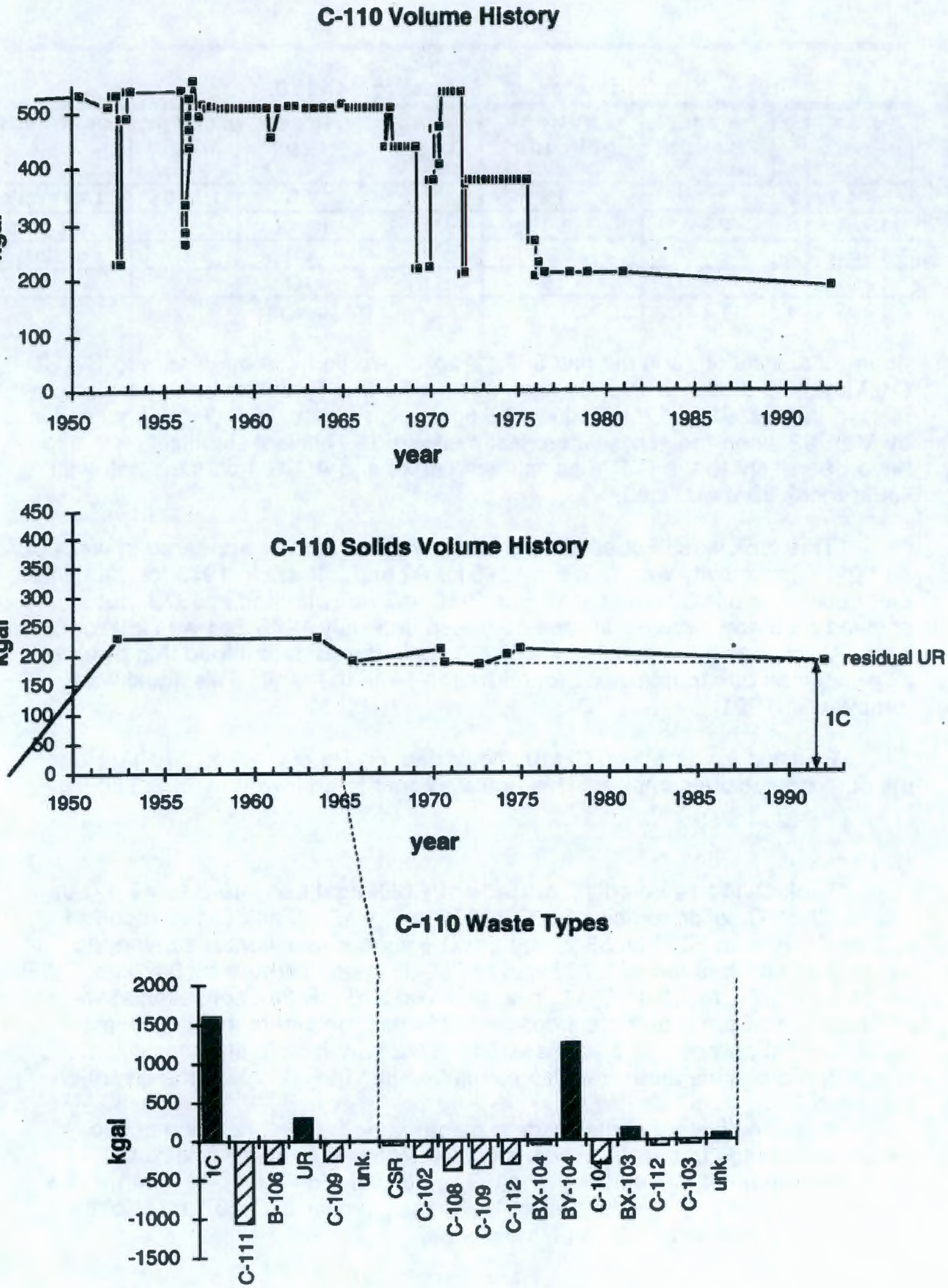

Fig. 14. Total volume, solids volume, and waste type histories for C-110.

The layering is very simple for C-111 (see Table 13) with 20 kgal 1C, 7 kgal FeCN, 27 kgal CWP, and 3 kgal TFeCN. About 38 kgal of the upper FeCN layer is completely missing and most likely went to C-104 and/or C-103 during stabilization of C-111.

Table 13.
Estimates of Solids for C-111.

date	q	meas. solids	solids gain/loss	pred. layer	layer type	primary waste volume	comments
1947	2		36		1C/cas	1,059	
1952	2	36			meas.		
1953	2		50		UR	990	
1953	2		-66	20	1C	990	unk. loss
1956	1		7	7	TFeCN	468	
1957	2		27	27	CWP	339	
1957	2	13??			meas.		ignore
1957	3	54			meas.		
1957	4		35		TFeCN	2,335	
1957	4	95	6		meas.		unk. gain
1982	2		-38	3	TFeCN		unk. loss
1982	2	57			meas.		

Tank C-111 is classified as stabilized and is listed as questionable integrity in 1968 because of an unexplained level decrease, which amounted to 23 kgal from '65-3 to '69-2. It was P-10 salt well pumped in 1978, but no dry well activity has been found. The "unexplained" level decrease was followed by an unexplained level increase in 1972 that recovered the previous volume completely (see Fig. 16). It is very unusual for this tank to have leaked 23 kgal of radioactive waste and yet for no activity to have been found in any of five dry wells. I therefore conclude that C-111 never did actually leak, but rather, there was an error in the level measurement.

In Fig. 16, one can see that C-111 had been plagued with a history of substantial volume errors that were both positive and negative. It therefore seems very reasonable to assign the errors in 1965-70 also to these measurement errors and not to a tank leak. According to a long term reading of the level, all volumes are accounted for and no actual "volume" was ever lost from this tank.

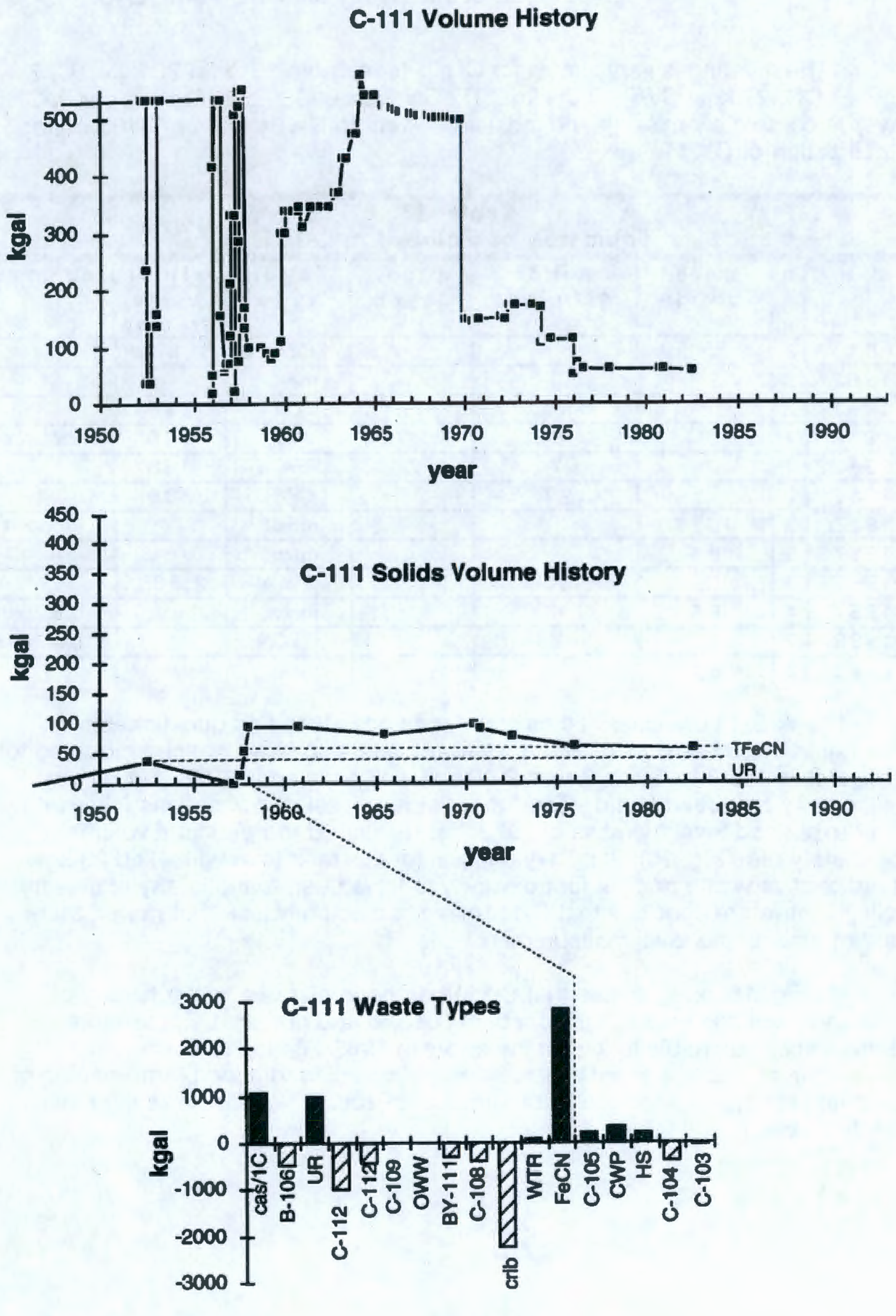

Figure 15. Total volume, solids volume, and waste type histories for C-111.

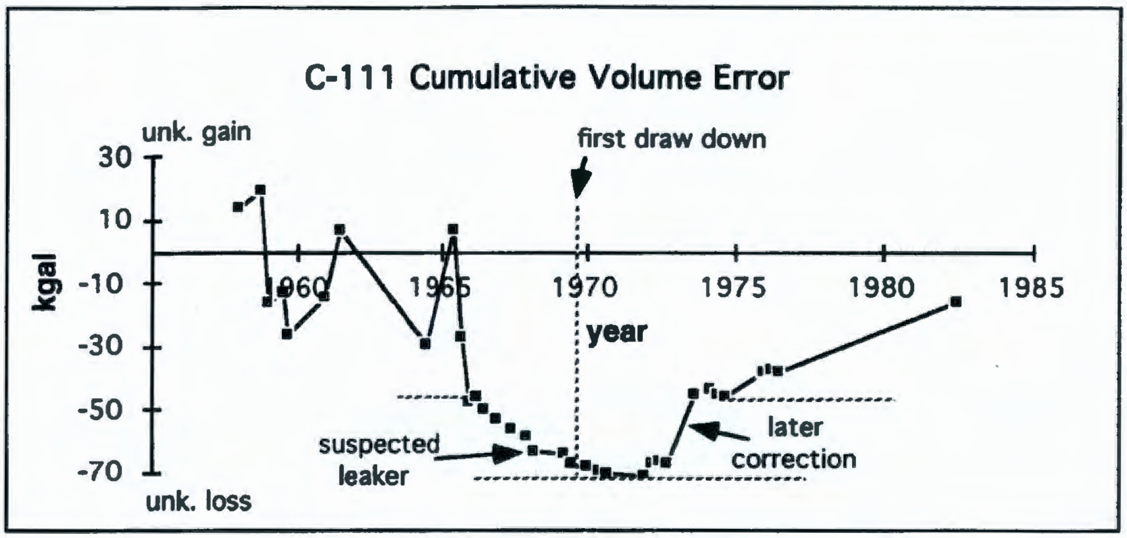

Figure 16. Plot of cumulative volume error for C-111 from 1955 to 1985.

C-112

Tank C-112 received 529 kgal from C-111 via cascade in '47-2, which should not have carried any solids, having originated in C-110, and then transferred through C-111. C-112 then received 502 kgal UR via cascade from C-111 in '53-2 (see Fig. 17), the primary waste of which was added to C-111 and should have resulted in 50 kgal solids in C-111. Very little of these solids should have been carried to C-112, and therefore I will ignore the '52-2 reported 15 kgal of solids. The first solids should have come with a primary UR waste addition of 321 kgal in '54-3, which was followed by scavenging of 4,442 kgal up till '57-4 and storage of the TFeCN solids in C-112. There is a 46 kgal level measurement in '58-1 that is inconsistent with the TFeCN accumulation, and is presumably incorrect. A CWP addition in '61-2 added another 20 kgal, and then there was an unknown increase of 25 kgal followed by a decrease during stabilization of 24 kgal. There was no other activity for C-112 during this period, although the analytical results are consistent with an accumulation of strontium solids from the HS waste addition. The solids loss upon stabilization would have moved high strontium HS solids to C-103.

The layering for C-112 (see Table 14) is 16 kgal UR, 67 kgal FeCN (in-tank), and 21 kgal CWP. Note I have ignored the 15 kgal solids level recorded in '52-2. It is unlikely that solids would make it all the way from C-110, especially since C-111, the intermediate tank, only accumulated 36 kgal of solids over the same period. Furthermore, C-112 was drawn down to 17 kgal in '53-3, and therefore unlikely that there could have been 15 kgal solids within the 17 kgal remnant (P-10 pumps require a 10" head). The FeCN layer is 1.4 vol% of the 4,442 kgal feed, which is consistent with the average solids content of these FeCN scavenging wastes (see App. 1). This tank should have the most

concentrated intact layer of FeCN due to in-tank scavenging in C-Farm, and yet the analysis[55] shows that very little ferrocyanide remains in the FeCN sludge.

Table 14.
Estimates of Solids for C-112.

date	q	meas. solids	solids gain/loss	pred. layer	layer type	primary waste volume	comments
1947	2		0	0	1C/cas	529	
1952	2	15					ignore
1953	2		0	0	UR/cas	496	
1954	3		16	16	UR	321	
1955	3	17	1	1	unk.		unk. gain
1957	4		67	67	TFeCN	4,442	
1958	1	46??			meas.		ignore
1961	2		21	21	CWP	254	8.1 vol%
1962	2			??	HS	58	solids??
1965	2	128	23		meas.		unk. gain
1990	3	104	-22	1	unk.		unk. loss

Tank C-112 is categorized as sound/deactivated. P-10 salt-well pumping was completed in 1979. Slight activity 67 c/s, was noted in 1978 which was attributed to a transfer line from the 252-C diversion box to C-112. Dry well 01 had a 10,000 c/s at 7', which is above the level of the tank in the ground.

An analysis[56] of C-112 reports 7,660 Btu/hr and the average dome space temperature is 80°F. My estimate of the heat generation rate is very close to that for C-112, and for 80°C, I calculate 7,500 Btu/hr.

On the other hand, there are some very significant differences between my analysis and that of Simpson, et al. For example, Simpson, et al. estimate the plutonium inventory at 1.6 kg, while my prediction based on the layer composition is 5.4 kg. Note that my estimate derives solely from the predicted 21 kgal (8") of CWP that should be the top layer of the waste. Of the three cores that were extracted, recovery for the upper segment ranged from 0 to 65 to 87 vol% of an expected 13 inches. Furthermore, only composite analyses were performed, despite the variable recovery of the upper layer. Moreover, the higher concentrations of plutonium were found in the portions of the tank with the largest FeCN concentrations (core 34 composite). It is possible that the upper layer was not adequately sampled, but it is more likely that there was entrainment and/or dissolution of the CWP solids during waste transfers that moved the CWP solids out of C-112.

An addition of 58 kgal of HS waste (hot semi-works, waste that came from a pilot plant for Sr recovery) may be responsible for the very large

[55] *ibid* Simpson, et al. 1993.
[56] *ibid* Simpson, et al. 1993.

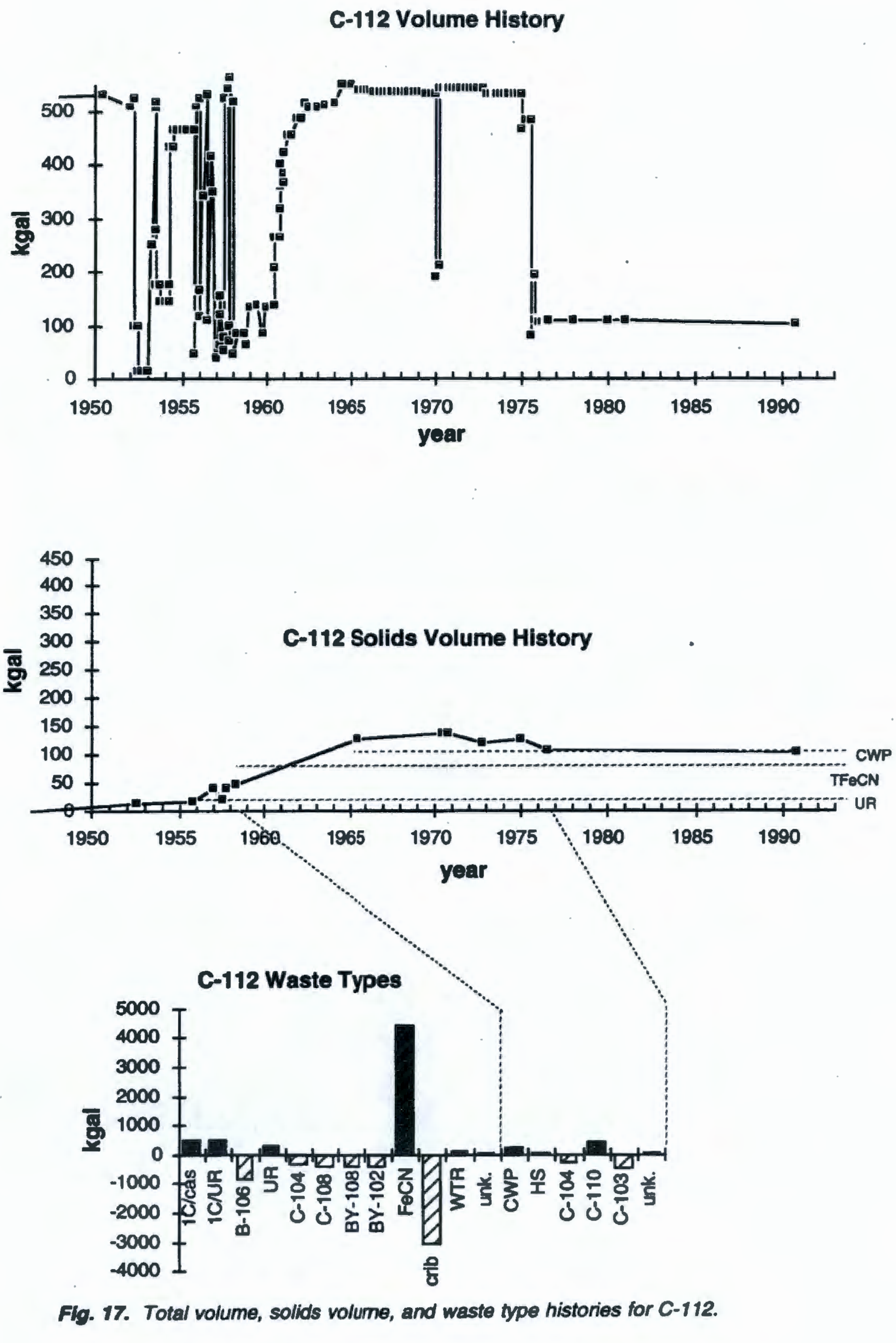

Fig. 17. Total volume, solids volume, and waste type histories for C-112.

concentrations of strontium that were reported for core 34 (4.9 Ci/L), despite the overall very low radionuclide inventory of C-112. I do not know the volume of solids in this HS waste, but in any case, it would not have been larger than about 20 vol% or 12 kgal.

Another discrepancy is the volume inventory estimate by Simpson, et al. of 77 kgal sludge and 36 kgal supernatant, for a total inventory of 113 kgal, while the official inventory is listed as 104 kgal solids with no supernatant. Furthermore, earlier photgraphic estimates of surface liquid concluded[57] that only some 0.2 kgal of liquid supernatant was present, and that it was located in discrete pools on the surface. I suggest that the drill sampling for C-112 may have been sampled such pools for cores 34 and 35, and that their liquids are not representative of the entire tank.

Analyses of C Farm Wastes

There have been some 99 reports[58] on various samples that have been taken from C-Farm tanks. Among these reports are ones for samples from thirteen cores taken from seven tanks on C Farm—one core each from C-102, C-104, C-105, and C-106, two cores from C-103, three from C-110, and three from C-112. The balance of the remaining reports are reanalyses for these cores, analyses of grab samples, and vapor space analyses. Thus, there exists a tremendous amount of analytical information about what is in the C Farm tanks in addition to the historical fill, level, and temperature records.

A more detailed comparison of predicted versus measured compositions for C-Farm tanks will have to wait for the next report.

Conclusions and Recommendations

Continued storage of the organic layer in C-103 represents the most significant safe storage hazard in C Farm. I made several recommendations in a previous report about C-103, and would recommend once again that the organic layer be removed from C-103.

There are two tanks on the high heat watch list: C-106 and C-105. I calculate that the dome space temperature for C-106 would rise to 188°F if its ventilation were stopped, and therefore recommend that the ventilation be maintained or some corresponding method to remove heat from the tank. My calculation suggests that the average dome space temperature will remain at its current 80°F if the losses are maintained at 44,000 Btu/hr.

I recommend dropping C-105 from the high heat watch list, since the heat content of this tank is actually fairly moderate. In fact, the heat content of C-105 is comparable to that of C-103 and C-107 (see Table 1). This is corroborated with both analytical measurements of the strontium and cesium in the sludge as well as average dome space temperature.

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[57] *ibid* Boyles

[58] Hill, J. H. "Catalog of Tank Characterization Documents," WHC-93-???, February 1993.

Correspondingly, I recommend reevaluation of the heat loads of both C-104 and C-107, and especially a determination of the peak waste temperature for C-104. The thermocouple tree for C-104 has been out of service ever since 1982, which is when the tank dried out. I recommend repairing that tree as soon as possible, since some of the temperatures that were recorded were very high.

Tank C-107 has never had a sludge analysis, but I predict based on its average dome space temperature that it has the second highest heat load of any tank on C-Farm, with the highest being C-106 (see Table 1).

Tank C-111 is listed as an assumed leaker, and I have evaluated the fill and level history for C-111 and have found that in all likelihood, this tank has never leaked. I recommend that C-111 be reevaluated and its status as a assumed leaker be reconsidered in light of the measurement error that I found for the tank level.

The plutonium analyses for many of the tanks in C Farm are exactly what is expected based on the waste types. However, for C-103, my estimate is lower than that of the anaylsis by a factor of two, and I cannot explain why that is. Even with the largest Pu concentrations measured on C Farm, I can find no criticality hazard with Pu-239/240 material in any C-Farm tanks.

Finally, the uncertainty in solids level measurements is the largest source of error in my analysis of C-Farm sludge compositions. Therefore, I respectfully request that in the future, all solids measurements be reported just as measured for at least two risers: one near the input and one near the output of the tank. This extra information would be extremely useful in accounting for all solids in the tank farms.

Acknowledgments

This work was performed under the auspices of the Department of Energy. I would like to thank Phyllis Baca and Mike MacInnes of Los Alamos for their help with the TDF data base that we obtained from Jungfleisch-84, and Julian Hill of Westinghouse Hanford Company for help in gathering the analytical data for C Farm, and Betty Hanlon of Westinghouse Hanford Company for help with the temperature and level data for C Farm.

Appendix 1.

Solids Volume Per Cent for Primary Wastes.

The values I have used for the solids contents of primary wastes are derived from the measured solids levels in the waste tanks themselves. The values are preliminary and subject to change. In a way, this strategy is very similar to that used by Borsheim and Simpson in their report on ferrocyanide sludge histories. Thus, I find for TFeCN (in-tank ferrocyanide sludge), 1.4 vol%, 1C is 24.9vol%, P is 2.2 vol%, and CWP is 8.1 vol%.

Furthermore, I have used 5.0 vol% solids for UR, but lack any good solids measurement during that time for a more definitive value. Likewise, MW solids is unknown since all MW was sluiced from the tanks in the early fifties. Any residual heels of MW less than 5 kgal would not be significant enough to show up in my accountability scheme for solids. The volume per cent solids for BL is that required to fit the solids accumulation recorded in C-106, since I have no other way of knowing how many solids were in BL waste. The other two BL receivers, B-101 (3,701 kgal '70-2 to '73-1) and BX-101 kgal ('68-4 to '69-2) were evaporator feed tanks and therefore did not provide accurate solids levels for their BL waste additions.

Finally, the solids content of TH and THL are very uncertain. There were only two tanks that received this waste: C-102 and C-104, and there were no adequate solids measurements to derive an independent value. Therefore, I have adjusted to value to fit the observed solids for these two tanks and have found 5.8 vol% to be a reasonable value that is consistent with the fill history. However, this value should be viewed with extreme caution and is very uncertain.

Table A1.
In-Tank FeCN Waste vol% Solids.

waste type	tank	primary volume	accumul. solids	vol% solids
TFeCN	C-108	1034	15	1.5
	C-109	2954	44	1.5
	C-111	2732	35	1.3
	C-112	4442	67	1.5
TFeCN	**avg.**	**11162**	**161**	**1.4**

For 1C wastes, I have found two distinct values for vol% solids, as shown in Table A2. Evidently, there was some kind of change in the process, since 1C waste during 1945-46 averaged 13.7 vol%, while waste during 1947-51 averaged 24.9 vol%. I cannot be certain yet what this process change was, but it might have been associated with the decladding wastes. According to records, decladding waste was added to 1C waste and constituted 50 vol%.

Perhaps the earlier 1C did not have the same amount decladding waste as did the later 1C waste.

I will therefore use a different value for 1C waste for these two different time periods—13.7±1 vol% for 1945-46 and 24.9±2 vol% for 1947 on.

Table A2.
1C Waste vol% Solids.

tank	start	qtr.	end	qtr.	waste type	pri.vol.	acc.sol.	vol%
BX-107	1948	3	1951	2	1C	1590	437	27.5
C-107	1947	1	1947	4	1C	1588	399	25.1
TX-109	1949	1	1950	2	1C	3032	722	23.8
U-110	1946	3	1951	1	1C	1394	336	24.1
avg.	**1947**	**1**	**1951**	**2**	**1C**	**7604**	**1894**	**24.9**
B-107	1945	2	1946	2	1C	1590	220	13.8
C-110	1946	2	1947	4	1C	1589	231	14.5
T-107	1945	1	1947	4	1C	1590	201	12.6
avg.	**1945**	**1**	**1947**	**4**	**1C**	**4769**	**652**	**13.7**

The values for P waste are very close to 2.2±1 vol%, with the exception of A-106, which accumulated solids of 8.1 vol%. I have not included this value in my average for P waste and suggest that it is not representative of the average vol% solids in P waste. Note that according to the record, the solids from A-106 were the ones being washed in AR-002 when the inadvertent addition of terminal solids to C-106 occurred. These solids evidently did not settle properly in AR-002, which is why they were transferred to C-106.

Table A3.
P Waste vol% Solids.

tank	start	qtr.	end	qtr.	waste type	pri.vol.	acc.sol.	vol%
A-101	1956	1	1973	4	P	4545	83	1.83
A-102	1956	1	1961	3	P	7138	102	1.43
A-103	1956	2	1960	3	P	3813	102	2.68
A-104	1959	3	1961	4	P	6765	171	2.53
AX-104	1966	3	1969	2	P	1202	47	3.91
avg.	**1956**	**1**	**1973**	**4**	**P**	**23463**	**505**	**2.15**
A-106	1960	4	1962	2	P	1460	118	8.08
AX-101	1968	2	1969	2	P	40	??	??
AY-101	1971	2	1971	4	P	14	??	??
C-104	1970	4	1976	2	P	91	??	??

CWP waste during 1956-62 averaged 8.1±1 vol %, and involved only aluminum cladding. From 1962-65, however, the solids content of CWP changed dramatically as shown in Table A4. The solids vol% for CWP added to C-102 during this period is consistent with 3.1 vol%. The solids in CWP may have decreased because of the increase in the level of caustic added, thereby solubilizing more aluminum.

Table A4.
CWP Waste vol% Solids.

tank	start	qtr.	end	qtr.	waste type	pri.vol.	acc.sol.	vol%
C-101	1960	4	1962	2	CWP/Al	660	56	8.5
C-103	1960	2	1960	4	CWP/Al	479	35	7.3
C-104	1956	1	1957	2	CWP/Al	1118	90	8.1
C-105	1957	3	1960	2	CWP/Al	3130	262	8.4
C-106	1958	2	1960	2	CWP/Al	420	28	6.7
avg.	**1956**	**1**	**1965**	**2**	**CWP/Al**	**5807**	**471**	**8.1**
C-102	1960	3	1965	2	CWP/Al	5355	184	3.4
C-104	1969	4	1970	1	CWP/Zr	535		
C-104	1970	2	1972	3	CWP/Al	3816	108	2.5
C-102	1965	3	1969	4	CWP/Al&Zr	6448	??	??
C-107	1961	3	1962	2	CWP/Al	1364	??	??
C-108	1961	2	1961	2	CWP/Al	502	??	??
C-111	1957	1	1960	4	CWP/Al	347	??	??
C-112	1960	3	1961	2	CWP/Al	254	??	??

Between 1966 and 1969, a change was made to processing zirconium cladded fuel elements, and then in 1970 a change was made back to aluminum cladding. However, the solids contents during this latter period were still very low, averaging 2.5 vol% in C-104. Evidently, whatever process change occurred after 1962 for Al cladding dissolution was maintained for this later campaign.

I have renamed the CWP during 1966-70 CWP/Zr to distinguish it from CWP/Al. Note that C-102 and C-104 are the only tanks that received CWP/Zr with direct additions, and I will use 2.5 vol% solids as representative of CWP/Zr. According to Jungfleisch-84, CWP/Zr was only active during the years 1966-69, but my results suggest that CWP/Zr was active over the years 1966-70. In other words, if there were no CWP/Zr processed in 1969-70, C-104 would not have received any Zr at all. The anaytical results suggest that C-104 actually received the most Zr of any C-Farm tank.

Tank C-102 received a combination of CWP solids from both CWP/Al and CWP/Zr, but there was also a very large washout of CWP solids from C-102

(see text). For these reasons, I have not used C-102's solids measurement in the CWP solids calculation. I have instead calculated C-102's solids using the above numbers and assumed that the remaining solids were lost because of entrainment/dissolution during subsequent waste removal.

Appendix 2.

Plutonium concentrations in P waste sludge.

There are several tie analytes that can be used to double check the Pu values for process sludge. One such analyte for Purex sludge is iron. For example, ferrous ammonium sulfate is used to control the oxidation state of plutonium in the Purex process, and so the amount of iron added is always proportional to the amount of plutonium being processed. As long as the *average* Pu extraction efficiency was more or less constant for a given waste type, the Pu/Fe ratio will also be a constant for Purex high level waste. The primary waste stream from Purex is concentrated and neutralized, and this neutralization precipitates both the iron and the plutonium together as oxides and hydroxides. It has been known for many years[59] that iron hydroxide sequesters plutonium oxides very effectively, and therefore the iron phase should also sequester the plutonium residue of Purex as well.

Thus, I have derived a tentative Pu/Fe ratio criterion for Purex high level sludge, which is largely based on data from Allen-76 for plutonium and iron in Purex sludges. Using this data, I derive a value of 1.5±?? mCi Pu / mol Fe. I suggest that any Pu/Fe ratios that are much larger than 1.5 mCi Pu / mol Fe are not possible for Purex sludge and should be reviewed.

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[59] *ibid* Bratzel.

Appendix 3.

Glossary of Hanford Terminology.

This is a glossary of Hanford terminology that I have compiled to aid in my analyses. These definitions have come from so many different sources that it is difficult to name them all. A lot of these terms have come from Anderson-90, Jungfleisch-84, and from Strode-93. Where there have been conflicting uses of the same term, I have tried to indicate that, and where I am uncertain as to the exact meaning, I have used "??" to indicate that uncertainty.

If you have any corrections to this glossary, please send them to me and I will gladly incorporate them into my master list.

0.17	Transaction flag key—monthly volumes derived from semi-annual reports.
0.33	Transaction flag key—monthly volumes derived from quarterly reports.
1	Monthly report
3	Quarterly report.
6	Semi-annual report.
5-6#	Cells 5&6 from B-Plant
1AYIN	CONCENTRATED COMPLEX WASTE FROM 101AY INVENTORY
1AZIN	PRE 2-81 101AZ INVENTORY
1C	1st cycle decontamination-BiPO4 process. Often included cladding waste. Held 10% of FP, 1% of Pu.
1CEB	1st cycle evaporator bottoms
1CF	??1st cycle feed?? Set to water in TRAC.
1CS	1st Cycle Scavenging waste. TY-101 and TY-103 received 1C waste that was scavenged with FeCN before it was added to the tanks.
222-B	B-Plant used for BiPO4 1944-52, then for FP recovery.
222-T	T-Plant used for BiPO4 1944-52.
224-F	224-U waste. LaF Pu Finishing Plant. Same as Z-Plant?
224-2	Same as 224?
231Z	dilute waste from 231Z lab

231Z	DILUTE, PHOSPHATE WASTE FROM 231Z LABORATORIES	
242-A	Reduced pressure evaporator in East Area designed for 30% solids, 1977-pres. AW-102 is feed.	
242-B	Atmospheric evaporator used for concentrating wastes, 1952-56. B-106 was feed tank.	
242-S	Reduced pressure evaporator designed for 30% solids 1973-80. S-102 was feed '73-'77. SY-102 was feed '77-'81.	
242-T	Atmospheric evaporator used to concentrate wastes. 1952-56 and 1965-76. TX-118 was feed tank.	
2AYIN	PRE 2-81 102AY INVENTORY	
2AZIN	PRE 2-81 CONCENTRATED COMPLEX WASTE FROM 102AZ INVENTORY	
2C	2nd Cycle decontamination waste from BiPO4 process. Supernatant often cribbed, 0.1% of FP, 1% of Pu.	
2SYIN	PRE 2-81 102SY INVENTORY	
3AWIN	PRE 2-81 103AW INVENTORY	
5AWIN	PRE 2-81 105AW INVENTORY	
6AWIN	CONCENTRATED PHOSPHATE WASTE IN 106AW INVENTORY	
ADD	Add primary waste from process	
ADJ	Adjustment to waste amount-see CORR	
AGE	Aging waste-see AGING	
AGING	Aging waste-see AGE	
A-Plant	See Purex Plant.	
AR Vault	PSL (Purex sludge) was sluiced from A and AX Farms and placed here (for Sr extraction?). AR-002 (or TK-002) was slurry receiver in AR Vault. Solids are then transferred to TK-004, acidified, and the PAS transferred to TK-003.	Any solids left in TK-004 following acid dissolution are caustic digested and transferred to back TK-002 for the next cycle.
B	B-Plant HLW. Also identifies waste returned to tanks from Sr recovery. Also used as destination, B-Plant, for Cs/Sr recovery. BIPO4 ran in B Plant from Apr. 1945 to Oct. 1952, while Cs/Sr recovery from tank farms ran from1967 to 1976, and Cs/Sr recovery from NCAW and CAW ran from 1967-72, and then from1983-91.	B-Plant's mission from '67 was to take the acid stream from Purex through cesium and strontium recovery operations.

B86ON	DILUTE, NON-COMPLEXED WASTE FROM B PLANT CELL DRAINAGE
BFSH	B-Plant Flush
BIPO4	First process for separating Pu, in 222-B and 222-U, 1944-56. Left U in waste. See MW, 1C, 2C.
BIX	B-Plant ion exchange
BIXBN	??
BIXRI	??
BL	B-Plant low level. From '68-'76 added to AX-103, BX-101, B-101, and C-106. Wash(?) waste after concentration in cell 23 (i.e. low solids). 3.6 vol% solids.
BLEB	B-Plant low level evaporator bottoms
BLIX	B-Plant Low Level Ion Exchange?
BLIXB	B-Plant Low Level Ion Exchange bottoms?
BN	??
BNW	Battelle NW
BPDCC	DILUTE, COMPLEXED WASTE FROM B PLANT CESIUM PROCESSING
BPDCS	DILUTE, COMPLEXED WASTE FROM B PLANT STRONTIUM PROCESSING
BPDCV	DILUTE, COMPLEXED WASTE FROM B PLANT VESSEL CLEAN-OUT
BPFPS	B PLANT HIGH TRU SOLIDS FROM RETRIEVED PFP SOLIDS
BPLCS	DILUTE, NON-COMPLEXED WASTE FROM B PLANT STRONTIUM PROCESSING
BPLDC	DILUTE, COMPLEXED WASTE FROM B PLANT CESIUM PROCESSING
BPLDN	DILUTE, NON-COMPLEXED WASTE FROM B PLANT CESIUM PROCESSING
BVCLN	DILUTE, NON-COMPLEXED WASTE FROM B PLANT VESSEL CLEAN-OUT
CARB	Carbonate
CARB	CARBONATED WASTE—?same as OWW?

CAS	Cascade-see SET and END. This process filled three tanks with one pump by using overflow siphoning. Normal use was with a sequence of tanks such as 101, 102, 103, or 110, 111, 112.
CAW	Current Acid Waste—this is Purex acid HLW.
CB	??
CC	Complexant Concentrate
CCGL	B PLANT HIGH TRU SOLIDS FROM RETRIEVED COMPLEXED CONCENTRATE
CCGR	DILUTE, NON-COMPLEXED WASTE FROM RETRIEVED COMPLEXED CONCENTRATE
CCPLX	Complexant Concentrate—see CPLX
CCW	CC Waste?
CD	??
CDF	Composition Data File or Transaction Flag Key—unit volume assumed to make stream active.
CE	Evaporator Concentrate
CEM	Concrete-see CON
CF	Cesium Feed
CON	Concrete-see CEM
COND	Condensate-see EVAP, EB.
COOL	Change in waste volume due to cooling? see CORR
CORR	Correction to waste amount-see ADJ, LEAK, COOL
CP	Concentrated Phosphate waste (from 100 N reactor decontamination)
C-Plant	See SSW.
CPLX	Complexed Waste—see CC, CCPLX
CRIB	Ground site for low level supernatants (from tanks) or condensates (from evaporators). B-##, S-##, T-##.
CSFD	Cesium Feed?
CSKW	??
CSR	Waste sent to B-Plant for cesium recovery

CST	Caustic Solution
CSWLE	COMPLEXED SALT WELL LIQUID EAST AREA
CSWLW	COMPLEXED SALT WELL LIQUID WEST AREA
CTW	??Caustic waste for makeup??
CW	Cladding Waste
CWP	Cladding Waste-Purex
CWP/Zr	Cladding waste from Purex 1966-70 that used Zirflex clad fuel elements.
CWR	Cladding Waste-Redox
CX70	DILUTE, COMPLEXED (MIXTURE) HOT-SEMIWORKS TRU SOLIDS
D	Transaction Flag Key-Amount by difference.
DC	Dilute Complexed waste.
DCS	Dilute Caustic Solution
DE	Diatomaceous Earth added to BX-102, SX-113, TX-106, TX-117, U-104 from 1970 to 1972
DEF	??
DIL	Dilution??
DILFD	Dilute Feed?
DN	Dilute non-complexed waste (i.e. contains no complexants) defined as waste with TOC <1wt% (10 g/L).
DN/PD	DN with P TRU solids-see DN, P, TRU.
DN/PT	DN with PFP TRU solids-see DN, PFP.
DSS	Double Shell Slurry (from EOFY 77 inventory?). This waste is a concentrate of DSSF, but with a TOC<10g/L (<1wt% TOC is NC).
DSSF	Double Shell Slurry Feed
DUMM	Dummy Waste
DUMMY	Dummy Waste
DW	Decontamination Waste

DWBIX	Decon. Waste and B-Plant Ion Exchange
E	Transaction Flag Key-Waste transferred through evaporator.
EB	Evaporator Bottoms
EF	Evaporator Feed
EFD	Evaporator Feed Dilute
END	Disconnect Cascaded Tanks, see CAS, SET.
EV	evaporation
EVAP	Evaporator connected to tank-see COND, EB.
EVAPF	DILUTE, NON-COMPLEXED WASTE FROM EVAPORATOR PAD FLUSH
EVS	Partial neutralization in 242-S Evaporator.
EVT	HEDTA destruction in 242-B or 242-T evaporators.
FeCN	Ferrocyanide wastes created during a scavenging campaign in 1953-57. See SCAV, P00, T00.
FD	Feed Dilute
FLSH	Flush water.
FP	Fission Product Waste. Cs and Sr recovery began in 222-B in 1967. Cs was removed from Purex SU and Sr from Purex SL, and both from acidic waste.
GA	gain to tank
GAS	SLUURY GROWTH AS A RESULT OF GAS GENERATION
GROUP	A group of tanks where ITS averaged the supernatant phases-see ITS
H2O	water, see WTR.
HDRL	Hanford Defense Residual Liquid
HEAT	A tank correction, see CORR, COOL
HLO	Hanford Lab Operations
HLW	High Level Waste—generic for all Hanford tank wastes.
HOT-SEMI	See HS, SSW.

HS	Hot Semi-Works. A pilot facility that had a variety of operations. See SSW.
HWVP	DILUTE, NON-COMPLEXED WASTE FROM THE VITRIFICATION PLANT
I&S	Tank Isolated and Stabilized
IC	Synonym (misspelling?) for 1C-1st cycle decontamination waste-BiPO4
ICEBC	?? (1st cycle evaporator bottoms concentrate??)
INST	CHANGE IN TANK LEVEL Due TO CHANGE IN INSTRUMENTATION
ISO	Tank is Interim-Isolated
ITS	In-Tank Solidification-Program using steam evaporators inside of certain tanks on BY-Farm. ITS#1 ran 1965-70 in BY-101 (or 102?) and ITS#2 ran 1968-74 in BY-112, with ITS#1 used as cooler 1971-74.
IWW	INORGANIC WASH WASTE TO SST—same as P or NCAW.
IX	Ion Exchange. Identifies waste returned from Cs recovery.
IXROW	??Ion-eXchange Redox Organic Wash??
LaF	Lanthanum fluoride waste generated in plutonium finishing plant operation from 1945-??. See 224-F.
L222S	222S lab dilute non-complexed waste
L3A4A	dilute non-complexed lab wastes from 300 and 400 areas.
LEAK	Tank leak volume, see CORR.
LETF	LIQUID EFFLUENT TREATMENT FACILITY FROM N REACTOR
LO	loss from tank
LUNC	DILUTE, NON-COMPLEXED WASTE FROM UNC FUELS FABRICATION FACILITY
LW	Lab Waste
MW	Metal Waste from BiPO4. 90% of FP, all of U, 1% of Pu (see 1C, 2C).
MWF	Metal Waste Feed? Set to water in TRAC.

N	N-Reactor waste (see CP)
NCAW	Neutralized Current Acid Waste (see also IWW) primary HLW stream from Purex process.
NCPLEX	Non-Complexed Waste-see NCPLX
NCPLX	Non-Complexed Waste- see NCPLEX
NCRW	Neutralized Cladding Removal Waste—same as CWP.
NFAW	AGING WASTE FROM PUREX/PFM HIGH LEVEL WASTE (FFTF-NCAW)
NHAW	AGING WASTE FROM PUREX/PFM PROCESSING OF NPR FUEL
NIT	HNO3/KMNO4 solution (from evaporator operation?)
NRAW	AGING WASTE FROM PUREX/PFM RESIDUE ACID WASTE (FFTF-NCAW)
NRP82	DILUTE, NON-COMPLEXED WASTE FROM FY82 100-N AREA WASTE TRANSFER
NRPO4	DILUTE, PHOSPHATE WASTE FROM 100 N AREA
NRSO4	DILUTE, NON-COMPLEXED WASTE FROM 100 N AREA
OWW	Organic Wash Waste from Purex. Often assumed to be 1:1 with P HLW.
P	Purex HLW, 1956-72. Sometimes assumed to be 50% OWW. Used NPH/TBP to extract both Pu and U. Np also 1963-72.
P00-P##	In-Plant scavenging with FeCN-see SCAV, T00-T##
PADFG	PUREX AMMONIA DESTRUCTION WASTE, FROM FUELS GRADE FUEL
PADWG	PUREX AMMONIA DESTRUCTION WASTE, FROM WEAPONS GRADE FUEL
PAS	Purex Acidified Sludge—refers to sludge that has been sluiced from waste tanks and acidified to 0.1 M HNO3 (as part of Cs/Sr recovery) in AR-Vault.
PASF	PUREX AMMONIA SCRUBBER FEED
PAW	Purex Acidified Waste. Also used to refer to aluminum cladded fuel (as opposed to ZAW for zirconium cladded fuel). See NCAW.
PD	Purex decladding waste. See CWP, NCRW, PN.

PDBNG	DECLADDING SLUDGE (NON-TRU) FROM B PLANT PROCESSING
PDBSU	DILUTE, NON-COMPLEXED WASTE FROM B PLANT DECLADDING WASTE
PDBTG	B PLANT AGING WASTE SOLIDS FROM PUREX DECLADDING WASTE
PDCSS	DILUTE NON-COMPLEXED PUREX DECLADDING WASTE, FY 1986 ONLY
PDL87	PUREX DECLADDING SUPERNATANT, 1987
PDL89	PUREX DECLADDING SUPERNATANT, NON TRU, SPENT METATHESIS REMOVED
PDNSG	NON-TRU DECLADDING SLUDGE FROM PUREX
PDS87	PUREX DECLADDING SLUDGE
PDS89	PUREX DECLADDING SLUDGE AFTER FY89
PDSLG	PUREX DECLADDING SLUDGE SOL PUREX
PDSUP	DILUTE, NON-COMPLEXED WASTE PUREX DECLADDING WASTE
PFeCN	Ferrocyanide sludge produced by in-plant savenging of waste from uranium recovery. See FeCN, TFeCN, UR, P00, T00.
PFM	??? (but see NFAW, NRAW, NHAW).
PFMMS	DILUTE, NON-COMPLEXED WASTE FROM SHEAR/LEACH PROCESSING OF NPR FUEL
PFP	Pu finishing plant waste (see Z, 224, PRF).
PFPGR	DILUTE, NON-COMPLEXED WASTE FROM RETRIEVED PFP SOLIDS
PFPNT	NON-TRU SLUDGE FROM THE PFP SOL Z PLANT
PFPPT	DILUTE, NON-COMPLEXED WASTE FROM THE PFP (WITH TRUEX)
PFPSL	HIGH-TRU SLUDGE FROM THE PFP SOL Z PLANT
PL	Purex Low-Level
PML89	PUREX SPENT METATHESIS LIQUID AFTER FY89
PMS89	PUREX SPENT METATHESIS SOLIDS AFTER FY89

PN	Purex Neutralized cladding waste, see PD, NCRW, CWP.	
PNF	Partial Neutralization Feed. Indicates addition of nitric acid at an evaporator in an attempt to produce more salt cake during volume reduction.	
PRF	Plutonium Reclamation Facility—Type of waste generated in Z-Plant for "finishing wastes". Solvent based extraction process using CCl4/TBP.	
PSL	Purex sludge sluiced during recovery of Sr.	
PSS	Purex Sludge Supernatant	
PSSF	Purex Sludge Supernatant Feed?	
PT	TRU solids from 200W.	
PT100	TRU waste from ??	
PUREX	Plant where Purex process ran from Jan.1952-Jun. 1972, then was in standby and ran again from Nov. 1983 to 1991, and is now shutdown (see P, CWP, OWW).	Also called A-Plant.
PX86S	DILUTE, NON-COMPLEXED WASTE FROM PUREX MISC. STREAMS (NPR FUEL) FY 86	
PXBAW	B PLANT AGING WASTE SUPERNATANT FROM RETRIEVED AGING WASTE	
PXBSG	B PLANT AGING WASTE SOLIDS FROM RETRIEVED AGING WASTE	
PXFTF	DILUTE, NON-COMPLEXED WASTE FROM PUREX MISC. STREAMS (FFTF)	
PXLOW	PUREX LOW LEVEL WASTE THAT WENT TO SST	
PXMET	PUREX DILUTE, NON-COMPLEXED DECLADDING: SPENT METATHESIS	
PXMSC	DILUTE, NON-COMPLEXED WASTE FROM PUREX MISC. STREAMS (NPR FUEL)	
PXNAW	AGING WASTE FROM PUREX HIGH LEVEL WASTE	
R	Redox waste was generated from 1952 to 1966. It used methylisobutylketone (hexone) as a solvent, and extracted both uranium and plutonium. (S-Plant)	Ran from Jan. 1952 to Dec. 1967.
RCC	??Redox CC??	
REC	Receive waste from another tank-see XFER	
REDOX	Plant where redox process ran 1956-67? (see R,CWR).	

RESD	Residual
RIX	Redox Ion Exchange-see RTX, SIX
RMC	Remote Mechanical C-Line—Process used in Z-Plant.
RSN	Redox Supernatant
RSS	Redox Sludge Supernatant
RTX	Redox Ion Exchange-see SIX, RIX
S	Transaction Flag Key-Partial neutralization (PNF).
SCAV	Scavenging campaign with FeCN on TBP, 1952-57. See T00-T##, P00-P##
SET	Connect cascaded tanks together-see CAS and END
SF	slurry feed?
SIX	Redox Ion Exchange-see RTX, RIX
SL	Sludge
SL3SY	DOUBLE-SHELL SLURRY FROM EOFY 80 103SY INVENTORY
SPRG	Sparge-transfer of water or volume?
SRR	Waste sent to B-Plant for strontium recovery
SRS	Strontium Recovery Supernatant
SSW	Strontium Semi-Works. Called C-Plant earlier and was pilot for both Redox and Purex Jul. 1952 to Jul. 1956. Then reconfigured for strontium recovery pilot plant from Jul. 1960 to Jul. 1967.
STAB	Tank stabilized by removal of liquid. Both floating suction and salt-well jet pumps used to remove liquid.
Strontium Semi-Works	see SSW.
SU	Supernatant
SV	Transaction Flag Key-Amount by difference in solids.
SWLIQ	DILUTE, NON-COMPLEXED WASTE FROM EAST AREA SINGLE-SHELL TANKS
SWLQW	DILUTE, NON-COMPLEXED WASTE FROM WEST AREA SSTs

SW RCR	Salt Well Receiver	
TK	Tank. TK-17-2, however, was early designation for B-Plant	
T-Plant	Decontamination plant for various equipment. Originally built for BiPO4 process, but since only used for decon.	BiPO4 ran from Dec. 1944 to Aug. 1956.
T00-##	In-Tank scavenging with FeCN-see SCAV, P##	
TBP	Tri-Butyl Phosphate-waste from solvent based Uranium Recovery operation in '50's.	
TCO	DILUTE NON-COMPLEXED WASTE FROM TERMINAL CLEANOUT	
TFeCN	Ferrocyanide sludge produced by in-tank or in-farm scavenging. See FeCN, PFeCN, UR, P00, T00.	
TH	Thoria HLW or Cladding waste	
THL	Thoria Low Level	
TL	Terminal Liquor	
TPLAL	T-Plant liquid	
TPLAL	DILUTE, NON-COMPLEXED WASTE FROM T PLANT	
TPLAN	DILUTE, NON-COMPLEXED WASTE FROM T PLANT	
TPLAS	SLUDGE FROM T PLANT OPERATIONS	
TR	transfer from tank	
trFlag	Transaction Flag Keys—used by W-Trac—see CDF,D,E,S,SV,1,3,6,.17,.33	
U-Plant	Uranium Recovery plant (see UR, TBP) from Mar. 1952 to Jan. 1958, UO3 plant from then until Sept. 1972. Restarted in Mar. 1984, and is now shutdown.	
U1U2	DILUTE, NON-COMPLEXED WASTE FROM U1/U2 GROUNDWATER PUMPING	
UNKN	UNKNOWN WASTE ORIGIN SINK	
UR	Uranium Recovery operation in 222-U, 1952-57. Created TBP (primary waste) and FeCN (scavanging wastes). See TFeCN, PFeCN, P00, T00, FeCN.	
WATER	FLUSH WATER FROM MISCELLANEOUS SOURCES	
WTR	Water-see H2O	

WVP	Waste Volume Projections	
XFER	Transfer of waste out of tank.	
Z	234-5Z waste/Z-Plant Pu Finishing	
ZAW	Zirconium Acidified Waste (Purex waste stream from zirconium (Zircaloy II) cladded fuel.	
Z-Plant	Pu Finishing plant (see Z, PFP, 224).	Operated from 1949 to 1991, and is in standby now.
ZHIGH	Z-Plant high level waste	
ZHIGH	DILUTE, NON-COMPLEXED WASTE FROM THE PFP (WITHOUT TRUEX)	
ZLAB	Z-Plant lab waste	
ZLAB	DILUTE, NON-COMPLEXED WASTE FROM PFP LABORATORIES	
ZLOW	Z-Plant low level waste	
ZLOW	DILUTE, NON-COMPLEXED WASTE FROM PRE-FY85 Z PLANT OPERATIONS	
ZPRFL	Z-Plant PRF liquid waste	
ZPRFL	DILUTE, NON-COMPLEXED WASTE FROM PRF PROCESSING	
ZPRFS	Z-Plant PRF solid (TRU) waste	
ZPRFS	PFP TRU SOLIDS FROM PRF PROCESSING	
ZRMCL	Z-Plant RMC liquid waste	
ZRMCL	DILUTE, NON-COMPLEXED WASTE FROM PFP RMC PROCESSING	
ZRMCS	Z-Plant RMC solid waste	
ZRMCS	PFP TRU SOLIDS FROM PFP RMC PROCESSING	

Note on transactions involving:

CAS-Cascades that "overfill" are assumed to have been directed to low-level "sites" (cribs or trenches?). No MW or R was cascaded to low-level sites.

EVAP-Operations involving evaporators are assumed to change the waste by the difference in the transaction and status reports.

R-Redox plant used concentrator 1967-72.

B-B plant used concentrator 1967-68.

capacities and tanks

55 kgal	530 kgal/SST	758 kgal/SST	1,000 kgal/SST	1,000 kgal/DST	1,160 kgal/DST
B-200	B-100	BY	A	AY	AN
C-200	BX-100	S	AX	AZ	AP
T-200	C-100	TX	SX		AW
U-200	T-100	TY			SY
	U-100				

Appendix 4. Review comments and reply.

I received 103 specific comments and 3 1/2 pages of more general comments from three DET reviewers, as well as numerous internal review comments from LANL colleagues. I appreciate the time the reviewers have taken with this report and have found many of the comments very useful. I will reply to all comments with which I take exception, and will not will not specifically reply to those comments with which I have agreed completely.

REVIEW COMMENT RECORD (RCR)

1. Date	2. Review No.
08/27/93	
3. Project No.	**4. Page**
	1 of 9

5. Document Number(s)/Title(s)	6. Program/Project/ Building Number	7. Reviewer	8. Organization/Group	9. Location/Phone
Agnew, S. F., *History of 241-C Farm*, LAUR-93-0000 (draft), July 1993		B. C. Carpenter editor for, H. Babad, G.L. Borsheim, D.A. Reynolds	Evaluation, Documentation & Reporting	200E/2750/D256 373-2666

17. Comment Submittal Approval:

Organization Manager (Optional)

10. Agreement with indicated comment disposition(s)

Date

Reviewer/Point of Contact

Author/Originator

11. CLOSED

Date

Reviewer/Point of Contact

Author/Originator

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/ resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
1	P. 1, Abstract, first paragraph, last sentence, Item 3): (Reviewer #2), 'Mention C-108 & C-111 here too?' These were discussed in paragraph 2.		#1: My analysis shows that C-108 and C-111 have lost most of the original ferrocyanide layers, and therefore they do not have substantial amounts of ferrocyanide any longer.	
2	P. 3, sentence 1, "This report was largely ..": (#2), Delete the phrase "in final form".			
3	P. 3, paragraph 1, sentence 1, "Later, Jungfleisch ...": (#2), Define S2K.			
4	P. 3, paragraph 1, TRAC Review References: (Reviewer #1), 'Please contact Louis Jenson (WHC) for additional references relating the review of the TRAC system that were done by WHC and PNL staff.' JENSEN, LOUIS 509/373-2779 WHC OPS/Process Analytical Labs MISN T6-07 LOCATION: MO039/5/200W FAX 509/373-4652	BC		
5	P. 3, paragraph 1, sentence 5, "Unfortunately, the input data ...": (#2), Add the phrase; 'The program was never optimized and benchmarked and ...'			
6	P. 3, paragraph 2, sentence 5, "Furthermore, is was not clear ...": grammatical error; ... *It* was not clear ...			

REVIEW COMMENT RECORD (RCR)

1. Date	2. Review No.
08/27/93	
3. Project No.	**4. Page**
	2 of 9

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/ resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
7	P. 4, paragraph 2, sentence 6, "It does not distinguish ...": (#2), Replace "contains" with "contained".			
8	P. 5, paragraph 3, sentence 3, "When primary waste ...": (#2), Define "primary".			
9	P. 5, paragraph 5, sentence 2, "For one thing, since salt slurry ...": (Reviewer #3), 'Why?'			
10	P. 6, paragraph 2, last sentence, "The other category ...": (#2), Replace "total" with "added".			
11	P. 6, paragraph 3, sentence 2, reference to other liquids: (#1), 'The meaning of "other liquids" in tanks C-106 and C-109 is not clear. The author has previously mentioned that C-103 contains an organic liquid.'	BC	#11: Other liquids include aqueous and organic liquids within my definition.	
12	P. 6, last paragraph, "There will be an ...": (#2), 'The solids percentage from Tables A2, A3, & A4 need to be QA'ed.'	BC	#12: Of course. That is why I have put all of the information that I have down. However, for this report, I will proceed with the information that I have.	
13	P. 7, sentence 4, "For example, there was a report ...": (#3), TFeCN 'not defined here nor in definitions.'			
14	P. 7, paragraph 1, sentence 1, reference to measurements "at the outer edge of the tanks", & paragraph 2, sentence 1, "Finally, core removed ...": (#2), 'True for 530 kgal tanks but not necessarily true for 750 or 1,000 kgal tanks.'			
15	P. 7, paragraph 1, sentences 6 & 7, "In particular, during sluicing ..." & "These doughnut heels ...": (#2), 'What is basis or reference for these statements.	BC		
16	P. 7, paragraph 2, reference to treatment of zero volumes: (#1), 'The interpretation that challenges zero volumes is correct only for the first significant (12.5 Kgal) addition of solids to a tank. Beyond that point, with the dish filled, zero volume may truly represent the solids addition to the tank.'	BC	#16: I thought that is what I said.	
17	P. 9, first (partial) sentence: (#2), 'B-Plant shutdown in 1952, T-Plant shutdown in 1956.'			
18	P. 9, paragraph 1, sentence 2, "Second Cycle (2C) waste ...": (#2), Insert "second" in place of "final" plutonium purification cycle.			

REVIEW COMMENT RECORD (RCR)

1. Date	2. Review No.
08/27/93	
3. Project No.	**4. Page**
	3 of 9

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19	P. 9, paragraph 2, sentence 2, "C-101,2,3 and ...": (#2), C-4,5,6? Should say C-*104*,5,6; Replace years 1945-49 with 1946-52.			
20	P. 9, paragraph 3: (#2), The next major item is the 1952-4 concentration of 1C waste in 242-B.	BC		
21	P. 9, paragraph 3, reference to "pits": (#1) 'Describe generically the pits added to C-101-C-106 — the pump or sluicing pits... (e.g., It is a concrete lined structure that ....).'	BC		
22	P. 9, paragraph 4, last sentence, "This operation was ...": (#2), Suggested sentence structure; 'This operation was performed in the CR vault and involved tanks C-108, C-109, C-111, and C-112 for settling and storing the ferrocyanide solids.'			
23	P. 9, last paragraph, sentence 3, "Cesium and strontium recovery ...": (#3), Don't you mean 'ion exchange ' instead of chromatographic operations? (#2), Suggested sentence structure; '... and involved a *solvent extraction process for strontium and rare earths and an ion exchange process for* cesium.'			
24	P. 9, last sentence, "It was during this campaign ...": (#2), Note: C-105/106 high Sr was accidental; C-103/104/107 was deliberate. These were different time frames (1971-72 and 1977)		#24: That is what I have been told. However, I could find no documentation to that effect.	
25	P. 11, first paragraph, sentence 3, "The only major sludge component ...": (#2), 'Should have 1C/2C sludge, OWW sludge, & CW sludge?'		#26: FMJ missed AX-104. I added it to my list.	
26	P. 11, first paragraph, last sentence, "These supernatents were ...": (#2), What about AX-104?			
27	P. 11, paragraph 3, sentence 2, "Solids were washed ...": (#2), Please add the following to sentence. '... in preparation for their *dissolution in nitric acid and* being fed into ...'			
28	P. 11, paragraph 3, Reference to "inadvertant transfer": (#2), needs a citation. Replace "sediment" with "settle" in last sentence.	BC		
29	P. 11, last paragraph, sentence 2, "First, the noxious vapor emissions ...": (#2), Attributed by who? Provide reference.	BC		

REVIEW COMMENT RECORD (RCR)

1. Date	2. Review No.
08/27/93	
3. Project No.	**4. Page**
	4 of 9

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30	P. 12, paragraph 1, sentence 5, "P waste was produced ...": (#2), P waste was not directly placed into C-Farm tanks. Check against Purex operation dates.		#30: According to FMJ, there were direct additions.	
31	P. 12, Figure 3: (#2), 'What function is this plot supposed to represent? Where do the ^{90}Sr Ci/L values come from?'	BC		
32	P. 12, Citation 23: "February" is misspelled.			
33	P. 12, paragraph 1, sentence 7, "Strontium in Purex ...": (#2), Source?	BC		
34	P. 13, Table 1: (#2), What is basis (measured) here and what is calculated or estimated? How were estimates made? What is source of measured data?	BC		
35	P. 13, sentence 1 & 2 (look also in Table 1): (#2), Replace each occurance of "dome" with "dome space".	BC		
36	P. 13, sentence 5, "$T_{reservoir}$ is the average ...", reference to average temperature (65°F): (#2), 'Hanford site average temperature is 57°F.'			
37	P. 14, Figure 4, C-106 meas. temperature: (#2), 'Where shown?'			
38	P. 14, last paragraph, sentence 2, "I calculate the amounts ...": (#2), 'How did you calculate this?'	BC		
39	P. 15, citation 25: (#2), Author initals are "B. C." Simpson. Also refer to new C-112 & C-109 documents authored by B. C. Simpson.	BC	#39: I have C-112 report, but have nothing on C-109.	
40	P. 15, citation 26: (#2), Should be WHC-EP-0640, not ibid.	BC		
41	P. 15, sentence 4, "The largest energy content ...":(#2), 8.5 cal/g, not 30-40 cal/g.	BC		
42	P. 15, citation 28: (#2), 'Same as citation 19? In most cases this report doesn't discuss leaks.'		#42: But sometimes it does.	
43	P. 16, paragraph 1, "There is a criticality ...": (#3), 'We don't need opinion or criticality specifications.'; (#2) 'Basis for statement?'; (#1) 'The comment on there being tanks with >50 kg Pu at Hanford, even though they pose no risk is gratuitous and has no place in this document on the C-Farm. Please delete it.'	BC	#43: Sorry it sounded like an unnecessary comment, but I thought it was important to mention the 50 kg Pu inventory limit. I have reworded the passage to perhaps make the comparison more to the point.	

REVIEW COMMENT RECORD (RCR)

1. Date	2. Review No.
08/27/93	
3. Project No.	**4. Page**
	5 of 9

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/ resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
44	P. 16, C-106, comments: (#2), 'C-101 was used as the feed tank to CR vault for scavenging wastes that were not originally in C farm. So, in addition to the primary UR waste solids, C-101 probably settled out some solids from approximately seventeen, 530 kgal tanks. Let's say (400 kgal)*17*0.5% = 34 kgal?		#44: Of course, but I did not need to invoke an unknown solids source for C-101.	
45	P. 16, Table 3: (#2), 'Some of the unknown loss may be due to compaction rather than a solids transfer.			
46	P. 16, C-102, sentence 2, reference to "... 267 kgal of CWP by cascade ...": (#2), 'I doubt this. That CW was cascaded.'		#46: According to FMJ, cascade ran during 1961-2.	
47	P. 16, C-102, sentence 3, "A direct addition of UR ...": (#2), 'Anderson 1990 only shows one UR waste addition.'		#47: FMJ shows three additions of UR waste.	
48	P. 18, Table 4, Measured Solids: (#2), 'What happened to 238 kgal solids in 1965-68?'; calculated solids column, What does "filled" refer to?	BC	#48: I've completely reworked C-102 solids history. See text.	
49	P. 18, paragraph 1, "The unknown source ...": (#3), 'I don't know what you are saying here. Which solids are unexpected? Are you discussing Table 4 or Figure 6?'		#49: See new table 4.	
50	P. 18, paragraph 2, first sentence, "The layering in C-102 ...": (#2), Data input error. Should say "28 kgal *UR*" rather than "CWP".'	BC		
51	P. 18, paragraph 2, sentence 4, Evidently, even though C-102 ...": (#2), Wrong word choice. Perhaps try "... after the tank *accumulated* 317 kgal ..." in place of "received".; 'Possible, I guess, I tend to believe input solids percentage wasn't as high as you show.'		#51: I think you are right. I've found that different campaigns of CWP had different solids per cent.	
52	P. 18, paragraph 3, sentence 1: (#2), Poor word choice. Perhaps try "An organic layer *was noted* ..." in place of "appeared".			
53	P. 18, paragraph 3, sentence 4, "Presumably, this 33 kgal transfer ...": (BC), Sentence suggests single transfer. Try "Presumably, this *combined* 33 kgal transfer ..."			
54	P. 20, paragraph 1, sentence 2, "These analysis are consistent ...": (#2), 'In what way are they consistent?'	BC		
55	P. 20, C-103, sentence 1, "Tank C-103 received ...": (#2), Incorrect date. Tank 103-C was sluiced in 1952-*53*.	BC		

REVIEW COMMENT RECORD (RCR)

1. Date	2. Review No.
08/27/93	
3. Project No.	**4. Page**
	6 of 9

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/ resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
56	P. 20, C-103, sentence 2, "Then, C-103 received ...": (#2), Reference to "94 kgal cascaded?" 'Anderson says TBP waste (> 500 kgal) was received from C-101 (pumped).	BC	#56: Actually, Anderson doesn't say how much, but FMJ says 308 kgal cascaded while 167 kgal was direct added. I corrected my numbers.	
57	P. 20, C-103: (#2), 'What happened to the 45 kgal MW waste heel that LAUR-93-1989 stated was present?'		#57: With an 8.1 vol% prediction for CWP, there is no need to invoke an MW heel to explain the solids. This data was not known at the time of LAUR-93-1989. Note that if you disagree with my 8.1 vol% solids for CWP, I will need a MW heel to explain the solids in C-103.	
58	P. 20, Table 5: (#2), Type UR waste?; How was the 24 kgal predicted layer of AR solids estimated?; 111 kgal total primary volume of NPH/TBP?; Purex was on standby during 1972-83 period.	BC	#58: The 24 kgal AR solids transferred from C-106 agrees best with solids gain in C-103, solids lost in C-106, as well as heat loading in C-106 and C-103.	
59	P. 20, C-103, last paragraph, sentnece 1, "Tank C-103 has a bottom layer ...": (#2), 'EB from 101-BX & 102-B likely to have added some solids.'		#59: Perhaps, but I don't know that yet.	
60	P. 22, paragraph 1, reference to incorrect solids measurements: (#2), 'Likely measurements high due to floating solids.'			
61	P. 22, paragraph 2, sentence 3, "I believe that this report ..." reference to 71-1 addition: (#2), 'The waste was not terminal solids near this date.' This term for solids remaining after several dissolutions was unknown in 1971.		#61 and 62: Yes, I am aware of that, but have not found any documentation to substantiate that yet. Furthermore, the average dome temperatures of C-106 and C-103 do not show any significant changes in 1977. Therefore, I need to stick with this analysis until proven wrong.	
62	P. 22, paragraph 2, last sentence, "Although C-103 received ...": (#2), 'Anderson 1990 shows Sr sludge in 1977?'			
63	P. 22, C-104, sentence 4, "It also received ... 912 kgal TH/THL ...": (#2), 'Basis for statement?'	BC	#63: FMJ.	
64	P. 22, C-104, bottom paragraph, sentence 1, "The only other solids ...": (#2), 'It ignores the reported 45 kgal UR waste solids (1956) it received. Also note that Purex was in standby during 1972-83 period.'		#64 & 65: My analysis suggests that they were CWP, not UR solids. Anderson often labeled waste as UR even though only supernatant was added to a tank. For example, C-104 received only 420 kgal UR supernatant from C-112, but received 1,118 kgal of CWP primary waste during this period.	
65	P. 23, Table 6: (#2), missing transaction - 45 kgal UR measured in 1956.	BC		
66	P. 23, paragraph 1, sentence 2, reference to "wash out": (#2), Do you mean entrainment?			
67	P. 23, last paragraph, sentence 2, reference to "spare inlets to C-105": (#2), Do you mean "C-104 to C-105 cascade overflow line"?		#67: No, the spare inlets are adjacent to the cascade line on the side of the tank.	
68	P. 25, sentence 1, reference to "... but C-104 only received BL waste ...": (#2), 'There was no BL waste in 1976/77 indicated in Anderson 1990. What is your source?'		#68: FMJ.	

REVIEW COMMENT RECORD (RCR)

1. Date	2. Review No.
08/27/93	
3. Project No.	**4. Page**
	7 of 9

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/ resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
69	P. 25, sentence 3, "According to the historical record, some 12 kgal of solids came from these additions from '70-4 to '76-2 ...": (#2), '??, Show how you came up with 12 kgal.'		#69: There were 527 kgal P/PL waste added x 0.022 = 12 kgal solids.	
70	P. 25, paragraph 1, sentence 4, "The analysis shows ...", reference to "11.0 and Ci/L Sr-90": (#3), Grammatical error. "... which would be 11.0 and Ci/L Sr-90 if it ..."			
71	P. 25, paragraph 2, last sentence, reference to "... Pu assays for C-102, C-103, C-104, and C-105 are suspect.": (#2), Yes. This was documented in an Internal Memo (72200-91-025) distributed on June 27, 1991.		#71: Got the ECN, except it did not change the values for C-102.	
72	P. 25, paragraph 4, sentence 1, "Moreover, the evaporation rate of the waste ...": (#2), 'Basis/reference for statement?'		#72: Elaborated on in text.	
73	P. 25, last paragraph, sentence 1, "Tank C-105 received ...": (#2), Reference to C-103 is incorrect; should be C-104.	BC		
74	P. 26, paragraph 1, sentence 2, "This last draw down ...": (#3), 'I don't understand what this says.'		#74: Explained better in text.	
75	P. 26, paragraphs 1 & 2: (#2), This needs to be discussed. I can't cover my concerns adequately in comments without writing excessively.			
76	P. 26, last paragraph, reference to "... but its temperature and fill history are inconsistent with such a large heat load.": (#2), 'Its getting some active ventilation from the C-106 exhauster through the cascade line (tank C-104 also). However, 90,000 Btu/h does seem exccessive!'			
77	P. 28, paragraph 1, last sentence, "Note that the temperature of ...": (#2), Lower temperature for C-105 is 'consistent with active ventilation.'			
78	P. 28, Table 8, row '76-2: (#2), What is the basis for the 2.5 vol% predicted layer?		#78: See new App. 1.	
79	P. 31, paragraph 1, sentence 3, reference to "riser 14" in Figure 2: (#2), 'Figure 2 doesn't show riser 14; Figure 1 does.'			
80	P. 31, paragraph 1, last sentence, "Riser 8 and Riser 14 ...": (#3), 'I don't understand what you are saying.'			

REVIEW COMMENT RECORD (RCR)

1. Date	2. Review No.
08/27/93	
3. Project No.	**4. Page**
	8 of 9

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81	P. 31, paragraphs 2-3, Chimney Hypothesis: (#1), ∘ 'For completeness, please add the alternate hypothesis such as the ring around the walls to this one in your discussion. These can be obtained from Oliver Wang. ∘ In addtion, the test and or hypotheses should be discussed in a separate section.' (#2), 'The mechanism to form a "cold spot" is speculation. Why doesn't heat flow to this "cold spot" and raise its temperature?'		#81: I also mention alternate hypothesis, but do not have a reference. My mechanism to cool the waste around the tc tree is based on free convection of liquid in a "chimney" formed by the water lancing during insertion of the tc tree. I am not sure what you mean by speculation. Is it speculation that convection would cool the tc tree at all, or just not enough to explain the observed differences? Is it speculation that the sludge "chimney" would remain intact over such a period of time?	
82	P. 31, last paragraph, sentence 2, reference to "... being on average 25 vol% solids.": (#2), 'Yes, if you ignore 3 out of 7 data points.'		#82: I have found that early 1C waste had the lower solids per cent, as stated now in App. 1.	
83	P. 34, C-108, sentence 1: (#2), Should say "Tank C-108" rather than "Tank C-109"			
84	P. 34, C-108, sentence 2, "Then, 902 kgal UR from ...": Sentence wording.			
85	P. 34, C-108, sentence 4, "This waste was produced by ...": (#2), 'Scavenging was performed in CR vault, not in the field (tanks)!'	BC		
86	P. 34, Table 10: (#2), What is the basis for the 19 kgal predicted layer in '48-3?			
87	P. 34, reference to C-108 transfers: (#2), 'I disagree with this. We need to get deeper into it with you.'			
88	P. 36, paragraphs 2 & 3: (#2), 'I disagree with this analysis. Unjustified gains and losses are given. See WHC-EP-0668 (draft).'	BC	#88: I've tried to justify my gains and losses as well as I've been able.	
89	P. 38, paragraph 1, sentence 2, "Thus, any solids above this level ...": (#2), 'Not necessarily, its tough to move solids except right around inlet/outlet lines.'		#89: Solids were obviously moved around quite a bit, otherwise why would C-106 and C-103 have their Sr layers? And what about all of the other ups and downs in the solids levels reported for C Farm tanks? Are they all just measurement anomalies? Clearly, there are problems with the solids measurements, but I find that there must be a way to transfer certain types of solids fairly readily in order to explain the solids accumulations that are observed.	
90	P. 40, paragraph 1, sentence 1, "Tank C-111 received ...": (#2), 'Plugged overflow from C-110 in 1952 probably means C-111 received both 1C & UR solids.'		#90: That is included in my analysis.	
91	P. 40, Table 13, reference to FeCN transaction in '56-1: (#2), 'No! The UR waste in C-111 was scavenged (through CR vault) to C-112 in January 1956. C-111 didn't receiveFeCN waste to settle until April 1957.'	BC	#91: FMJ has C-111 receiving scavenged waste from C-105 and C-108 in '56-1, then cribbing the supernatant to B-020 in '56-3. I see that this particular scavenging operation does not appear in WHC-SD-WM-ER-133, and I don't know why. C-105 and C-108 were scavenged during the quarters I mentioned, and so must have ended up somewhere. For now, I'll stay with what I've got.	
92	P. 42, paragraph 2, C-112: (#2), 'Why is the 15 kgal measurement of 2Q 1952 ignored?'	BC	#92: Yes, I did ignore that measurement, and now have added a better explanation as to why.	

REVIEW COMMENT RECORD (RCR)

1. Date	2. Review No.
08/27/93	
3. Project No.	**4. Page**
	9 of 9

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93	P. 43, paragraph 2, reference to thermal energy values: (#2), 'Why don't you use the values quoted in reference 50? e.g. B. C. Simpson had for C-112 heat load: 8100 ± 1000 Btu/h (TC tree profile), 8327 Btu/h (FP analysis & waste model), 7535 Btu/h (dome space temperature).'	BC	#93: Have done it.	—
94	P. 45, paragraph 1, sentence 1, "Continued storage of the organic layer ...": (#2), 'I agree.'			—
95	P. 45, paragraph 3, "I recommend dropping C-105 from the high heat watch list ...": (#2), 'I disagree.'			—
96	P. 45, paragraph 4, "The thermocouple tree for C-104 ...": (#2), 'I agree. Thermocouple measurements probably were taken in 1992.'			—
97	P. 45, paragraph 5, "Tank C-107 has never had ...": (#2), 'The heat load for tank C-105 is greater than tank C-107.'		#97: Based on my analysis, both C-103 and C-107 have marginally greater heat loads that C-105. The point that I want to make, though, is that they are at least comparable.	—
98	P. 45, paragraph 6, "Tank C-111 is listed as an assumed leaker ...": (#2), 'I doubt this is worth the required effort.'		#98: Retrieval in the future might be directly impacted by assumed leaker status.	—
99	P. 47, Appendix 1, last paragraph: (#2), 'Why do you pick the higher of the two populations for both 1C & CW percent solids? Have you looked at how they both fit the data?'		#99: Look at rework of App. 1. I believe that you will find it much better now.	—
00	P. 48, Table A3: (#2), 'I don't thik any primary P waste went into C Farm before Purex shut down in 1972.'		#100: According to FMJ, there were several Purex waste additions in C Farm.	—
01	P. 49, Table A4, reference to U-107 waste transfer in 1969: (#2), 'It wasn't CWP waste. Transfer was cladding waste from Redox via 107/102-S.'		#101: Yes, I deleted it.	—
02	P. 51, Glossary, sentence 1: (#3), Grammatical error.			—
03	P. 51, Glossary: (#2), 'Lots of these items are specifically for the TRAC program - they aren't really waste descriptions.'		#103: That's true, as I stated in App. 3.	—

GENERAL COMMENTS

Reviewer #1:

Overview — This easy to read well written report contains a great deal of useful information that will benefit all those who will have to deal with the C-Tank farm in the future. This is as detailed and generally complete a tank history and adds significantly to those C-Farm reviews prepared by various summer students during the last two years. I did not have time to review the glossary, but applaud its presence. More about that below.

The Risk of Mixing Historical Data and Data Analysis [C-103]. —' This review finds that the report is somewhat marred by the authors extensive mixing of fact and hypothesis in their report. Although, I would tend to agree with the author that removal of the organic liquid from tank C-103 may be desirable, the safety issues associated with the tank are more complex then the simple solution suggest. Furthermore, the task set to the author by the DREAM team was to FIRST review and correlate information about the 241-C-Tank Farm. SECOND, the authors was to identify any NEW safety risks (Such as a possible high heat issue in C-107) that were identified during data collection and collation. It is not the authors primary task to recommend explicit remediation or mitigation actions — That is the appearance given by the present text of the abstract; that is the role of the Westinghouse Tank Waste Safety Program working with our customer, DOE.

Specifically, the author, in the abstract recommends removal of the organic layer in C-103. Since there are three safety questions associated with the tank, the authors suggestion, in the absence of more complete data, is somewhat simplistic.

There are three issues related with tank C-103. They are:

[1] the existence of a possibly flammable layer in the tank (the source of the USQ);

[2] the possible existence of an organic rich nitrate-nitrite rich solid in the tank (making the tank a candidate for the organic watch list); and

[3] data that lead one to believe that the tank is a source of noxious random fugitive emission that might endanger worker health and safety.

The first issue listed has also been interpreted to mean that the vapor space in Tank C-103 may be flammable, since in general high boiling organic liquids need to volatilize before they can burn.

Mitigation or remediation (the line between the two runs thin in tank C-103) of the safety issue(s) dealing with vapor ignition or vapor toxicity could rely on use of an external ventilation system equipped with suitable scrubbers. Given enough time such a system would also serve to remove the more volatile components of the organic layer and by so doing reduce its potential flammability. However, it has not been demonstrated that the organic layer is the root cause of the vapor problem. There is no data to either support or refute a alternate hypothesis that the gases generated in the aqueous phase or in the sludge may not be the cause of the noxious gas. Certainly the source of organics

associated with a pool fire will be reduced by removing them, leaving the DOE a requirement to evaluate the organic contents of the rest of the tank to determine the risk from fuel-oxidizer reactions.

The Risk of Mixing Historical Data and Data Analysis [Ferrocyanide Tanks]. --- Although in this instance I agree with the authors recommendation of the ferrocyanide tanks; I again do not believe that it should be the primary focus of a data report on the C-Tank Farm.

The Document Abstract --- Please abstract the data discovered about the C-Farm in this section. Rename the present abstract something like A Summary of Findings modifying it in a manner that reflects these and other review comments. Include the new section as a separate summary section to this document.

The Glossary of Hanford Terminology --- This reviewer applauds the authors attempt to identify and make sense out an often arcane and (historically) constantly changing set of fuel reprocessing, waste processing and waste handling semantics. This effort could be strengthened (in the future) to create a stand alone ANNOTATED BIBLIOGRAPHY OF HANFORD TERMINOLOGY document if the author were to provide a uniformly formatted description of information describing the waste along with the literal definition of the term. The description might contain added information on the general chemical composition of the waste stream (principal chemical constituents and radionuclides; a clearer indicator not only of the process or facility that generated the waste stream but an indications generally where in a flowsheet or facility the specific waste type was generated. Such of a description would benefit not only this and similar future documents, but all future tank farm waste data analysis efforts.

Rationalization Of Waste Transfer(s) Modes --- As stated in my review on C-103 (LAUR-93-1989), this report would benefit if the transfer mode, especially the location of the pump intake, was defined. There is only one place where the author has explicitly described how (use of a P-10 pump) the waste was transferred. The text correctly implies that waste was added either through a riser or from a overflow in the cascade system connecting groups of tanks, but the details are not made clear to the reader. Particularly the difference between operations in which waste was sluiced or supernate transferred is critical to the readers understanding of what is left in the tank.

Effect of Alkalinity of Transferred Waste on Residual Solids Volume --- As stated in my review on C-103 (LAUR-93-1989), the various waste transferred in C-Farm had various amounts of caustic in them. Adding a high caustic waste to a low alkaline solid would drastically affect the waste composition (and volume) especially if the precipitated waste contained appreciable aluminum. (See assumptions on page 5 paragraph 3). This has not been considered in this evaluation. I suggest that the authors add an appendix that contains a summary description of the dominant chemistry for each of the waste types reported.

I am also concerned that generalized statements about solubilities such as provided in paragraph 5 on page 5 (e.g., sodium carbonate) may be misleading. The general solubility of the most chemicals listed in paragraph 5 are significantly affected by the ionic strength of the medium, a consideration, although mentioned, was not explicitly dealt with in the report.

In general the amount of solids found in a tank may not reflect, in a additive fashion, the quantities of solids added or removed; although the present analyses by Dr. Agnew is a better approximation then that which has been done previously!

Generalized Tank Stratigraphy — This document needs a more extended discussion with illustrations (see page 7, Paragraphs 1 and 2) of the fact that although the author treats the waste, for simplicity of analysis, as if they were emplaced in horizontal pancakes; their thickness are most likely to be thinner on the side farthest from the inlet. Then later varied in accord with whether the waste was added by pumping or by cascade overflow. Furthermore, the inlet position may have varied with the tanks history. In addition, actions such as sludge sluicing tended to remove waste solids from the middle of the tank leaving material around the walls (e.g., C-106) creating conical donut like sections of waste solids in the tank. I find no fault with the authors assumption on this matter, only the fact that the assumption needs to be explicitly stated.

Glossary Additions Needed — LaF, 224-F

Suggested Changes In Document Style — There are a number of troublesome stylistic elements of the report which interfere with its general usefulness for which improvements are suggested.

- Use of the Term Hot Spot — The term hotspot is encumbered with so much baggage from the various discussions associated with the ferrocyanide tanks that its use should be discouraged. I suggest the term enhanced heat zone (or some such "term") be used. See page 25, Paragraph 4, the last sentence.
- Differentiation Between Liquid And Solid Wastes — Although the author goes to intensive efforts to distinguish liquid from solid containing feeds, there are places in the History section where this difference is difficult to follow. I suggest the author adopt the use of a parenthetic with the term liquid, or slurry) to clarify the nature of the transfer.
- Figure 1 — The riser numbers (Figure 2) need to be made more visible. (the size of the riser overwhelms the riser ID's but the former is not used in the report.) The location of the cascade from other tanks needs to be identified. Acronyms need to be explained (e.g., tc).

Conclusions and Recommendations — Please see comments provided above relative to the abstract and provided in my Review of Tank History Analysis: C-Farm and 103-C by Stephen F. Agnew, Phyllis Baca and Franz Biehl; LAUR-93-2989 (June 1993)

Reviewer #2:

1. I note that this document doesn't say anything about a metal waste (MW) heel in C-103 like the LAUR-93-1989 report stated.

2. Page 6; approach for C Farm. I think it is a logical one, but I don't understand its implementation. E.G., pages 47 and 48 note that two values of 1C and CW solids percent are seen and the higher value is used in each case - Why? I would like to

spend more time and see if we can't find a reason for the difference. Do the lower values fit the data better?

3. I think that each time a data point is ignored (e.g., the measured solids volume of 238 kgal in C-102 that occurred in 1965-68 (Anderson 1990) which is not given in Table 4, P. 18) the text should mention a reason. It is very difficult to try to follow what has been done with some data missing, seemingly arbitrarily.

4. Agnew correctly notes (e.g., on pages 20, 25, 28, et. al.) that the Pu analyses are high. This is also documented by J. G. Hill and B. C. Simpson in an Internal Memo (72200-91-025) dated June 27, 1991.

5. Agnew attributes any decrease over time in solids level to a loss of solids (i.e., a transfer of solids from the tank). While this is likely true in a few cases, it ignores the likelihood of solids compacting or decreasing in volume with time and the weight of overlying solids.

6. I wouldn't use this document for anything as it is, and considerable rework and verification would be required to make it useful.

<u>Reviewer #3:</u>

There are two issues that need to be worked out:

1) There are a number of places where the Pu inventory does not match the "official" Pu numbers. Agnew has estimated up to 190 kg of Pu in some of the tanks. Steve Agnew needs to work with Terry Vail to straighten out the Pu values and come to closer numbers.

2) On page 25 where Agnew talks about 104-C thermocouple data, he lists a high temperature of 350°F and suggests that there are hot spots in this tank. Are we really ready to claim hot spots?

There were 3 1/2 pages of attached general comments, which I will address by reviewer.

Reviewer #1:

Risk of mixing historical data and data analysis...

I guess that I consider this report an analysis of information, as opposed to a source of information, and therefore I am justified in attempting to correlate the various phenomena that have been reported by proposing hypotheses to explain facts or observations. I have always thought that the purpose of analysis is to explain observed phenomena with hypotheses and models. The reviewer is, however, correct in saying that I have not presented any new information within this document to support my recommendation to remove the organic from C-103. I was merely restating the recommendation of a previous report, LAUR-93-1989. However, I think that it is important enough to say again.

The three issues that are brought up with respect to C-103 are certainly the three main issues with which we are currently struggling. However, with respect to issue #3, potential noxious vapor emissions from C-103, there is a critical over-arching question that was not mentioned: Is there or is there not a noxious vapor problem in C Farm? If the answer is no, then issue #3 is moot. If the answer is yes, then issue #3 is critical. For if there is a noxious vapor problem in C Farm, and C-103 is not the source, then we had better be looking for the actual source. I have not found any other tank in C Farm with the combination of high organic and high radiolysis that exists in C-103. So, if you don't agree that there is enough evidence to link C-103 to the noxious vapor incidents that have occurred in C Farm, then which tank is more likely than C-103 to be the source of the problem? Do you even believe that there is a noxious vapor problem in C Farm at all?

For the ferrocyanide tanks, I have only repeated the recommendation within the C-112 report, WHC-EP-0640, that the low energy content of C-112 means that there is no energetic hazard for C-112 and therefore WHC-EP-0640 recommended removing C-112 from the ferrocyanide list. I have simply repeated that recommendation and extended it to the other three ferrocyanide tanks on C Farm.

I agree that more knowledge of the specifics of waste transfer would be useful, i.e. pump used, riser used, etc., but that information is very difficult to obtain.

The dissolution of solids upon caustic addition is, of course, a very real possibility, especially for $Al(OH)_3$. At this point, I do not want to say necessarily which of several mechanisms is at work when there is a solids loss. So, I will defer that to a later analysis and acknowledge that entrainment, dissolution, and compaction may all play some role in solids level changes.

As regards tank stratigraphy, I agree that there is a great deal of lateral inhomogeneity in waste tanks, which is exactly why historical analysis is so important, as I have mentioned in the General Approach section. The waste layers that I derive are simply my best estimates of the solids within each of the tanks and the waste additions from which they came. Moreover, the greatest degree of lateral inhomogeneity will occur where the waste is disturbed the most, that is close to the outlets and inlets, which is where sampling generally occurs as well.

Reviewer #2:

1) I added information about the MW heel to the C-103 section. LAUR-93-1989 was an attempt at solids history that lacked basic information such as how much solids came with CWP waste. Therefore, the question of a MW heel could not be resolved in LAUR-93-1989, and was left open. I believe with the more definitive estimate of the solids content of CWP, I can explain all of the early solids within C-103 as CWP sludge.

2) I have reworked App. 1 and have indeed found that there is justification for using the different solids volume per cent for 1C and CWP waste depending on the campaign that was run.

3) I have reanalyzed C-102 and found that my first analysis was incomplete. Nevertheless, C-102 solids layering is more uncertain than other tanks because of it history, but I have attempted to justify the solids measurements much better this time around, including the 238 kgal in 1965-68. However, the fact that CWP waste evidently changed significantly over the time this tank was used contributes greatly to the uncertainty in the layers in C-103.

4) I got that memo and made the corrections.

5) I have simply left the exact mechanism of solids loss open, and believe that solids dissolution and sediment compaction as well as entrainment can all play a role in solids loss.

6) Well, it is the best that I can do right now with the data at hand.

Reviewer #3:

1) I've reworked the Pu numbers.

2) There is a hotter layer in tank C-104 at the top of the waste. Call it a hot zone or whatever, but it is hotter.